Ludwig
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Faculty 16 "Mathematics, Informatics and Statistics": Research Report 1998 -- 2003

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This research report is the first of this kind and therefore covers a rather long, six year period of time: 1998 -- 2003. It consist of three parts devoted to (1) the Departments of Mathematics [see page 2] (in german), (2) the Institute for Informatics [see page 71] , and (3) the Institute for Statistics [see page 167] .

1 Department of Mathematics (in german)

> Die Mathematik ist eines der wichtigsten Grundlagenfächer der LMU und zwar nicht nur als grundständiges Fach in der Lehre, bei der Lehrerausbildung und als Dienstleister in sämtlichen naturwissenschaftlichen Fächern, sondern sie ist vor allem auch in der Forschung integraler Bestandteil von zukunftsträchtigen Fächern wie der Biotechnologie, der Genforschung und den Nanowissenschaften.
> (A. Heldrich, Rektor der LMU, August 2001)

Der vorliegende Bericht gibt einen Überblick über die Forschungsaktivitäten am mathematischen Institut von Mitte 1999 bis Ende 2003. Er ist gegliedert in Berichte der einzelnen Arbeitsgruppen, sowie der beiden im Berichtszeitraum am mathematischen Institut angesiedelten interdisziplinären Graduiertenkollegien: ‘‘Mathematik im Bereich ihrer Wechselwirkung mit der Physik’’ und ‘‘Logik in der Informatik’’.

In diesen Zeitraum fällt eine wesentliche personelle Erneuerung des Instituts, die noch mehrere Jahre andauern wird. Ein Lehrstuhl für Angewandte Mathematik, insbesondere Numerische Mathematik, war seit der Emeritierung von Professor Dr. G. Hämmerlin am 1. April 1996 vakant. Er wurde erst im Sommer 2003 durch die Berufung von Professor L. Erdös Ph. D. wieder besetzt. Ein weiterer Lehrstuhl für Angewandte Mathematik, insbesondere Analysis und Mathematische Physik, war seit der Emeritierung von Professor Dr. E. Wienholtz zum 1. Oktober 1997 vakant; er wurde im Sommer 2000 durch die Berufung von Professor Dr. H. Siedentop wieder besetzt. Seit dem 1. April 2000 war der ehemalige Lehrstuhl von Professor Dr. H. Kellerer, der in einen Lehrstuhl für Topologie umgewidmet wurde, vakant. Er wurde im April 2003 durch die Berufung von Professor B. Leeb Ph. D. neu besetzt. Eine C3-Professur wurde mit Professor Dr. K. Cieliebak besetzt. Seit dem 1. April 2002 ist der Lehrstuhl für Stochastik von Professor Dr. P. Gänßler vakant; der Lehrstuhl für Finanz- und Versicherungsmathematik ist durch Wegberufung von Professor Dr. M. Schweizer an die ETH Zürich seit dem 1. Oktober 2003 ebenfalls vakant. Das Berufungsverfahren für beide Lehrstühle ist im Gange. Diese Vakanzen hatten und haben, trotz Lehrstuhlvertretungen, starke Auswirkungen in den betroffenen Arbeitsgruppen, und darüber hinaus im ganzen Institut.

Grundlage für die Neuberufungen ist der Strukturplan des Mathematischen Instituts von 1999, der einen Wechsel von einer lehrstuhlorientierten Struktur zu einer Struktur mit fünf größeren wissenschaftlichen Arbeitsbereichen sowie einem Lehrstuhl für Didaktik der Mathematik vorsieht. Außerdem sah der Plan die Einrichtung eines neuen Studiengangs für Wirtschaftsmathematik und Aktuarwissenschaft sowie eines internationalen Master Studiengangs vor; beides ist inzwischen realisiert. In dem vorliegenden Bericht erscheinen nun die neuen Arbeitsbereiche Analysis und Numerik, Differentialgeometrie und Topologie, und Stochastik und Finanzmathematik. Die Schaffung des Arbeitsbereichs für Algebraische und Arithmetische Geometrie (bisher einerseits Algebra, und andererseits Komplexe Analysis und algebraische Geometrie) steht noch aus.

Im November 1999 und nochmals im Frühjahr 2003 wurde das Mathematische Institut evaluiert. Für die Mitarbeit in der Kommission konnten führende Mathematiker von auswärtigen Universitäten und Max-Planck-Instituten gewonnen werden. Unter den Gutachtern befanden sich drei Leibniz-Preisträger der DFG sowie ein Inhaber der Fields-Medaille. Die Evaluatoren befürworteten in ihrem Bericht vom Februar 2000 nachdrücklich den geplanten Strukturwandel sowie die Einrichtung der neuen Studiengänge. In ihrem erneueten Bericht vom Mai 2003 schreiben sie:

Seit der letzten Evaluation hat das Mathematische Institut eine äußerst erfreuliche Entwicklung genommen. Das wissenschaftliche Profil ist durch hochkarätige Berufungen (Siedentop, Schweizer, Leeb, Erdös, Cieliebak) wesentlich gestärkt worden. Damit verbunden war ein starker Anstieg der eingeworbenen Drittmittel. In einigen Gebieten der Mathematik befindet sich das Institut jetzt in der Spitzengruppe in Deutschland.

1.1 Arbeitsbereich Algebra

Wissenschaftler mit Dauerstellen: Prof. Dr. B. PAREIGIS, Prof. Dr. H.-J. SCHNEIDER, Prof. Dr. W. ZIMMERMANN, Prof. Dr. H. ZÖSCHINGER, Priv.-Doz. Dr. G. HAUGER (1#1 7. 7. 2001), Dr. E. SCHÖRNER (Seit 1. 10. 2002)

1.1.1 Forschungsschwerpunkte:

1.

- Verantwortliche: PAREIGIS, B. und SCHNEIDER, H.-J.
- Titel: Hopfalgebren, Quantengruppen und nicht-kommutative Algebra
- key words (engl.): quantum group, Hopf algebra, noncommutative geometry, Galois extension, braided Lie algebra, monoidal category, braidings and symmetries, Yetter-Drinfel'd module
- Beschreibung: Quantengruppen haben tiefliegende physikalische Anwendungen und einen interessanten mathematisch-algebraischen Hintergrund. Wir studieren nicht-kommutative, nicht-kokommutative Hopf-Algebren, die ,,Funktionenalgebren'' von Quantengruppen, ihre Strukturtheorie, ihr Auftreten als Automorphismen-Quantengruppen, die Darstellungstheorie (im Zusammenhang mit Tannaka-Krein-Rekonstruktion) und ihre homogenen Räume.

  Forschungsschwerpunkte sind:

  - Hopf-Galois- und Bigalois-Erweiterungen, verschränkte Produkte über speziellen Hopfalgebren (Hauptfaserbündel und homogene Räume von Quantengruppen),
  - Verzopfte Kategorien und algebraische Strukturen darin (Algebren, Hopfalgebren, Liealgebren),
  - Yetter-Drinfel'd-Hopfalgebren, (Ko-)Quasi-Hopfalgebren, Hopfalgebroide,
  - Darstellungstheorie halbeinfacher Hopfalgebren,
  - Klassifikation halbeinfacher Hopfalgebren,
  - Klassifikation der endlichdimensionalen punktierten Hopfalgebren mittels Cartan-Matrizen (Beispiele sind die Frobenius-Lusztig-Kerne halbeinfacher Liealgebren).

2.

- Verantwortlicher: PAREIGIS, B.
- Titel: Sequenziell dynamische Systeme
- key words (engl.): dynamical systems, simulation, cellular automata, limits and colimits of dynamical systems.
- Beschreibung: Die Simulation komplexer Systeme auf Computern wird häufig mit Hilfe von sequenziell dynamischen Systemen (SDS) durchgeführt. Diese sind wegen der Endlichkeit der Computer selbst endliche dynamische Systeme. Sie sind durch die Praxis motivierte Verallgemeinerungen von zellulären Automaten. Sequenziell bedeutet hier, daß die Übergänge der Zustände des Systems lokal in den einzelnen Zellen und zeitlich nacheinander erfolgen, ohne daß die vorhergehenden Zustände jeweils gespeichert werden.

Anwendungsgebiete solcher sequenziell dynamischen Systeme sind u. a. aerodynamische Modelle (stetig oder differenzierbar), biologische Prozesse und Zellwachstum (diskret), Straßenverkehr in Städten (hybrid), Telefonsysteme, Paketverkehr in Datenleitungen, verteilte Rechnersysteme, und der Kapitalfluß auf den Weltmärkten.

Es besteht Bedarf nach einer mathematischen Grundlegung, mit der viele Fragen überhaupt erst zugänglich gemacht und systematisch behandelt werden können. So sind inzwischen die zulässigen Abbildungen, gewisse Kolimites von SDS und mit ihnen der Begriff der Simulation genauer untersucht worden. Diese Untersuchungen dienen der Konstruktion effizienter und optimaler SDS.

3.

- Verantwortlicher: ZIMMERMANN, W.
- Titel: Moduln und Darstellungstheorie
- key words (engl.): Pure injective modules, Chain conditions for matrix subgroups, Auslander-Reiten sequences
- Beschreibung: Rein injektive Moduln kommen in vielen Bereichen der Algebra vor und haben eine Reihe von interessanten Eigenschaften. Ein wichtiges Instrument zu ihrem Studium sind die sog. matriziellen Untergruppen. Eine besondere Rolle spielen Moduln, die der aufsteigenden oder absteigenden Kettenbedingung für matrizielle Untergruppen genügen.

  Auslander-Reiten-Folgen dienen der Konstruktion unzerlegbarer Moduln. Sehr interessant ist die Frage nach der Existenz solcher Folgen über Ringen, die keine Artin-Algebren sind.

4.

- Verantwortliche: PRIESS, S.
- Titel: Bewertungstheorie, insbesondere ultrametrische Räume
- key words (engl.): valuation theory, ultrametric spaces, fixed point and coincidence theorems and applications, Hardy fields, foundations of projective geometry
- Beschreibung: Ultrametrische Räume sind als eine Verallgemeinerung bewerteter algebraischer Strukturen zu betrachten, analog der Beziehung zwischen metrischen Räumen und dem Körper der reellen Zahlen mit seinem Absolutbetrag. Dem Begriff der ,,Vollständigkeit bezüglich der Pseudokonvergenz‘‘ entspricht für ultrametrische Räume der Begriff der ,,sphärischen Vollständigkeit‘‘ (eine stärkere Eigenschaft als ,,vollständig‘‘). Maximal bewertete (= bezüglich der Pseudokonvergenz vollständige) Körper spielen eine universelle Rolle für die bewerteten Körper. In diesen Fragenkreis gehörende Zusammenhänge und Einbettungssätze für bewertete Körper wurden für ultrametrische Räume und Koordinatenstrukturen projektiver Ebenen untersucht. Hinter einigen dieser Beweise, wie überhaupt in der Bewertungstheorie, stecken allgemeine Fixpunktsätze. Diese wurden herausgearbeitet und auf ihre Anwendungsmöglichkeit auch in anderen Gebieten (z. B. Logikprogrammierung, Hardy-Körper und asymptotische Lösungen von Differentialgleichungen) untersucht.

1.1.2 Im Druck erschienene Publikationen:

1. **Zeitschriftenartikel:**
   - Andruskiewitsch, N., SCHNEIDER, H.-J.: Finite quantum groups over abelian groups of prime exponent, *Ann. Sci. Ec. Norm. Super. IV. Ser.* **35** (2002), 1-26.
   - Dabrowski, L., Grosse, H., HAJAC, P. M.: Strong connections and Chern-Connes pairing in the Hopf-Galois theory, *Commun. Math. Phys.* **220** (2001), 301-331.
   - DIDT, D.: Linkable Dynkin diagrams, *J. Algebra* **255** (2002), 373-391.
   - Futia, C., MÜLLER, E. F., Taft, E.: Bialgebras of Recursive Sequences and Combinatorial Identities, *Adv. Appl. Math.* **22** (2002).
   - HAJAC, P. M., Majid, S.: Projective module description of the *q*-monopole, *Commun. Math. Phys.* **206** (1999), 247-264.
   - HAJAC, P. M.: Bundles over quantum sphere and noncommutative index theorem, *K-Theory* **21** (2000), 141-150.
   - Laubenbacher, R., PAREIGIS, B.: Equivalence relations on finite dynamical systems, *Adv. Appl. Math.* **26** (2001), 237-251.
   - Montgomery, S., SCHNEIDER, H.-J.: Skew derivations of finite-dimensional algebras and actions of the double of the Taft Hopf algebra, *Tsukuba J. Math.* **25** (2001), 337-358.
   - MÜLLER, E. F.: Finite subgroups of the quantum general linear group, *Proc. Lond. Math. Soc. III. Ser.* **81** (2000), 190-210.
   - MÜLLER, E. F.: The coradical filtration of $U_q(g)$ at roots of unity, *Commun. Algebra* **28** (2000), 1029-1044.
   - MÜLLER, E. F.: Cosemisimple Hopf algebras and the FRT construction, *Commun. Algebra* **29** (2001), 4377-4394.
   - PRIESS-CRAMPE, S., Ribenboim, P.: Logic programming and ultrametric spaces, *Rend. Mat. VII. Ser.* **19** (1999), 155-176.
   - PRIESS-CRAMPE, S., Ribenboim, P.: Fixed point and attractor theorems for ultrametric spaces, *Forum Math.* **12** (2000), 53-64.
   - PRIESS-CRAMPE, S., Ribenboim, P.: A general Hensel's lemma, *J. Algebra* **232** (2000), 269-281.
   - PRIESS-CRAMPE, S., Ribenboim, P.: Ultrametric spaces and logic programming, *J. Log. Program.* **42** (2000), 59-70.
   - Radford, D., SCHNEIDER, H.-J.: On the even powers of the antipode of a finite-dimensional Hopf algebra, *J. Algebra* **251** (2002), 185-212.
   - SCHAUENBURG, P.: A generalization of Hopf crossed products, *Commun. Algebra* **27** (1999), 4779-4801.
   - SCHAUENBURG, P.: Bigalois objects over the Taft algebras, *Isr. J. Math.* **115** (2000), 101-123.
   - SCHAUENBURG, P.: The structure of Hopf algebras with a weak projection, *Algebr. Represent. Theory* **3** (2000), 187-211.
   - SCHAUENBURG, P.: Doi-Koppinen Hopf modules versus entwined modules, *New York J. Math.* **6** (2000), 325-329.
   - SCHAUENBURG, P.: The monoidal center construction and bimodules, *J. Pure Appl. Algebra* **158** (2001), 325-346.
   - SCHAUENBURG, P.: Turning monoidal categories into strict ones, *New York J. Math.* **7** (2001), 257-265.
   - SCHAUENBURG, P.: Cohomological obstructions to cleft extensions over

cocommutative Hopf algebras, *K-Theory* **24** (2001), 227-242.

- SCHAUENBURG, P.: Hopf bimodules, coquasibialgebras, and an exact sequence of Kac, *Adv. Math.* **165** (2002), 194-263.
- SCHAUENBURG, P.: Hopf modules and the double of a quasi-Hopf algebra, *Trans. Am. Math. Soc.* **354** (2002), 3349-3378.
- SCHNEIDER, H.-J.: Some properties of factorizable Hopf algebras, *Proc. Amer. Math. Soc.* **129** (2001), 1891-1898.
- SCHÖRNER, E.: Zur Konstruktion von Hahn-Ternärkörpern als Ternärkörper formaler Potenzreihen, *Geom. Dedicata* **80** (2000), 157-171.
- SCHÖRNER, E.: Hahn-Ternärkörper mit speziellen Faktorsystemen, *Geom. Dedicata* **80** (2000), 211-230.
- SCHÖRNER, E.: On the completion of real valued ternary fields, *Result. Math.* **38** (2000), 339-347.
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- SCHÖRNER, E.: On a generalization of Wyler's construction of topological projective planes, *Note Mat.* **21** (2002), 35-48.
- Kashina, Y., SOMMERHÄUSER, Y., Zhu, Y.: Self-dual modules of semisimple Hopf algebras, *J. Algebra* **257** (2002), 88-96.
- ZIMMERMANN, W.: On locally pure-injective modules, *J. Pure Appl. Algebra* **166** (2000), 337-357.
- ZÖSCHINGER, H.: Koassoziierte Primideale in 2-dimensionalen regulären Ringen, *Period. Math. Hung.* **40** (2000), 177-194.
- Laubenbacher, R., PAREIGIS, B.: Decomposition and simulation of sequential dynamical systems, *Adv. Appl. Math.* **30** (2003), 655-678.
- SCHAUENBURG, P.: Actions of monoidal categories and generalized Hopf smash products, *J. Algebra* **270** (2003), 521-563.
- SCHNEIDER, H.-J., Restuccia, G.: On actions of infinitesimal group schemes, *J. Algebra* **261** (2003), 229-244.
- ZÖSCHINGER, H.: Starke Kotorsionsmoduln, *Arch. Math.* **81** (2003), 126-141.
- PRIESS-CRAMPE, S.: Fixed Points and Stable Balls in Ultrametric Spaces, *Result. Math.* **43** (2003), 163--167.
- SCHÖRNER, E.: On maximal immediate extensions of valued division algebras, *Forum Math.* **15** (2003), 123-134.

2. **Beiträge zu Konferenzbänden, Buchkapitel u. ä.:**
   - Andruskiewitsch, N., SCHNEIDER, H.-J.: Pointed Hopf algebras, in: ,,New directions in Hopf algebras'', Hrsg.: S. Montgomery und H.-J. Schneider, *Math. Sci. Res. Inst. Publ.* **43** (2002), 1-68, Camb. Univ. Press, Cambridge.
   - Milinski, A., SCHNEIDER, H.-J.: Pointed indecomposable Hopf algebras over Coxeter groups, in: ,,New trends in Hopf algebra theory'', Hrsg.: N. Andruskiewitsch, W. Ferrer-Santos, H.-J. Schneider, Tagungsband zu ,,Colloquium on quantum groups and Hopf algebras'' (Córdoba, Argentinien, 1999), *Contemp. Math.* **267** (2000), 215-236, Am. Math. Soc., Providence.
   - PAREIGIS, B.: Quantum groups - The functorial side, in : Tagungsband der Konferenz ,,Categorical methods in algebra and topology CatMAT 2000'', Universität Bremen (2000), 321-332.
   - SCHAUENBURG, P.: Faithful flatness over Hopf subalgebras -- Counterexamples, in: ,,Interactions between Ring Theory and Representations of Algebras'' (Murcia 1998), Hrsg.: F. Van Oystaeyen und M. Saorin, *Lect. Notes Pure Appl. Math.* **210**

(2000), 331-344, Marcel Dekker, New York.

- SCHAUENBURG, P.: Duals and doubles of quantum groupoids ($\times_R$-Hopf algebras), in: ,,New trends in Hopf algebra theory‘‘, Hrsg.: N. Andruskiewitsch, W. Ferrer-Santos, H.-J. Schneider, Tagungsband zu ,,Colloquium on quantum groups and Hopf algebras‘‘ (Córdoba, Argentinien, 1999), *Contemp. Math.* **267** (2000), Am. Math. Soc., Providence.
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- SCHAUENBURG, P.: Morita base change in quantum groupoids, in: ,,Locally compact quantum groups and groupoids‘‘ (Tagungsband zu: ,,69ème rencontre entre physiciens théoriciens et matématiciens‘‘), *IRMA Lect. Math. Theor. Phys.* **2** (2002), 79-103, De Gruyter, Berlin.
- PAREIGIS, B.: Tensor products and forgetful dunctors of entwined modules, in: ,,Pumplün-70-Festschrift‘‘, Hrsg.: A. Krieg, S. Walcher, RWTH Aachen (2003), 1-12.
- PRIESS-CRAMPE, S., Ribenboim, P.: Systems of differential equations over valued fields, in: "‘Ultrametric functional analysis"’, Hrsg.: W. H. Schikhof, C. Peres-Garcia, Tagungsband zu "‘Seventh international conference on p-adic functional analysis"’, *Contemp. Math.* **319** (2003), 299--318, Am. Math. Soc., Providence.
- SCHÖRNER, E.: Ultrametric fixed point theorems and applications, in: Valuation theory and its applications, Vol. II, Hrsg: F.-V. Kuhlmann, S. Kuhlmann, M. Marshall, Tagungsband zu "‘International conference and workshop on valuation theory"’, *Fields Inst. Commun.* **33** (2003), 353--359, Am. Math. Soc., Providence.

3. **Bücher:**
   - PAREIGIS, B.: Lineare Algebra für Informatiker, *Springer-Lehrbuch*, Springer, Berlin, 2000.
   - SOMMERHÄUSER, Y.: Yetter-Drinfel’d Hopf algebras over groups of prime order, *Lect. Notes Math.* **1789**, Springer, Berlin, 2002.

1.1.3 Betreute wissenschaftliche Arbeiten:

1. **Habilitationsschriften:**
   - ANGELERI HÜGEL, L.: On some precovers and covers (2000)
2. **Dissertationen:**
   - SCHARFSCHWERDT, B.: Endlich dimensionale Yetter Drinfeld Hopfalgebren (Proff. Schneider H. und Pareigis B.) 2000
   - ULM, V.: Operationen von Hopfalgebren in Kategorien von Yetter-Drinfeld-Moduln (Proff. Schneider H.-J. und Pareigis B.) 2000
   - Didt, D.: Linkable Dynkin diagrams and quasi-isomorphisms for finite dimensional pointed Hopf algebras (Erstgutachter: SCHNEIDER, H.-J., Zweitgutachter: SCHAUENBURG, P.) (2003)

1.1.4 Eingeworbene Drittmittel:

1. **Förderprogramme der EU:**
   - Hajac, P. M. als Marie-Curie-Stipendiat bei H.-J. SCHNEIDER, 2 Jahre ab 1. 3. 2001, insgesamt 139950 Euro
   - Wisniewski, P.: Postdoktorand in München bei H.-J. SCHNEIDER mit EU-Mitteln über Antwerpen

2. **Sonstige:**
   - PAREIGIS, B.: 10000 kan. Dollar zur Organisation einer Tagung am Fields-Institut, Toronto, September 2002.
   - SOMMERHÄUSER, Y.: Reise- und Aufenthaltskosten, 12000 Hongkong-Dollar = 1558,50 Euro, Projektnummer: HKUST6136/00P, Hong Kong University of Science and Technology, China, Oktober 2002
   - UFER, S.: Promotionsstipendium der Graduiertenförderung des Landes Bayern, 17280 Euro.

1.2 Arbeitsbereich Analysis und Numerik

Wissenschaftler mit Dauerstellen: Prof. L. ERDÖS (Seit 1. 7. 2003), Ph.D., Prof. Dr. H. SIEDENTOP (Seit 1. 6. 2000) , Prof. Dr. H. KALF, Prof. Dr. W. RICHERT, Prof. Dr. A. SACHS, Prof. Dr. H. STEINLEIN, Priv.-Doz. Dr. E. SCHÄFER,
Dr. J. SCHMALZING (Seit 1. 10. 2003, Leiter des Rechenzentrums), Dr. E. JÖRN (Bis 30. 9. 2003, Leiter des Rechenzentrums) , Dr. W. SPANN (Mitarbeiter des Rechenzentrums.)

1.2.1 Forschungsschwerpunkte:

1.
   - Verantwortlicher: FARKAS, W.
   - Titel: Spektraltheorie für Differentialoperatoren auf Fraktalen
   - key words (engl.): fractal drum, eigenvalue distribution, Dirichlet-Laplacian, Dirichlet form, trace operator, reflecting diffusion
   - Beschreibung: Es ist gelungen weitreichende Aussagen zur Spektraltheorie fraktaler semi-elliptischer Differentialoperatoren, insbesondere scharfe Abschätzungen für die Eigenwertverteilung, zu erhalten. Diese stehen zum Teil im Zusammenhang mit der Problematik der fraktalen Trommel.

     Randwertprobleme für subordinierte Dirichlet und Neumann-Probleme wurden auf den Fall nicht glatter (fraktaler) Ränder übertragen.

2.
   - Verantwortlicher: FARKAS, W.
   - Titel: Pseudodifferentialoperatoren und Klassen von anisotropen Funktionenräumen
   - key words (engl.): anisotropic Sobolev space, atomic decomposition, Littlewood-Paley theory, pseudo-differential operator, continuous negative definite function, sub-Markovian semigroup
   - Beschreibung: Es wurden atomare und subatomare Zerlegungen anisotroper Funktionenräume erhalten.

     Anwendungen dieser Sätze über atomare Zerlegungen von Funktionenräumen findet man in einer umfangreichen Behandlung aller Grenzfälle der 'Spuren von Funktionenräumen'. Die Kenntnis der genauen Spur eines Funktionenraumes spielt eine Schlüsselrolle in der Behandlung von partieller Differentialgleichungen.

     Im Mittelpunkt zweier weiteren Arbeiten stand die systematische Untersuchung der L_p -Varianten von Funktionenräumen. Diese werden benötigt um Pseudodifferentialoperatoren zu behandeln, die L_p -sub-Markoffsche Halbgruppen erzeugen, falls das Symbol des Pseudodifferentialoperators mit einer stetig negativ definiten Funktion vergleichbar ist.

3.
   - Verantwortlicher: HAINZL, CH.
   - Titel: Mathematische Physik
   - key words (engl.): Many Particle quantum mechanics, decomposition of radial functions in R^n . Enhanced binding, Self-energy of an electron coupled to a photon field

- Beschreibung: Gemeinsam mit Robert Seiringer entwickelten wir eine Zerlegung für beliebige radiale Funktionen, die im unendlichen gegen 0 streben. Diese Verallgemeinerung der Fefferman-de la Llave Zerlegung des Coulomb Potentials kann verwendet werden, um frühere Resultate der *N* Teilchen Quantenmechanik auf allgemeinere Klassen von Wechselwirkungen zu verallgemeinern. Als Beispiel einer solchen Anwendung berechnen wir den Hochdichtelimes der Grundzustandsenergie von Jellium mit Yukawa Wechselwirkung, wobei wir eine Korrelationsabschätzung von Graf-Solovej verwenden.

4.

- Verantwortlicher: KALF, H.
- Titel: Spektraltheorie singulärer Differentialoperatoren
- key words (engl.): spectral theory, differential operators, Schrödinger operators, Dirac operators
- Beschreibung: Typische Fragestellungen in der Spektraltheorie (linearer) Differentialoperatoren, speziell der in der Quantenmechanik auftretenden Schrödinger- und Diracoperatoren, sind etwa die folgenden: Existenz und Eindeutigkeit selbstadjungierter Realisierungen solcher Operatoren in einem Hilbertraum, nähere Beschreibungen ihrer Definitionsbereiche, Abhängigkeit der Lage und Natur des Spektrums (Existenz oder Nichtexistenz von Eigenwerten, wesentliches, absolutstetiges und singulärstetiges Spektrum) vom Verhalten ihrer Koeffizienten. Für die zur Beantwortung solcher Fragen erforderlichen Hilfsmittel ist eine Mischung von konkreten Techniken, vornehmlich aus der klassischen reellen Analysis, und abstrakten Methoden charakteristisch, wodurch sich in natürlicher Weise Beziehungen zu einer Reihe anderer mathematischer Disziplinen ergeben.

5.

- Verantwortlicher: KRIECHERBAUER, T.
- Titel: Mathematische Physik
- key words (engl.): integrable systems, random matrix theory, Riemann-Hilbert problems, wave propagation
- Beschreibung:
  Aus dem Bereich der Mathematischen Physik werden die folgenden Themen behandelt.
  Wellenausbreitung in nichtlinearen Medien:
  Es werden diskrete Modelle (Gitter) der Wellenausbreitung studiert. Mit Hilfe von störungstheoretischen Methoden wird die Existenz periodischer und quasiperiodischer Wellenlösungen untersucht.
  Eigenwertstatistik von Zufallsmatrizen:
  Die Untersuchungen auf diesem Gebiet beziehen sich vor allem auf die Universalitätsvermutung für Ensembles Hermitescher Matrizen. Die damit verbundenen Fragestellungen können auf die asymptotische Analyse zugehöriger matrixwertiger Riemann-Hilbert Probleme zurückgeführt werden. Als Nebenprodukt gewinnt man hierbei auch neue Erkenntnisse über die Asymptotik orthogonaler Polynome.

6.

- Verantwortlicher: SIEDENTOP, H.
- Titel: Analysis, Mathematische Physik
- key words (engl.): Large Coulomb systems, asymptotics of spectra in large dimensions, quantum electrodynamics
- Beschreibung: Große Quantensysteme werden durch partielle Differentialgleichungen mit singulären Koeffizienten beschrieben. Diese Modelle sind teilweise mathematisch noch nicht konsistent formuliert (z. B.

Quantenelektrodynamik) oder sind mathematisch sehr komplex. Die derzeitige Forschung zielt auf die mathematisch konsistente Formulierung und die Untersuchung physikalisch relevanter Größen (z.B. dem Energiespektrum) dieser Modelle gerichtet.

7.

- Verantwortlicher: STEINLEIN, H.
- Titel: Nichtlineare Funktionalanalysis
- key words (engl.): Borsuk-Ulam theorems, equivariant degree, orthogonal representations of compact Lie groups, *G*-maps, steady-state bifurcation, Hopf bifurcation
- Beschreibung: Untersucht wird der äquivariante Abbildungsgrad für ($SO(3) \times S^1$)-Abbildungen. $SO(3) \times S^1$ ist die adäquate Lie-Gruppe für periodische Probleme mit räumlicher Symmetrie. Ziel der Untersuchungen sind konkrete Formeln und Berechnungsverfahren für verschiedene Typen von Verzweigungen, insbesondere in Verbindung mit der Multiplikativitätseigenschaft des äquivarianten Abbildungsgrades.

8.

- Verantwortlicher: WUGALTER, S.
- Titel: Untersuchung des diskreten Spektrums der Schrödinger Mehrteilchenoperatoren
- key words (engl.): Schrödinger operators with magnetic field, pseudorelativistic Schrödinger operators, eigenvalue distribution, pseudomomentum.
- Beschreibung: Die Existenz des diskreten Spektrums der Schrödinger-Mehrteilchenoperatoren im homogenen Magnetfeld, sowie desjenigen der Pseudorelativistischen Schrödinger-Operatoren wurden untersucht. Die Spektralasymptotiken wurden für den Spezialfall der Atome erhalten.

9.

- Verantwortlicher: WUGALTER, S.
- Titel: Bindungsfähigkeit der Elektronen in der nichtrelativistischen Quantenelektrodynamik
- key words (engl.): enhanced binding, Pauli-Fierz operators, binding energy.
- Beschreibung: Es wurde bewiesen, dass die Wechselwirkung mit dem Photonenfeld die Bindungsfähigkeit des Potenzials und die Bindungsenergie erhöht.

10.

- Verantwortlicher: ERDOS L.
- Titel: Magnetic Lieb-Thirring inequalities
- key words (engl.): Magnetic Schrodinger operator, eigenvalue moments, Lieb-Thirring estimate
- Beschreibung: The Pauli operator describes the energy of a nonrelativistic quantum particle with spin 1/2 in a magnetic field and an external potential. Bounds on the sum of the negative eigenvalues are called magnetic Lieb-Thirring (MLT) inequalities. We prove MLT estimates that grow with the sharp (first) power of the strength of the magnetic field. As a byproduct of the method, we also obtain optimal upper bounds on the pointwise density of zero energy eigenfunctions of the Dirac operator.

11.

- Verantwortlicher: ERDOS L.
- Titel: Many-body interacting quantum dynamics
- key words (engl.): Hartree equation, Vlasov equation, mean-field limit,
- Beschreibung: We consider a system of *N* weakly interacting fermions with a real

analytic pair interaction. We prove that for a general class of initial data there exists a fixed time *T* such that the difference between the one particle density matrix of this system and the solution of the non-linear Hartree equation is of order N^{-1} for any time $t \leq T$.

12.

- Verantwortlicher: ERDOS L.
- Titel: Quantum diffusion in scaling limit
- key words (engl.): Anderson localization, Quantum Brownian motion, extended states.
- Beschreibung: We investigate the long time behaviour of the evolution of a quantum particle in a weakly coupled random environment. On the kinetic scale, where the evolution is described by the Boltzmann equation. Beyond this time-scale diffusive behavior is expected in $d \geq 3$ dimensions. We prove this claim in the scaling limit.

13.

- Verantwortlicher: SØRENSEN T. Ø.
- Titel: Regularity of wave functions and electron densities of atoms and molecules
- key words (engl.): Mathematical Physics; Analysis of PDEs.
- Beschreibung: In an ongoing collaboration with M. and T. Hoffmann-Ostenhof (ESI, Vienna) and S. Fournais (Paris Sud), I study the regularity of solutions to the Schrödinger equation for atoms and molecules (wavefunctions), and derived quantities (the one- and two-electron densities). The short-term goal of the project is to understand how the singularities of the Coulomb-potential in the electron-electron and electron-nucleus interaction manifest themselves in the structure of the singularities of the wavefunction. In the future, we hope to be able to apply this insight to problems on the spectrum of the Schrödinger operator for these problems.

1.2.2 Im Druck erschienene Publikationen:

1. **Zeitschriftenartikel:**
   - Bach V, Barbaroux J-M, Helffer B, SIEDENTOP H: On the stability of the relativistic electron-positron field, *Comm. Math. Phys.* **201** (1999), 445-460.
   - BADER R: On the semilinear multivalued flow under constraints and the periodic problem, *Comment. Math. Univ. Carolin.* **41** (2000), 719-734.
   - BADER R: A topological fixed-point index theory for evolution inclusions, *Z. Anal. Anwendungen* **20** (2001), 3-15.
   - BADER R, Kamenskii M I, Obukhovskii V V: On some classes of operator inclusions with lower semicontinuous nonlinearities, *Topol. Meth. Nonlin. Anal.* **17** (2001), 143-156.
   - BADER R, Kryszewski W: On the solution sets of constrained differential inclusions with applications, *Set-Valued Analysis* **9** (2001), 289-313.
   - BADER R, Papageorgiou N S: Quasilinear vector differential equations with maximal monotone terms and nonlinear boundary conditions, *Ann. Pol. Math.* **73** (2000), 69-92.
   - Balanov Z, Krawcewicz W, STEINLEIN H: Reduced $SO(3) \times S^1$ -Equivariant Degree with Applications to Symmetric Bifurcation Problems. *Nonlinear Anal.* **47** (2001), 1617-1628
   - BATT J: N-Particle Approximation to the Nonlinear Vlasov-Poisson System,

Nonlinear Anal. **47** (2001), 1445-1456.

- BATT J: Leo August Pochhammer, *Neue Deutsche Biographie* **20** (2001), 554.
- BATT J: Der Anteil der Mathematik an unserer Orientierung in der Welt, *Ausblicke (Dokumentationsschrift des Zentrums Seniorenstudium an der Universität München)* Heft **11** (2002), 5-12.
- Benguria R, SIEDENTOP H, STOCKMEYER E: Dissociation of homonuclear relativistic molecular ions, *Ann. Henri Poincaré* **2** (2001), 27-40.
- Brummelhuis R, Röhrl N, SIEDENTOP H: Stability of the relativistic electron-positron field of atoms in Hartree-Fock approximation: heavy elements, *Doc. Math.* **6** (2001), 1-9 (electronic).
- Brummelhuis R, SIEDENTOP H, STOCKMEYER E: The ground state energy of relativistic one-electron atoms according to Jansen and Hess, *Doc. Math.* **7** (2002), 167-182 (electronic).
- Collis S S, Ghayour K, Heinkenschloss M, Ulbrich M, ULBRICH S: Optimal Control of Unsteady Viscous Flows, *Int. J. Numer. Meth. Fluids* **40** (2002), 1401-1429.
- Deift P, KRIECHERBAUER T, McLaughlin K T-R, Venakides S, Zhou X: Strong Asymptotics of Orthogonal Polynomials with Respect to Exponential Weights, *Comm. Pure Appl. Math.* **52** (1999), 1491-1552.
- Deift P, KRIECHERBAUER T, McLaughlin K T-R, Venakides S, Zhou X: Uniform Asymptotics for Polynomials Orthogonal with respect to Varying Exponential Weights and Applications to Universality Questions in Random Matrix Theory, *Comm. Pure Appl. Math.* **52** (1999), 1335-1425.
- Exner P, VUGALTER S A: On the number of particles that a curved quantum waveguide can bind, *J. Math. Phys.* **40** (1999), 4630-4638.
- FARKAS W: The behaviour of the eigenvalues for a class of operators related to some self-affine fractals in R^2 , *Z. Anal. Anwendungen* **18** (1999), 875-893.
- FARKAS W: Atomic and subatomic decompositions in anisotropic function spaces, *Mathematische Nachrichten* **209** (2000), 83-113.
- FARKAS W: Eigenvalue distribution of some fractal semi-elliptic differential operators, *Mathematische Zeitschrift* **236** (2001), 291-320.
- FARKAS W, Jacob N: Sobolev spaces on non-smooth domains and Dirichlet forms related to subordinate reflecting diffusions, *Mathematische Nachrichten* **224** (2001), 75-104.
- FARKAS W, Jacob N, Schilling R L: Feller semigroups, L^p -sub-Markovian semigroups, and applications to pseudo-differential operators with negative definite symbols, *Forum Math.* **13** (2001), 59-90.
- FARKAS W, Jacob N, Schilling R L: Function spaces related to continuous negative definite functions: ψ -Bessel potential spaces, *Dissertationes Math.* **393** (2001), 1-63.
- FARKAS W, Johnsen J, Sickel W: Traces of Besov-Lizorkin-Triebel spaces - a complete treatment of the borderline cases, *Math. Bohem.* **125** (2000), 1-37.
- FARKAS W, Triebel H: The distribution of eigenfrequencies of anisotropic fractal drums, *J. London Math. Soc.* **60** (1999), 224-236.
- Georgieva A, KRIECHERBAUER T, Venakides S: Wave Propagation and Resonance in a 1-d Nonlinear Discrete Periodic Medium, *SIAM J. Appl. Math.* **60** (2000), 272-294.
- Georgieva A, KRIECHERBAUER T, Venakides S: 1:2 resonance mediated second harmonic generation in a 1-D nonlinear discrete periodic medium, *SIAM J. Appl.*

Math. **61** (2001), 1802-1815.

- Griesemer M, Lewis R T, SIEDENTOP H: A minimax principle for eigenvalues in spectral gaps: Dirac operators with Coulomb potentials, *Doc. Math.* **4** (1999), 275-283 (electronic).
- Griesemer M, SIEDENTOP H: A minimax principle for the eigenvalues in spectral gaps, *J. London Math. Soc. (2)* **60** (1999), 490-500.
- HAINZL CH, Seiringer R: General decomposition of radial functions on R^n and applications to *N*-body quantum Systems, *Lett. Math. Phys.* **61** 2002, 75-84.
- Hoever G, SIEDENTOP H: Stability of the Brown-Ravenhall operator, *Math. Phys. Electron. J.* **5** (1999), 6-11 (electronic).
- Hundertmark D, Röhrl N, SIEDENTOP H: The sharp bound on the stability of the relativistic electron-positron field in Hartree-Fock approximation, *Comm. Math. Phys.* **211** (2000), 629-642.
- Iantchenko A, SIEDENTOP H: Asymptotic behavior of the one-particle density matrix of atoms at distances Z^{-1} from the nucleus, *Math. Z.* **236** (2001), 787-796.
- KALF H: A Remark on Claus Müller's Version of Nicholson's Formula, Integral Transforms and Special Functions **11** (2001), 273-280.
- KALF H, Yamada O: Note on the Paper ''Strong Unique Continuation Property for the Dirac Equation'' by DeCarli and Okaji, *Publ. Research Inst. Math. Sci. Kyoto Univ.* **35** (1999), 847-855.
- KALF H, Yamada O: Essential Self-Adjointness of Dirac Operators with a Variable Mass Term, *Proc. Japan Acad. Ser.* **A 76** (2000), 13-15.
- KALF H,Yamada O: Essential Self-Adjointness of n-Dimensional Dirac Operators with a Variable Mass Term, *J. Math. Phys.* **42** (2001), 2667-2676
- KRIECHERBAUER T, Marklof J, Soshnikov A: Random Matrices and Quantum Chaos, *Proc. Natl. Acad. Sci. USA* **98** (2001), 10531-10532.
- KRIECHERBAUER T, Remling C: Finite gap potentials and WKB asymptotics for one-dimensional Schrödinger operators, *Comm. Math. Phys.* **223** (2001), 409-435.
- Lieb E H, SIEDENTOP H: Renormalization of the regularized relativistic electron-positron field, *Comm. Math. Phys.* **213** (2000), 673-683.
- ULBRICH S: Adjoint-Based Derivative Computations for the Optimal Control of Discontinuous Solutions of Hyperbolic Conservation Laws, *Systems Control Lett.* **48** (2002), 153-168.
- ULBRICH S: A Sensitivity and Adjoint Calculus for Discontinuous Solutions of Hyperbolic Conservation Laws with Source Terms, *SIAM J. Control Optim.* **41** (2002), 740-797.
- VUGALTER, S A, Zhislin, G M: Spectral properties of a pseudorelativistic system of two particles with finite masses (Russian), *Teoret. Mat. Fiz.* **121** (1999), 297-306; translation in *Theoret. and Math. Phys.* **121** (1999), 1506-1515.
- VUGALTER, S A, Zhislin, G M: On the discrete spectrum of Hamiltonians of atoms in a homogeneous magnetic field (Russian), *Funktsional. Anal. i Prilozhen.* **34** (2000), 80-83.
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- H.KALF: Franz Rellich. Neue Deutsche Biographie **21** (2003), 406-407
- H.KALF, T. Okaji, O.Yamada: Absence of eigenvalues of Dirac operators with potentials diverging at infinity. Math. Nachr. **259** (2003), 19-41

- A.Iantchenko, D.H.JAKUBASSA-AMUNDSEN: On the positivity of the jansensen-Hess operator for arbitrary mass. Ann. Henri Poincare **4** (2003) 1-17
- C.D.JÄKEL: The Reeh-Schlieder Property for ground states. Ann. Phys. (Leipzig) **12** (2003) 14
- T.NAGAO: On the flux-across surfaces theorem for short-range potentials. A.. Henri Poincare **4** (2003)
- S.VUGALTER, T.Weidl: On the discrete spectrum of pseudo-relativistic two-body pait operator. Ann Henri poincare **4** (2003) No.2 301-341
- T.Chen, V.Vougalter, S.VUGALTER: The increase of binding energy and enhanced binding in nonrelativistic QED. J.Math. Phys. **44** (2003) No.5 1961-1970
- C.HAINZL, V.Vougalter, S.VUGALTER: Enhanced binding in non-relativistic QED. Commun. Math. Phys. **233** (2003) No.1 13-26
- C.HAINZL: One non-relativistic particle coupled to a photon field. Ann. Henri Poincare **4** (2003) 217-237
- B.CAMUS: A semiclassical trace formula at a non-degenerate critical energy level. Journal of Functional Analysis (2003)
- B.CAMUS: Semiclassical trace formula at a totally degenerate critical energy level. Case of a local extremum. Commun. Math. Phys. **233** (2003)
- R. L. FRANK: On the scattering theory of the Laplacian with a periodic boundary condition. I. Existence of wave operators. *Documenta Mathematica*. **8** (2003) 547-565

2. **Beiträge zu Konferenzbänden, Buchkapitel u. ä.:**
   - FARKAS W: On function spaces of generalised smoothness in the theory of Markov processes, Tagungsband *Conference 'New Trends in Potential Analysis and Applications'*, Bielefeld, 26-30. März 2001.
   - FARKAS W: On sub-Markovian semigroups and the domain of definition of their generator, Tagungsband der *DMV- Jahrestagung*, Dresden, 17-22 Sept. 2000.
   - FARKAS W: The behaviour of the eigenvalues for a class of operators related to some self-affine fractals in the plane, *Third European Congress of Mathematics - Abstracts*, Barcelona, 2000.
   - KALF H, Yamada O: Essential Self-Adjointness of n-Dimensional Dirac Operators with a Variable Mass Term, *International Conference on Partial Differential Equations Held July 24-28, 2000, in Clausthal*, in: Operator Theory: Advances and Applications **126** (2001), 165-167.
   - Haugg S, RICHERT W, Leoson R: Test Drive on RV ‘‘Polarstern’’ Using the EGNOS Test Signal.in ‘‘Proceedings GNSS-2001, Session 3B’’.
3. **Bücher:**
   - Operator Algebras and Mathematical Physics, Conference Proceedings, Constanta (Romania), Edited by Jean-Michel Combes, Joachim Cuntz, George A. Elliott, Gheorghe Nenciu, SIEDENTOP H, Serban Stratila, Theta, Bucharest 2003

1.2.3 Betreute wissenschaftliche Arbeiten:

1. **Habilitationsschriften:**
   - KRIECHERBAUER, T.: On the existence of quasi-periodic lattice oscillations (1999/2000)
   - FARKAS W: Function spaces of generalised smoothness and pseudo-differential operators associated to a continuous negative definite function
   - Hundertmark D: Some contributions to the spectral theory of Schrödinger operators

- VUGALTER S: Discrete spectrum of multiparticle Schrödinger operators with magnetic field

2. **Dissertationen:**
   - RODEWIS, T.: Partikelmethoden zur numerischen Behandlung des symmetrischen Vlasov-Poisson- und Vlasov-Einstein-Systems (Proff. Batt J. und Petras (TU Braunschweig)) 2000
   - HöVERMANN, F.: Quantum Motion in Periodic Potentials (Proff. Kalf H. und Spohn H.) 2000
   - DIETZ, S. (geb. SHEVCHENKO): Flache Lösungen des Vlasov-Poisson-Systems (Proff. Batt, J. und Kalf, H.) 2002
   - Röhrl, N: Stabilität und Instabilität des relativistischen Elektronen-Positronen-Felds in Hartree-Fock-Näherung, 2000 (SIEDENTOP).

1.2.4 Eingeworbene Drittmittel:

1. **DFG** (außer Graduiertenkollegien):
   - BATT J: Aufenthalt am *Tata Institute for Fundamental Research Bangalore (Indien)*.
   - KALF H: DM 13.200 für einen dreimonatigen Gastaufenthalt 2001/2002 von Prof. Dr. Ts. Boldsukh aus Ulan Bator, Mongolei (446 MON 112/1/01)
   - SIEDENTOP H: BAT IIA/2-Stelle, DFG-Schwerpunktprogramm, Az.SI348-8: Modelle zur Beschreibung von relativistischen Vielteilchen-Coulomb-Systemen.
   - SIEDENTOP H: Euro 950 für Reise nach Birmingham USA, Az. SI 348/9-1.
   - WUGALTER S: Euro 950, Zuwendung zur Finanzierung der Reise zur Konferenz *Partial Differential Equations and Mathematical Physics, Birmingham (USA) 2002*.
2. **Förderprogramme der EU:**
   - SIEDENTOP H: Euro 163 820 Marie-Curie-Fellowship, Dr. Christian HAINZL 1.3.2001-28.2.2003.
   - SIEDENTOP H: TMR Network ‘‘Postdoctoral Training Program in Partial Differential Equations and Applications in Quantum Mechancis’’, Netzwerkkoordinator, bis 31. 8. 2000.
   - SIEDENTOP H: IHP Network ‘‘Postdoctoral Training Program in Mathematical Analysis of Large Quantum Systems’’, Netzwerkkoordinator, ab 1. 10. 2002.
   - SIEDENTOP H: TMR-Netzwerk der EU, Contract.No.: ERBFMRX-CT-96-0001 Network Short Title: ’’Relativistische Coulombsysteme Mitteleingang 2003: 153205,71 Euro - Mittelumfang für 2003: 48001,39 Euro
3. **Sonstige:**
   - KALF H: Euro 5.970 vom DAAD (A/02/04799) für einen dreimonatigen Gastaufenthalt 2002 von Prof. Dr. Ts. Bayasgalan aus Ulan Bator, Mongolei
   - KALF H: Euro 1.687,26 von der Gesellschaft von Freunden und Förderern der Universität München (Bewilligungsguthaben Nr. 31006) für Reise- und Aufenthaltskosten von Professor Dr. M. Solomyak aus Rehovot (Israel) im Juni 2002
   - SIEDENTOP H. und KOTSCHICK D.: Euro 310 799, DAAD: International Quality Network 1.10.2001-31.12.2003.
   - SIEDENTOP H. und Benguria R.: Euro 72 572 VW-Stiftung: Kooperation mit der Katholischen Universität Santiago de Chile: ‘‘Mathematical Analysis of Relativistic Atoms and Molecules’’ under the ‘‘Program of Partnerships. Joint Research Projects in the Natural, Engineering and Economic Sciences with Institutes in Africa, Asia and Latin America’’

- SIEDENTOP H: Bayerisch-Französisches Hochschulzentrum: Austausch von Wissenschaftlern und Hochschullehrern zwischen der Ludwig-Maximilians-Universität München und der Universität Nantes
- SIEDENTOP H: Bayerisch-Französisches Hochschulzentrum: Austausch von Wissenschaftlern und Hochschullehrern zwischen der Ludwig-Maximilians-Universität München und der Universität Toulon
- ERDOS L: NSF Grant (DMS-0200235) Erhalten: 34,000 $ in 2003 vor Dienstantritt.

1.3 Arbeitsbereich Differentialgeometrie und Topologie

Wissenschaftler mit Dauerstellen: Prof. D. KOTSCHICK, D. Phil., Prof. B. LEEB (Seit 1. 4. 2003') , Ph.D., Prof. Dr. K. CIELIEBAK (Seit 1. 10. 2001)

1.3.1 Forschungsschwerpunkte:

1.
   - Verantwortlicher: KOTSCHICK D.
   - Titel: Flächenbündel, Lefschetz Faserungen und Abbildungsklassengruppen
   - key words (engl.): Lefschetz fibration, mapping class group, surface bundle
   - Beschreibung: Lefschetz Faserungen auf vier-dimensionalen Mannigfaltigkeiten sind eine Verallgemeinerung einer klassischen Konstruktion aus der algebraischen Geometrie. Sie liefern im Prinzip eine kombinatorische Beschreibung aller symplektischen vier-Mannigfaltigkeiten durch ihre Monodromie-Darstellungen. Wir haben die Geometrie von Lefschetz Faserungen benutzt, um neue Beispiele von Flächenbündeln über Flächen zu konstruieren, deren Existenz Aussagen über die Gromov-Thurston Norm in der zweiten Homologie der Abbildungsklassengruppen implizieren. Weiterhin haben wir, mit Hilfe von Seiberg-Witten Theorie und symplektischer Geometrie, Ungleichungen zwischen den kombinatorischen Invarianten von Lefschetz Faserungen bewiesen, und diese angewendet um untere Schranken an die Kommutator-Längen von Potenzen von Dehn Twists herzuleiten. Diese zeigen insbesondere, dass Abbildungsklassengruppen nicht gleichmässig perfekt sind, obwohl sie perfekt sind. Es ergeben sich auch Verallgemeinerungen der sogenannten Szpiro Ungleichung für semistabile symplektische Faserungen.
2.
   - Verantwortlicher: K. CIELIEBAK
   - Titel: Symplectic Vortex Equations
   - key words (engl.): Hamiltonian group actions, quantum cohomology, mirror symmetry, toric manifolds
   - Beschreibung: The symplectic vortex equations are a system of nonlinear partial differential equations on a symplectic manifold with a Hamiltonian group action. In cooperation with D.Salamon, we have derived a wall crossing formula for the corresponding invariants if the group is a torus. This led us to a proof of Batyrev's conjecture on the quantum cohomology ring of monotone toric manifolds. Our present research concerns extensions of this result to nonabelian groups, as well as the semi-monotone case. These extensions will have applications to the Verlinde algebra and mirror symmetry.
3.
   - Verantwortlicher: CIELIEBAK K.
   - Titel: Symplektische Geometrie
   - key words (engl.): symplectic and contact geometry, Hamiltonian systems, moduli spaces
   - Beschreibung: Der Schwerpunkt meiner derzeitigen Forschung liegt auf dem Studium der symplektischen Vortex-Gleichungen. Dies ist ein System von nichtlinearen partiellen Differentialgleichungen auf symplektischen Mannigfaltigkeiten mit Hamiltonschen Gruppenaktionen. In Zusammenarbeit mit R. Gaio, I. Mundet und D. Salamon haben wir in den letzten zwei Jahren die Lösungstheorie dieser Gleichungen entwickelt und mit ihrer Hilfe neue Invarianten

definiert. Im nächsten Stadium wenden wir nun diese Invarianten auf Fragen der symplektischen und der algebraischen Geometrie an. Als erste Anwendung konnten wir eine 10 Jahre alte Vermutung von Batyrev über den Quantenkohomologiering monotoner torischer Mannigfaltigkeiten bestätigen. Wir arbeiten an Erweiterungen dieses Ergebnisses auf nichtmonotone Mannigfaltigkeiten, an Gromov-Witten-Invarianten von höherem Geschlecht und an Wirkungen nichtabelscher Gruppen. In einer anderen Richtung wenden wir die symplektischen Vortex-Gleichungen auf die Frage der Äquivalenz verschiedener Invarianten für glatte 4-Mannigfaltigkeiten an.

4.

- Verantwortlicher: KOTSCHICK D.
- Titel: Geometrische Formalität
- key words (engl.): formality, harmonic form
- Beschreibung: Eine differenzierbare Mannigfaltigkeit heisst geometrisch formal, wenn es eine Riemannsche Metrik gibt für die alle Produkte harmonischer Formen ebenfalls harmonisch sind. Hieraus folgt zum Beispiel die Formalität im Sinne der reellen Homotopie-Theorie. Wir haben damit begonnen geometrisch formale Mannigfaltigkeiten systematisch zu untersuchen, und haben in kleinen Dimensionen Klassifikations- und Struktursätze bewiesen. In höheren Dimensionen haben wir, ausgehend vom klassischen Beispiel invarianter Metriken auf kompakten symmetrischen Räumen, vor allem homogene Räume auf ihre geometrische Formalität untersucht. Weiterhin wurden Beziehungen zur Geometrie von Blätterungen, zur symplektischen Geometrie, und zur Holonomie-Theorie untersucht. Diese ergeben sich weil harmonische Formen auf geometrisch formalen Mannigfaltigkeiten durch ihre speziellen Eigenschaften weitere geometrische Strukturen induzieren.

5.

- Verantwortlicher: KOTSCHICK D.
- Titel: Geometrie und Dynamik von Blätterungen
- key words (engl.): foliation, asymptotic linking, secondary characteristic classes, Lagrangian foliation
- Beschreibung: Es wurden neue charakteristische Klassen für Familien von Blätterungen eingeführt, die differenzierbar von einem Parameter abhängen. Diese Klassen quantifizieren die Variation gewisser dynamischer Eigenschaften. Ausserdem wurden mittlere asymptotische Verschlingungszahlen für Paare von divergenz-freien Vektorfeldern auf drei-dimensionalen Mannigfaltigkeiten untersucht. Dies wurde dann verallgemeinert auf mittlere asymptotische Verschlingungszahlen für ein divergenz-freies Vektorfeld und eine (singuläre) Blätterung der Kodimension zwei mit einem Holonomie-invarianten transversalen Mass. Dies liefert eine geometrische Interpretation gewisser charakteristischer Klassen für Familien.

  Schliesslich wurden Paare von komplementären Lagrangeschen Blätterungen auf (fast-) symplektischen Mannigfaltigkeiten untersucht.

6.

- Verantwortlicher: D. KOTSCHICK
- Titel: Einstein Metriken auf Vier-Mannigfaltigkeiten
- key words (engl.): Einstein metric, Seiberg-Witten theory, monopole class, smooth structure
- Beschreibung: Aus der Betrachtung von Monopol-Klassen in der Seiberg-Witten

Theorie ergeben sich subtile Einschränkungen an die differenzierbaren Strukturen von vier-dimensionalen Einstein-Mannigfaltigkeiten. Wir haben diese systematisch untersucht, und, mit Methoden der algebraischen und der symplektischen Geometrie, grosse Klassen von Beispielen konstruiert, die u. a. zeigen, dass es viele Vier-Mannigfaltigkeiten gibt die unendlich viele differenzierbare Strukturen ohne Einstein Metriken haben, und die gleichzeitig eine beliebig grosse Anzahl von differenzierbaren Strukturen mit Einstein Metriken zulassen. Weiterhin haben wir die ersten Beispiele von spin Vier-Mannigfaltigkeiten konstruiert, auf denen es differenzierbare Struktuen mit und ohne Einstein Metriken gibt. Wir haben auch Resultate zur Klassifikation von Ricci-flachen Vier-Mannigfaltigkeiten bewiesen, dies sind Einstein-Mannigfaltigkeiten bei denen die Skalarkrümmung verschwindet.

7.

- Verantwortlicher: K. CIELIEBAK
- Titel: Symplectic Field Theory
- key words (engl.): symplectic and contact manifolds, Lagrangian embeddings, punctured holomorphic curves
- Beschreibung: Symplectic field theory is a generalization of Gromov's theory of holomorphic curves in symplectic manifolds, in which closed holomorphic curves are replaced by punctured holomorphic curves with suitable asymptotics. In cooperation with K.Mohnke and J.Latschev, we work on the foundations of this theory, as well as applications in symplectic and contact geometry. Applications obtained so far include: a non-squeezing theorem for Lagrangian embeddings, a new symplectic capacity, the strong version of Arnold's chord conjecture in some cases, and counterexamples to Nash's conjecture.

8.

- Verantwortlicher: SEMMELMANN U.
- Titel: Dirac-Operatoren und spezielle Holonomie
- key words (engl.): Dirac operators, special holonomy, extremal metrics,
- Beschreibung: Der Forschungsschwerpunkt im Berichtszeitraum lag auf den spektralen Eigenschaften des Dirac-Operators und deren Auswirkungen auf die zugrundeliegende Riemannsche Mannigfaltigkeit. In einer Arbeit wurde die Frage geklärt, auf welchen nicht-kompakten symmetrischen Räumen der Dirac-Operator Punktspektrum besitzt. In zwei anderen Arbeiten wurden geeignete Weitzenböckformeln für getwistete Dirac-Operatoren benutzt, um extremale Metriken zu untersuchen. Dadurch konnten Abschätzungen für die Skalarkrümmung auf gewissen Kähler-Mannigfaltigkeiten bewiesen werden. Ausserdem wurde in diesem Zusammenhang eine Vermutung von M. Gromov über extremale Metriken auf symmetrischen Räumen bewiesen. Das wohl wichtigste Resultat konnte für quaternionisch-Kähler Mannigfaltigkeiten bewiesen werden. Hier lieferte eine Kombination von Darstellungstheorie und Indexberechnungen getwisteter Diracoperatoren das Verschwinden von ungeraden Bettizahlen der kompakten quaternionisch-Kähler Manigfaltigkeiten, insbesondere auch bei denen mit negativer Skalarkrümmung.

9.

- Verantwortlicher: B. HANKE
- Titel: Positive scalar curvature: Obstructions and existence.
- key words (engl.): differentiable manifold, positive scalar curvature, *K*-theory of C^* -algebras, bordism
- Beschreibung: We investigate the question which oriented closed smooth manifolds admit metrics of positive scalar curvature. Obstructions coming from Seiberg-Witten theory (in cooperation with D. Kotschick and J. Wehrheim) as well as from index

theory and *K*-theory of C^* -algebras (in cooperation with T. Schick (Göttingen)) are studied. It is also intended to establish new existence results using methods related to equivariant bordism theory.

1.3.2 Im Druck erschienene Publikationen:

1. **Zeitschriftenartikel:**
   - BOHR C.: *Lifting obstructions, ordinary obstructions and spherical fibrations*, Arch. Math. **78** (2002), 90-96.
   - BOHR C.: *On the signatures of even 4-manifolds*, Math. Proc. Camb. Phil. Soc. **132** (2002), 453-469.
   - BOHR C.: *Immersions of surfaces in almost complex 4-manifolds*, Proc. Amer. Math. Soc. **130** (2002), 1523-1532.
   - BOHR C.: *Stabilisation, bordism and embedded spheres in 4-manifolds*, Alg. Geom. Top. **2** (2002), 219-238.
   - BOHR C., HANKE B. und KOTSCHICK D.: *Cycles, submanifolds, and structures on normal bundles*, Manuscripta math. **108** (2002), 483-494.
   - BOHR C. und Lee R.: *Homology cobordism and classical knot invariants*, Comment. Math. Helv. **77** (2002), 363-382.
   - CIELIEBAK K. und Séré E.: *Pseudo-holomorphic curves and the Shadowing Lemma*, Duke Math. J. **99** (1999), 41-73.
   - CIELIEBAK K., Gaio A. und Salamon D.: *J-holomorphic curves, moment maps, and invariants of Hamiltonian group actions*, International Math. Research Notices **2000, No. 16**.
   - Biran P. und CIELIEBAK K.: *Symplectic topology on subcritical manifolds*, Comment. Math. Helv. **76** (2001), 712-753.
   - Biran P. und CIELIEBAK K.: *Lagrangian Embeddings into subcritical Stein Manifolds*, Israel Journal of Math. **127** (2002), 221-244.
   - CIELIEBAK K.: *Handle attaching in symplectic homology and the Chord Conjecture*, J. European Math. Society. **4** (2002), 115-142.
   - ENDO H.: *Meyer's signature cocycle and hyperelliptic fibrations*, Math. Ann. **316** (2000), 237-257.
   - ENDO H. und KOTSCHICK D.: *Bounded cohomology and non-uniform perfection of mapping class groups*, Invent. math. **144** (2001), 169-175.
   - ENDO H., Korkmaz M., KOTSCHICK D., Ozbagci B. und Stipsicz A.: *Commutators, Lefschetz fibrations and the signatures of surface bundles*, Topology **41** (2002), 961-977.
   - HANKE B.: *Symmetrie der Sphären*, Mitt. DMV **3** (2001), 41-45.
   - HANKE B.: *Actions of finite p-groups on homology manifolds*, Math. Proc. Camb. Phil. Soc. **131** (2001), 473-486.
   - HOSTER M.: *A new proof of the signature formula for surface bundles*, Topology Appl. **112** (2001), 205-213.
   - HOSTER M. und KOTSCHICK D.: *On the simplicial volumes of fiber bundles*, Proc. Amer. Math. Soc. **129** (2001), 1229-1232.
   - KOTSCHICK D.: *On products of harmonic forms*, Duke Math. J. **107** (2001), 521-531.
   - PUSCHNIGG M.: *Excision in cyclic homology theories*, Invent. math. **143** (2001), 249-323.
   - Hubbard J., SCHLEICHER D. und Sutherland S.: *How to find roots of complex*

polynomials by Newton's method, Invent. math. **146** (2001), 1-33.

- Moroianu A. und SEMMELMANN U.: *Parallel spinors and holonomy groups*, J. Math. Phys. **41** (2000), 2395-2402.
- Goette S. und SEMMELMANN U.: *Spin^c Structures and Scalar Curvature Estimates*, Ann. Global Anal. Geom. **20** (2001), 301-324.
- Goette S. und SEMMELMANN U.: *The point spectrum of the Dirac operator on noncompact symmetric spaces*, Proc. Amer. Math. Soc. **130** (2002), 915-923.
- SEMMELMANN U. und Weingart G.: *Vanishing Theorems for Quaternionic Kähler Manifolds*, J. Reine Angew. Math. **544** (2002), 111-132.
- Goette S. und SEMMELMANN U.: *Scalar Curvature Estimates for Compact Symmetric Spaces*, Differential Geom. Appl. **16** (2002), 65-78.
- VOGEL T.: *On the asymptotic linking number*, Proc. Amer. Math. Soc. **131** (2003), no. 7, 2289-2297.
- G. BANDE, *Couples contacto-symplectiques*, Trans. Amer. Math. Soc. **355** (2003), 1699-1711.
- C. BOHR, *Embedded spheres and 4-manifolds with spin coverings*, J. reine angew. Math. **565** (2003), 161-182.
- V. BRAUNGARDT and D. KOTSCHICK, *Clustering of critical points in Lefschetz fibrations and the symplectic Szpiro inequality*, Trans. Amer. Math. Soc. **355** (2003), 3217-3226.
- K. CIELIEBAK, I. Mundet i Riera, D. A. Salamon, *Equivariant moduli problems, branched manifolds, and the Euler class*, Topology **42** (2003), 641-700.
- C. Allday, B. HANKE, V. Puppe, *Poincaré duality in P. A. Smith theory*, Proc. Amer. Math. Soc. **131** (2003), 3275-3283.
- B. HANKE, *Inner products and Z/p-actions on Poincaré duality spaces*, Forum Math. **15** (2003), 439-454.
- B. HANKE, D. KOTSCHICK and J. WEHRHEIM, *Dissolving four-manifolds and positive scalar curvature*, Math. Zeitschrift **245** (2003), 545-555.
- D. KOTSCHICK and S. TERZIC, *On formality of generalized symmetric spaces*, Math. Proc. Cambridge Phil. Soc. **134** (2003), 491-505.
- D. KOTSCHICK and T. VOGEL, *Linking numbers of measured foliations*, Ergodic Theory Dynam. Systems **23** (2003), 541-558.
- T. KUESSNER: *Efficient fundamental cycles of cusped hyperbolic manifolds*, Pacific J. of Mathematics **211** (2003), 283-314.
- P.-A. NAGY: *Rigidity of Riemannian foliations with complex leaves on Kähler manifolds*, J. Geom. Anal. **13** (2003), 659-667.

2. **Beiträge zu Konferenzbänden, Buchkapitel u. ä.:**
   - HANKE B.: *Poincaré duality and deformations of algebras*, Contemp. Math. **279** (2001), 129-133.
   - SCHLEICHER D.: *Rational parameter rays of the Mandelbrot set*, in Géométrie complexe et systèmes dynamiques, Astérisque **261** (2000), 405-443.
   - SCHLEICHER D.: *On Newton's method for complex polynomials*. Proceedings of the Research Institute of Mathematical Sciences, Kyoto (2000).
   - SEMMELMANN U. und Weingart G.: *Vanishing Theorems for Quaternionic Kähler Manifolds*, Quaternionic structures in mathematics and physics (Rome, 1999), 377-404.
   - D. KOTSCHICK, *Godbillon-Vey invariants for families of foliations*, in ''Symplectic and Contact Topology: Interactions and Perspectives'', Fields Institute

Communications, American Mathematical Society 2003.

- S. Kumar, B. LEEB and J. Millson, *The generalized triangle inequalities for rank 3 symmetric spaces of noncompact type*, Contemporary Math. **332** (2003), Explorations in Complex and Riemannian Geometry, (volume dedicated to Robert Greene), 171-195.

1.3.3 Betreute wissenschaftliche Arbeiten:

1. **Habilitationsschriften:**
   - SEMMELMANN U.: Conformal Killing forms on Riemannian manifolds, 2002
2. **Dissertationen:**
   - BOHR, C.: Embedded Surfaces and the Intersection Forms of non-simply Connected 4-Manifolds (Prof. Kotschick) 2000
   - Riedl J.: Arcs in Multibrot sets, locally connected Julia sets and their construction by quasiconformal surgery (Prof. SCHLEICHER) (2001)
   - HOSTER, M.: Derived Secondary Classess for Flags of Foliations (Prof. Kotschick) 2001

1.3.4 Eingeworbene Drittmittel:

1. **DFG** (außer Graduiertenkollegien):
   - BOHR C.: Forschungsstipendium der DFG 2000-02. Erhaltene Beträge: DM 16.500 (2000), DM 47.590 (2001), ca. Euro 11.000 (2002).
   - HANKE B.: Forschungsstipendium der DFG von Oktober 2000 bis März 2001, Az. Ha 3160/1-1, Gesamtsumme 30.480 DM.
   - KOTSCHICK D.: Sachbeihilfe *Geometrie von Flächenbündeln* Az. KO 2028/1-1, 2000-01 (2000: 48.600 DM, 2001: 50.600 DM) und Az. KO 2028/1-3, 2002-04 (2002: 41.000 Euro), (2003: ca. Euro 31.000).
   - K. CIELIEBAK: ‘‘The symplectic vortex equations and applications’’ im Schwerpunktprogramm ,,Globale Differentialgeometrie‘‘,, CI 45/1-1, 2003-2005 (2003: 8.000 Euro).
   - K. CIELIEBAK und K. Mohnke: ‘‘Punctured Holomorphic Curves in Symplectic Geometry’’ im Schwerpunktprogramm ,,Globale Differentialgeometrie‘CI 45/2-1, 2003-2005 (2003: ca. 15.000 Euro).
   - B. HANKE: ‘‘Geometry of differentiable manifolds: Existence and classification of metrics of positive scalar curvature’’ im Schwerpunktprogramm ,,Globale Differentialgeometrie‘‘, in Kooperation mit T. Schick (Göttingen). Bewilligt: Sachmittel (Euro 4500)
   - D. KOTSCHICK: ‘‘Geometric Formality’’ im Schwerpunktprogramm ,,Globale Differentialgeometrie‘, 2003 Bewilligung von Sachmitteln und von einer BAT IIa/2 Stelle für 2 Jahre
   - B. LEEB: ‘‘Geometrisierung in Dimension 3 und Geometrie singulärer Räume’’, Az. LE 1312/1-1, 01.10.2001-01.10.2003, LE 1312/1-2, 01.10.2003-01.10.2004
   - B. LEEB: ‘‘Polygons in symmetric spaces and Euclidean buildings with applications to algebra’’ im Schwerpunktprogramm ,,Globale Differentialgeometrie‘‘, Az. LE 1312/2-1, 01.06.2003-31.05.2005
   - H. WEISS: ‘‘Deformations of 3-dimensional cone-manifold structures’’, im Schwerpunktprogramm ,,Globale Differentialgeometrie‘‘
2. **Förderprogramme der EU:**

- AMORÓS J.: *European Algebraic Geometry Research Training Network* (EAGER), HPRN-CT-2000-00099, 2000-03.
- KOTSCHICK D.: Knotenpunkt im *European Differential Geometry Endeavour* (EDGE) 2000-04, bewilligt: 186.000 Euro.

3. **Sonstige:**
   - **CICYT BFM2000-0799-C02-02:** AMORÓS J.: Fibraciones de variedades algebraicas y moduli, 2001-03. Financed by Ministerio de Ciencia y Tecnología, Kingdom of Spain, 15.536,16 Euro.
   - **Acción integrada España-Francia HF2000-0044:** AMORÓS J.: *Sistemas diferenciales y singularidades*, 2001-02. Financed by Ministerio de Ciencia y Tecnología, Kingdom of Spain, 6.800,00 Euro.
   - **National Science Foundation Grant:** CIELIEBAK K.: DNS-0072267, 2000-2003, US$ 82.587.
   - **Grant of State Committee for Scientific Research (Poland)**: KEDRA J.: ‘‘Characteristic classes of smooth fibrations’’ no 5 PO3A 017 20; principal investigator, 2001-2002.
   - **VolkswagenStiftung:** KOTSCHICK D.: Projekt *Seiberg-Witten Theorie und Blätterungen*, 2000-01, 40.200 DM.
   - **VolkswagenStiftung:** KOTSCHICK D.: Projekt *Asymptotic Topology, Foliations, and Dynamical Systems*, 2002, 18.200 Euro.
   - **Spektrum der Wissenschaft:** SCHLEICHER D.: Geometrie-Wochenende: ca. DM 5000.
   - **CNRS:** SEMMELMANN U.: drei Monate Gastforscherstelle 2002, ca. 12.000 Euro.
   - **Studienstiftung des deutschen Volkes:** VOGEL T.: Promotionsstipendium seit Mai 2002.

1.4 Arbeitsbereich Komplexe Analysis und Algebraische Geometrie

Wissenschaftler mit Dauerstellen: Prof. Dr. O. FORSTER, Prof. Dr. H.-W. SCHUSTER, Prof. Dr. K. WOLFFHARDT (Bis 31. 3. 2003) , Prof. Dr. G. KRAUS,
Prof. Dr. M. SCHOTTENLOHER

1.4.1 Forschungsschwerpunkte:

1.
   - Verantwortlicher: FORSTER, O.
   - Titel: Algebraische Geometrie und Algorithmische Zahlentheorie mit Anwendungen auf die Kryptographie
   - key words (engl.): algorithmic number theory, elliptic curves, cryptography
   - Beschreibung: In der modernen Kryptographie spielen bei sog. Public-Key-Verfahren Elliptische Kurven über endlichen Körpern (und in Verallgemeinerung davon hyperelliptische Kurven und ihre Jacobi-Varietäten) eine wichtige Rolle. Probleme dabei sind u.a. die effiziente Implementierung der Arithmetik auf diesen Kurven und Varietäten sowie die Gewinnung von schnellen Algorithmen zur Bestimmung der Punkteanzahl.
2.
   - Verantwortlicher: SCHOTTENLOHER, M.
   - Titel: Konforme Feldtheorie und verwandte Gebiete
   - key words (engl.): conformal field theory, quantum field theory, string theory, conformal group, deformation quantization, geometric quantization, quantum groups, knot theory, moduli spaces of stable vector bundles, vertex operator algebras
   - Beschreibung: Die konforme Feldtheorie ist die konform invariante Feldtheorie in zwei Dimensionen. Die mathematischen und die physikalischen Aspekte der Theorie haben enge Beziehungen zur Algebraischen Geometrie, zur Darstellungstheorie von Lie-Algebren, zur Knotentheorie, zur Theorie der Vertex-Operatoren, zur Statistischen Physik, zur Stringtheorie, u.a.
3.
   - Verantwortlicher: SCHOTTENLOHER, M.
   - Titel: Interaktive, dreidimensionale Visualisierung für das Internet.
   - key words (engl.): Computer visualization, virtual reality, Java, VRML, Java 3D, computational geometry, algorithmic geometry, nurbs (non uniform rational splines)
   - Beschreibung: Es geht um die Erstellung von interaktiven und dreidimensionalen Modellen, die auch für das Internet geeignet sind und die daher mit sehr wenig Speicherplatz auskommen müssen. Die Programmiersprachen, die hier zum Einsatz kommen, sind Java und VRML, neuerdings bzw. in Zukunft auch Java 3D. Von Bedeutung sind in diesem Umfeld mathematische Ideen und Kenntnisse aus der Geometrie und aus der Numerischen Mathematik.
4.
   - Verantwortlicher: SCHUSTER, P. M.
   - Titel: Konstruktive Mathematik, speziell Topologie und algebraische Geometrie ohne Punkte
   - key words (engl.): constructive mathematics, mathematical logic, theoretical computer science; point-free algebraic geometry, formal topology

- Beschreibung: Die konstruktive Mathematik verzichtet auf die Verwendung von Existenzaussagen, denen es an einer Konstruktionsvorschrift mangelt, wie etwa dem Zornschen Lemma. Aus einem konstruktiven Existenzbeweis kann folglich eher ein Programm extrahiert werden, da er bereits auf einem expliziten Algorithmus basiert. In Zusammenarbeit mit Ishihara wurde eine von Bridges und Vîta ins Leben gerufene konstruktive Verallgemeinerung der Theorie der uniformen Räume weiterentwickelt, deren Grundbegriff derjenige des Entferntseins ist. Nachdem unlängst auch der konstruktive Gehalt des Hilbertschen Nullstellensatzes über dem Körper der komplexen Zahlen isoliert werden konnte, geht es nun darum, der abstrakten Formulierung der algebraischen Geometrie nach Grothendieck et al. ein konstruktives Fundament zu verschaffen. Ein solches muß notwendigerweise punktfrei sein; die aus der Martin-Löfschen Typentheorie entwachsene formale Topologie à la Sambin hat sich als natürlicher Rahmen dafür herausgestellt.

1.4.2 Im Druck erschienene Publikationen:

1. **Zeitschriftenartikel:**
   - Bridges, D., Ishihara, H., SCHUSTER, P., ‘Sequential compactness in constructive analysis’. *Österreich. Akad. Wiss. Math.-Natur. Kl. Sitzungsber. II* **208** (1999) 159-163
   - Bridges, D., Richman, F., SCHUSTER, P., ‘Linear independence without choice’. *Ann. Pure Appl. Logic* **101** (2000) 95-102
   - SCHUSTER, P.M., ‘A constructive look at generalised Cauchy reals’. *Math. Logic Quart.* **46** (2000) 125-134
   - Bridges, D., Richman, F., SCHUSTER, P., ‘A weak countable choice principle’. *Proc. Amer. Math. Soc.* **128** (2000) 2749-2752
   - Bridges, D., Richman, F., SCHUSTER, P., ‘Adjoints, absolute values and polar decompositions’. *J. Operator Theory* **44** (2000) 243-254
   - SCHUSTER, P.M., ‘Too simple solutions of hard problems’. *Nordic J. Philos. Logic* **6** (2001) 138-146
   - Ishihara, H., SCHUSTER, P., ‘A constructive uniform continuity theorem’. *Quart. J. Math.* **53** (2002) 185-193
   - Bridges, D., Richman, F., SCHUSTER, P., ‘Trace-class operators’. *Houston J. Math.* **28** (2002) 565-583
   - Bridges, D., SCHUSTER, P., Vîta, L., ‘Apartness, topology, and uniformity: a constructive view’. *Math. Logic Quart.* **48** (2002) Suppl. 1, 16-28
   - SCHUSTER, P.M., ‘Real numbers as black boxes’. *New Zealand J. Math.* **31** (2002) 1-14
   - SCHUSTER, P., D. Bridges, L. Vîta, ‘Strong versus uniform continuity: a constructive round’. *Quaestiones Math.* **26** (2003) 171-190
   - SCHUSTER, P., ‘Unique existence, approximate solutions, and countable choice’. *Theoret. Comput. Science* **305** (2003) 433-455
2. **Beiträge zu Konferenzbänden, Buchkapitel u. ä.:**
   - SCHUSTER, P.M., ‘Elementary choiceless constructive analysis’. In: P.G. Clote and H. SCHWICHTENBERG, eds., *Computer Science Logic.* 14th International Workshop, CSL 2000. 9th Annual Conference of the EACSL. Fischbachau, Germany, August 21-26, 2000. Proceedings. Springer, Berlin and Heidelberg. *Lect. Notes Comput. Sci.* **1862** (2000) 512-526
   - SCHUSTER, P., Bridges, D., Vîta, L., ‘Apartness as a relation between subsets’. In: C.S. Calude, M.J. Dinneen, S. Sburlan, eds., *Combinatorics, Computability and Logic*. 3rd International Conference, DMTCS01. Constanta, Romania, July 2-6,

2001. Proceedings. Springer, London. *Discr. Math. Theoret. Comput. Sci. Ser.* (2001) 203-214

- Bridges, D., Ishihara, H., SCHUSTER, P., 'Compactness and continuity, constructively revisited'. In: J. Bradfield, ed., *Computer Science Logic.* 16th International Workshop, CSL 2002. 11th Annual Conference of the EACSL. Edinburgh, Scotland, September 22-25, 2002. Proceedings. Springer, Berlin and Heidelberg. *Lect. Notes Comput. Sci.* **2471** (2002) 89-102
- SCHOTTENLOHER, M., 'Data Re-presentation as a First Step Towards a Unified IT-Structure' In: Challenges between Competition and Collaboration, Springer-Verlag 2003, p. 203-207.

3. **Bücher:**
   - FORSTER, O., *Analysis I*, 6. verbesserte Aufl. 2001.
   - SCHUSTER, P., Berger, U., OSSWALD, H., eds., *Reuniting the Antipodes--Constructive and Nonstandard Views of the Continuum*. San Servolo, Venice, Italien, May 16-22, 1999. Symposion Proceedings. Kluwer, Dordrecht. *Synthese Library* **306** (2001), xii+316 pp.
   - FORSTER, O. und Szymczak, T., *Übungsbuch zur Analysis 2*, 3. Aufl., Vieweg 2003.

1.4.3 Betreute wissenschaftliche Arbeiten:

1. **Habilitationsschriften:**
   - SCHUSTER, P.M: From Spectra to Sheaves in Formal Topology. Habilitationsschrift 2003.
2. **Dissertationen:**
   - LANG, J.: Relative Moduli Spaces of Semi-Stable Sheaves on Families of Curves (Proff. Schottenloher M. und Forster O.) 2000
   - Wiesbeck, Alois: Unendlichdimensionale Vektorbündel, Schleifenräume und Dirac-Operatoren. 2001 (SCHOTTENLOHER, M.)
   - Wollner, Manfred: Eine Cauchysche Integralformel für Schnitte in kohärenten Modulgarben. 2002 (FORSTER, O.)

1.4.4 Eingeworbene Drittmittel:

1. **DFG** (außer Graduiertenkollegien):
   - SCHUSTER, P.M., Euro 2.800,50 unter Zeichen 447 NSL-111/2/02 erhalten für Forschungsaufenthalt an der University of Canterbury, Christchurch, Neuseeland
2. **Sonstige:**
   - SCHUSTER, P. M.: Euro 60.099,12 erhalten vom DAAD im Rahmen des Programms INNOVATEC für Gastprofessur von D. S. Bridges in 2003/04
   - SCHUSTER, P. M.: Euro 456,- erhalten unter Konto 31057 von der Münchner Universitätsgesellschaft für Tagungsteilnahme CSL 2002 in Edinburgh, Schottland, September 2002
   - CROSILLA, M.L., SCHUSTER, P.M.: Euro 21.500,- erhalten von der Volkswagen-Stiftung unter Az. I/79 251 für Reise- und Aufenthaltskosten der Teilnehmer an *From Sets and Types to Topology and Analysis: Towards Practicable Foundations for Constructive Mathematics*, Workshop, Venedig, Italien, Mai 2003
   - SCHUSTER, P.M.: Euro 332,88 erhalten unter Konto 31101 von der Münchner

Universitätsgesellschaft für Forschungsaufenthalt in Göteborg, Schweden, Juni 2003

1.4.5 Verschiedenes:

- **Software.** FORSTER, O.: Weiterentwicklung des Programms ARIBAS, eines interaktiven Multipräzisions-Interpreters für Arithmetik.

1.5 Arbeitsbereich Mathematische Logik

Wissenschaftler mit Dauerstellen: Prof. Dr. H. SCHWICHTENBERG,
Prof. Dr. H.-D. DONDER, Prof. Dr. H. OSSWALD, Prof. Dr. W. BUCHHOLZ

1.5.1 Forschungsschwerpunkte:

1.
   - Verantwortliche: Berger U., BUCHHOLZ W. und SCHWICHTENBERG H.
   - Titel: Programmextraktion aus klassischen Beweisen
   - key words (engl.): proof theory, lambda calculus
   - Beschreibung: Bekanntlich ist es im allgemeinen unentscheidbar, ob ein Programm seine Spezifikation erfüllt. Im Gegensatz dazu kann man leicht durch eine Maschine überprüfen lassen, ob ein formaler Beweis korrekt ist; ferner läßt sich aus einem konstruktiven Beweis automatisch ein entsprechendes Programm extrahieren, das aufgrund seiner Herkunft ebenfalls korrekt ist. Dadurch erhält man - mindestens im Prinzip - einen Weg, zuverlässige Software zu produzieren, etwa für sicherheitskritische Anwendungen. Ferner sind aus Beweisen erhaltene Programme in einem extremen Sinn ‘‘kommentiert’’. Sie lassen sich deshalb leicht warten und an veränderte Anforderungen anpassen. In dem Forschungsschwerpunkt konzentrieren wir uns auf die Frage, in welcher Weise auch klassische Beweise hierfür verwendbar sind. Es ist bekannt, daß jeder klassische Beweis einer Spezifikation der Form $\forall x \exists y A(x,y)$ mit $A(x,y)$ quantorenfrei in einen konstruktiven

     Beweis derselben Formel umgeformt werden kann. Dieses theoretische Resultat ist jedoch ohne Verfeinerungen für Anwendungen unbrauchbar; derartige Verfeinerungen sind ein Gegenstand unserer Untersuchungen.
2.
   - Verantwortlicher: BUCHHOLZ W.
   - Titel: Ordinalzahlanalyse; finite Präsentation unendlicher Herleitungen
   - key words (engl.): proof theory, ordinal notations, cut-elimination
   - Beschreibung: Ein zentrales Thema der Beweistheorie ist die sogenannte Ordinalzahlanalyse von (mathematisch oder grundlagentheoretisch relevanten) Axiomensystemen. Das Ziel dabei ist u.a. die genaue Charakterisierung der Konsistenzstärke sowie der beweisbar rekursiven Funktionen der betreffenden Axiomensysteme durch eine konkret angebbare primitiv rekursive Wohlordnung (Ordinalzahlbezeichnungssystem). Die aktuelle Entwicklung auf diesem Gebiet (Ordinalzahlanalyse von Π^1_2 -CA durch M. Rathjen und T. Arai) hat einen extrem

     hohen Grad an Kompliziertheit und mathematischer Tiefe erreicht, so dass weitere Untersuchungen erforderlich sind, um zu einem besseren Verständnis der betreffenden Ergebnisse und Beweise zu kommen. Durch Aufdeckung von Zusammenhängen zwischen bestimmten Operationen auf unendlichen bzw. endlichen Herleitungen wird versucht, einen Beitrag zu diesem Ziel zu leisten. -- Die finite Darstellung unendlicher Herleitungen war auch Ausgangspunkt für Untersuchungen zur Komplexität von durch höherstufige Rekursionsgleichungen definierten Funktionalen. Dabei ergaben sich u.a. Zusammenhänge mit Themen der theoretische Informatik (z.B. Co-Rekursion und -Induktion, Produktivität von Strömen), denen weiter nachgegangen werden soll.
3.

- Verantwortlicher: DONDER H.-D.
- Titel: Äquikonsistenzresultate in der Mengenlehre
- key words (engl.): fine structure, core model, large cardinals
- Beschreibung: Ein Hauptprogramm der modernen Mengenlehre besteht darin, die Konsistenzstärke von natürlichen Eigenschaften durch grosse Kardinalzahlen zu messen. Wir untersuchen in dieser Hinsicht insbesondere modelltheoretische Prinzipien und Aussagen über Ultrafilter.

4.

- Verantwortlicher: OSSWALD H.
- Titel: Anwendungen der Modelltheorie in der Analysis
- key words (engl.): model theory, stochastic processes, malliavin calculus
- Beschreibung: Aus Ergebnissen der Modelltheorie, einem Teilgebiet der Mathematischen Logik, erhält man für jedes mathematische Gebiet ein Modell, in dem man einerseits, wie üblich, Mathematik machen kann. Andererseits ist in diesem Modell jede (interne) Menge k-kompakt, wobei k eine genügend grosse Kardinalzahl ist. Es folgt, dass jede standard unendliche Menge zu einer, im Sinne des neuen Modells, endlichen Menge erweitert werden kann. Diese unglaubliche aber wahre Tatsache ermöglicht eine Approximation unendlicher Objekte durch endliche von ‘‘oben’’. Dabei ist der Fehler unendlich klein, das heisst, kleiner als jede positive reelle Zahl.

  In meiner Arbeit wende ich diese Einsichten an auf die Maßtheorie (es entstehen neue Produkträume) und auf die unendlich dimensionale stochastische Analysis.

5.

- Verantwortlicher: SCHWICHTENBERG H.
- Titel: Komplexität funktionaler Programme und beschränkte Arithmetik
- key words (engl.): proof theory, lambda calculus, feasibility, subrecursive hierarchies
- Beschreibung: Rekursion über Bezeichnungen in allen endlichen Typen läßt sich derart einschränken, daß man genau die in polynomialer Zeit berechenbaren Funktionen erhält. Die Einschränkungen bestehen darin, daß eine verzweigte Typenstruktur benutzt wird, sowie lineare Konzepte zum Lamba-Kalkül hinzugefügt werden. Untersucht wird, welche Entsprechung (im Sinn der Curry-Howard Korrespondenz) ein solcher Termbegriff in arithmetischen Theorien hat, und ob sich auf diese Weise effiziente Programme extrahieren lassen.

6.

- Verantwortlicher: H. OSSWALD
- Logik, Malliavin Kalkuel, Gauss und Poisson Maße
- key words (engl.): Logic, Malliavin Calculus, Gaussian and Poisson measures, infinite dimensional stochastic analysis.
- Beschreibung: It follows from results in model theory, a field within mathematical logic, that there exists a model of mathematics, in which, on the one side, we are able to make the same mathematics as in the usual standard model. On the other side each (internal) set can be handled as though it were k-kompakt (k-saturated), where k is an arbitrarily fixed sufficiently large cardinality. Then any infinite set in the usual model of mathematics can be extended to a finite set in the sense of this new model. This fact makes it possible to approximate infinite entities of standard mathematics by finite objects in the new model from above. The difference between the standard entity and this finite approximating object is in general smaller than any

positive real number.

At the moment I apply this result to spaces of continuous functions, endowed with Gaussian measure, and to spaces of functions that are right continuous and have left hand limits, endowed with Poisson measure (Malliavin Calculus).

1.5.2 Im Druck erschienene Publikationen:

1. **Zeitschriftenartikel:**
   - Bellantoni S., Niggl K.-H., SCHWICHTENBERG H.: Higher Type Recursion, Ramification and Polynomial Time, Annals of Pure and Applied Logic **104** (2000), 17-30
   - BERGER J., OSSWALD H., Sun Y., Wu J.L.: On nonstandard product measure spaces, Illinois Journal of Mathematics **46** (2002), 319-330
   - Berger U., BUCHHOLZ W., SCHWICHTENBERG H.: Refined program extraction from classical proofs, Annals of Pure and Applied Logic **114** (2002), 3-25
   - BUCHHOLZ W.: Explaining the Gentzen-Takeuti reduction steps: a second order system, Arch. Math. Logic **40** (2001), 255-272
   - BUCHHOLZ W.: Finite representation of infinitary derivations, Math. Log. Quart. **47** (2001) 3, 363-396
   - DONDER H.-D.: Cardinal Elementary Extensions, Proc. AMS **129** (2000), 1503-1506
   - SCHWICHTENBERG H.: Beweise und Programme. Anmerkungen zu Heytings Formalisierung der intuitionistischen Logik, in *Berichte und Abhandlungen der Berlin-Brandenburgischen Akademie der Wissenschaften*, vol. 8 (2000), 71-94
   - AEHLIG K. and SCHWICHTENBERG H.:, A syntactical analysis of non-size-increasing polynomial time computation. ACM Transactions of Computational Logic **3** (2002) 3, 383-401.
   - Berger U., Eberl M. and SCHWICHTENBERG H., Term rewriting for normalization by evaluation, Information and Computation **183** (2003) 19-42.
   - DEISER O. and DONDER D., Canonical functions, non-regular ultrafilters and Ulam's problem on ω_1 , Journal of Symbolic Logic **68** (2003) 713-739.
   - OSSWALD H.:, Malliavin Calculus in abstract Wiener space using infinitesimals, Advances in Mathematics **176** (2003) 1-37
   - OSSWALD H.:, On the Clark Ocone formula for the abstract Wiener space, Advances in Mathematics **176** (2003) 38-52
2. **Beiträge zu Konferenzbänden, Buchkapitel u. ä.:**
   - BUCHHOLZ W.: Assigning ordinals to proofs in a perspicious way. In: Reflections on the Foundations of Mathematics: Essays in Honor of Solomon Feferman. Wilfried Sieg, Richard Sommer, Carolyn Talcott (eds.), ASL Lecture Notes in Logic **15** (2002), 37-59
   - OSSWALD H.: Infinitesimals in abstract Wiener spaces, in *Stochastic processes, physics and geometry: new interplays*, II Leipzig, 1999 (A volume in honor of Sergio Albeverio, eds. F. Gesztesy et al) pp539-546, CMS Conf. Proc. **29**, Amer. Math. Soc., Providence, RI, 2000.
   - SCHWICHTENBERG H.: Refined Program Extraction from Classical Proofs: Some Case Studies, Foundations of Secure Computation, in *Foundations of Secure Computation*, NATO Science Series F: Computer and Systems Sciences, vol. 175, IOS Press, Amsterdam, 2000, 147-166

- SCHWICHTENBERG H., S. Bellantoni: Feasible computation with higher types, in *Proof and System-Reliability*, Proceedings NATO Advanced Study Institute, Marktoberdorf, 2001, Kluwer Academic Publisher, 2002, 399-415

3. **Bücher:**
   - Clote P., SCHWICHTENBERG H. (eds.): Computer Science Logic. 14th International Workshop, CSL 2000, LNCS, vol. 1862, Springer, 2000
   - Troelstra A., SCHWICHTENBERG H.: Basic Proof Theory, 2nd edition, Cambridge University Press, 2000
   - DEISER O., Einführung in die Mengenlehre, 336 Seiten, Springer Lehrbuch, 2002.

1.5.3 Betreute wissenschaftliche Arbeiten:

1. **Dissertationen:**
   - BERGER J.: An Infinitesimal Approach to Stochastic Analysis on Abstract Wiener spaces, Universität München (OSSWALD H.) (2002)
   - Eberl M.: siehe Bericht des Graduiertenkollegs "'Logik in der Informatik"' (2002)
   - IRRGANG B.: Kondensation und Moräste, Universität München (DONDER H.-D.) (2002)
   - Joachimski F.: siehe Bericht des Graduiertenkollegs "'Logik in der Informatik"' (2001)
   - König B.: Trees, Games and Reflections, Universität München (DONDER H.-D.) (2002)
   - Maidl M.: siehe Bericht des Graduiertenkollegs "'Logik in der Informatik"' (2000)
   - Weich K.: siehe Bericht des Graduiertenkollegs "'Logik in der Informatik"' (2001)
   - Zuber W.: siehe Bericht des Graduiertenkollegs "'Logik in der Informatik"' (2001)
   - AEHLIG K.: On Fragments of Analysis with Strengths of Finitely Iterated Inductive Definitions, 2003. (BUCHHOLZ)
   - SEISENBERGER M.: On the Constructive Content of Proofs, 2003. (SCHWICHTENBERG)

1.5.4 Eingeworbene Drittmittel:

1. **DFG** (außer Graduiertenkollegien):
   - SCHWICHTENBERG H.: DFG Sachbeihilfe (SCHW 245/7-1), ‘‘Extraktion effizienter Programme aus formalen Beweisen’’ (Freisemester WS 2000/2001 in Stanford). Erhaltene Mittel 12.180,- DM. Anordnungsstellennummer 1507011/841 641 - 4
   - SCHWICHTENBERG H.: Graduiertenkolleg ‘‘Sprache, Information, Logik’’ (Beteiligung) Duration: 9 years (10/92 - 9/2001). Funds (for 10/1998 - 9/2001) 1.240.680 DM. Anordnungsstellennummer 820 041 - 2
   - OSSWALD H.: 1033 EURO fuer den Vortrag bei der Tagung Annual Meeting AMS/MAA Phoenix Arizona, 7.1.2004-10.1.2004, genehmigt am 6.11.2003 durch die DFG.
2. **Förderprogramme der EU:**
   - BUCHHOLZ W., SCHWICHTENBERG H.: TYPES Working Group (IST-1999-29001): Erhaltene Mittel 13.200 Euro. Anordnungsstellennummer 85 16 13 - 0
   - Hofmann M., SCHWICHTENBERG H.: Applied Semantics, 29.752 Euro. Anordnungsstellennummer 85 16 17 - 1.
3. **Sonstige:**

- SCHWICHTENBERG H.: Kooperationsvertrag mit Siemens (Dr. Maidl, 4/2000 - 3/2001). Erhaltene Mittel: 75.000 Euro. Anordnungsstellennummer 821 651 - 7
- SCHWICHTENBERG H.: Kooperationsvertrag mit Siemens (Dr. Pattinson). Laufzeit 2 Monate (8/2001 - 9/2001). Erhaltene Mittel: 9.500 Euro. Anordnungsstellennummer 821 651 - 7
- Tiuryn J., SCHWICHTENBERG H.: Nato Advanced Study Institute ‘‘Proof and System-Reliability’’ Summer School Marktoberdorf, 24. July to 5. August 2001. Erhaltene Mittel: 109.000 DM. Anordnungsstellennummer 821 6699
- Nipkow T., SCHWICHTENBERG H.: NATO Advanced Study Institute on *Proof Technology and Computation*, Marktoberdorf 29. Juli bis 10. August 2003. Erhaltene Mittel: 55.000 Euro. Anordnungsstellen-Nr. 82 16 699.

1.6 Arbeitsbereich Stochastik und Finanzmathematik

Wissenschaftler mit Dauerstellen: Prof. Dr. P. GÄNSSLER (Bis 31. 3. 2002) , Prof. Dr. H. KELLERER (Bis 31. 3. 2000) , Prof. Dr. M. SCHWEIZER (Vom 6. 9. 2001 bis 30. 9. 2003) , Prof. Dr. D. DÜRR, Prof. Dr. H.-O. GEORGII, Prof. Dr. U. OPPEL,
apl. Prof. Dr. H. PRUSCHA

1.6.1 Forschungsschwerpunkte:

1.
   - Verantwortlicher: DÜRR D.
   - Titel: Bohmsche Mechanik, Grundlagen der Statistischen Physik
   - key words: Bohmian mechanics, foundations of quantum theory, scattering theory, relativistic quantum theory, statistical physics
   - Beschreibung: Die bekannten physikalischen Grundgesetze sind deterministisch. Dennoch erfahren wir in vielen Situationen zufälliges Verhalten. Wie lässt sich dies mit den physikalischen Grundgesetzen vereinbaren und wie begründet man die Verwendung der sogenannten Gleichgewichtsverteilungen in der statistischen Physik? Diese Fragen sind bislang im Rahmen der klassischen Physik ungelöst. Dagegen ist die statistische Bohmsche Mechanik, die im idealen mathematischen Falle zur angewandten Beschreibung durch selbstadjungierte Operatoren auf einem Hilbertraum führt, geradezu ein Paradigma für die Bedeutung von Wahrscheinlichkeit und der Bedeutung von Gleichgewichtsverteilung in der Physik. Die statistische Analyse relativistischer Quantenmechanik steht allerdings noch aus. Zu den Anwendungen der Bohmschen Mechanik gehört die Austritts-Statistik eines Bohmschen Teilchens, welche in Streusituationen durch das Flux Across Surfaces Theorem erfasst wird. Die bestehende Forschungsarbeit bemüht sich um die Ausweitung dieser Resultate auf mehrere Teilchen und um die Einbettung in die relativistische Raumzeit.
2.
   - Verantwortliche: GÄNSSLER P. und ROST D.
   - Titel: Empirische Prozesse und Smoothing, mit Anwendung in der Nichtparametrischen Statistik.
   - key words (engl.): Empirical measures and processes, nonparametric statistics, resampling, bootstrapping, partial-sum processes, random measure processes, goodness-of-fit tests
   - Beschreibung: Statistische Verfahren, wie das Testen von Hypothesen bzw. das Schätzen unbekannter Parameter, wurzeln in ihrer Wirksamkeit bei wachsendem Stichprobenumfang n auf der asymptotischen Theorie empirischer Prozesse (Gleichmäßige Gesetze großer Zahlen bzw. funktionale Zentrale Grenzwertsätze). In der modernen Theorie empirischer Prozesse mit Daten in allgemeinen Stichprobenräumen ist - unter Einsatz von Funktionalanalysis (Probability in Banach Spaces) und topologischer Maßtheorie - die Tür für vielfältige Anwendungen in der nichtparametrischen Statistik geöffnet worden. Das von uns entwickelte stochastische Modell der sog. Random Measure Processes umfasst u.a. empirische Prozesse, Partialsummen-Prozesse mit festen bzw. zufälligen Lokationen in allgemeinen Stichprobenräumen, sowie geglättete empirische Prozesse, basierend auf Daten in linearen metrischen Räumen. Bei glatten Verteilungen zugrunde liegender Grundgesamtheiten tritt anstelle empirischer Maße eine geglättete (empirische) Version. Diese besitzt in der Regel bessere asymptotische

Eigenschaften hinsichtlich der Approximation an die unbekannte Verteilung der Grundgesamtheit.

3.
- Verantwortlicher: GEORGII H.-O.
- Titel: Räumliche stochastische Prozesse
- key words (engl.): Gibbs measures, percolation, point processes, lattice models, large deviations, statistical physics
- Beschreibung: Gibbsmaße dienen zur Beschreibung von stochastischen Systemen mit unendlich vielen, in Wechselwirkung zueinander stehenden Komponenten. Unter geeigneten Bedingungen führt die Wechselwirkung zum Auftreten eines Phasenübergangs, d.h. der Existenz verschiedener Gibbsmaße (‘‘Phasen’’). Ein geometrischer Zugang zu diesem Phänomen führt über die Existenz unendlicher Cluster in geeigneten zufälligen Graphen. Ein thermodynamischer Zugang beruht auf der Theorie großer Abweichungen, welche die Wahrscheinlichkeiten für untypisches Verhalten beschreibt und eng mit dem Begriff der Entropie verknüpft ist.

4.
- Verantwortlicher: LIEBSCHER V.
- Titel: Quantenstochastik
- key words (engl.): Point processes, random sets, stochastic analysis, quantum probability, quantum Markov processes, quantum Markov random fields
- Beschreibung: Es werden Punktprozess- und Zufallsmengenmodelle in operatoralgebraischen Strukturen konstruiert und zur Charakterisierung derselben verwendet. Weiterhin werden allgemeine Versionen eines (quanten-)stochastischen Kalküls untersucht.

5.
- Verantwortlicher: OPPEL U.G.
- Titel: Konstruktion und Simulation stochastischer Prozesse.
- key words (engl.): Monte-Carlo methods, causal-probabilistic networks, radiative transfer.
- Beschreibung: Konstruktion und Simulation von multivariaten Verteilungen und stochastischen Prozessen mit Markov-Kernen und deren Anwendung in stochastischen Expertensystemen und auf Probleme des Strahlungstransportes, insbesondere auf die LIDAR-Mehrfachstreuung.

6.
- Verantwortlicher: PRUSCHA H.
- Titel: Statistische Inferenz in stochastischen Prozessen
- key words (engl.): Asymptotic statistics, nonlinear regression, semiparametric regression, time series regression models, point process intensity models
- Beschreibung: Nichtlineare Zeitreihenmodelle - insbesondere solche für kategorielle Daten - werden auf der Basis von semiparametrischen Regressionsmodellen aufgebaut. Das Gleiche gilt für Intensitätsmodelle in Punktprozessen. Untersucht werden Schätz- und Testmethoden der parametrischen und nichtparametrischen Komponenten der Modelle. Dies ist in der Regel nur mit Hilfe asymptotischer statistischer Verfahren möglich. Ferner sind Residuenmethoden und Prognoseverfahren von Interesse. Angewandt werden die Methoden vor allem auf jährlich erhobene Waldschadensdaten.

7.
- Verantwortlicher: SCHWEIZER M.
- Titel: Finanzmathematik und stochastische Analysis

- key words (engl.): mathematical finance, martingale theory, stochastic analysis, incomplete markets, stochastic integrals, semimartingales
- Beschreibung: Zentrales Forschungsthema ist die Bewertung und Absicherung von Derivaten in allgemeinen Modellen für unvollständige Finanzmärkte. Schwerpunkte liegen dabei auf quadratischen Ansätzen zur Risikomessung bei der Konstruktion optimaler Strategien und einem Ansatz zur Bewertung über exponentielle Nutzenindifferenz. Die benutzten mathematischen Techniken stammen aus der stochastischen Analysis und der Martingaltheorie.

8.

- Verantwortlicher: WINKLER G.
- Titel: Statistische Bildanalyse
- key words (engl.): Statistical image analysis, Baysian statistics, Markov chain Monte Carlo methods, Markov random fields, exact sampling
- Beschreibung: Schwerpunkt ist Bayessche Inferenz, speziell im Bereich der Bayessche Bild- und Signalanalyse mit Anwendungen in Medizin, Biologie und Lebenswissenschaften. Dazu ist es unerlässlich, robuste, effektive und zuverlässige Schätzverfahren zu entwickeln.

9.

- Verantwortlicher: ZIEGLER K.
- Titel: Nichtparametrische Kurvenschätzer
- key words (engl.): Nonparametric regression, random design, Nadaraya-Watson estimator, mode of regression functions, data-dependent bandwidth
- Beschreibung: Die mittlere Abhängigkeit einer Zufallsvariablen *Y* von einer anderen Zufallsvariablen *X* wird beschrieben durch die allgemeine Regressionsfunktion $\mu(x) = E(Y|X = x)$. Durch eine gewichtete, gleitende Mittelwertbildung (mittels eines Fensters mit datengesteuerter Breite) entlang der bivariaten (*x*,*y*)-Stichprobe gewinnt man einen nichtparametrischen Kurvenschätzer für $\mu(x)$. Von besonderem Interesse sind die Stellen, an welchen die Funktion $\mu(x)$ maximale Werte aufweist (*modes*). Auf der Grundlage einer Stichprobenfolge ist für den *mode* eine geeignete Schätzerfolge zu finden und ein Konfidenzintervall zu konstruieren. Hierfür benötigt man u.a.\ bootstrap Verfahren und die Theorie der allgemeinen empirischen Prozesse.

10.

- Verantwortlicher: GEORGII H.-O.
- Titel: Stochastische Prozesse in Physik und Biologie
- key words (engl.): Gibbs measures, large deviations, entropy, point processes, branching processes.
- Beschreibung: Zu den zentralen Konzepten der Wahrscheinlichkeitstheorie zählt die Entropie. Im Rahmen der Theorie großer Abweichungen beschreibt sie die Größenordnung unwahrscheinlicher Ereignisse. Von hier führt einerseits eine direkte Querverbindung zur Theorie der Gibbsmaße, welche zur Beschreibung von interagierenden physikalischen Systemen im thermodynamischen Gleichgewicht, und somit zur Analyse von Phasenübergängen dienen. Eine andere Anwendung der Theorie großer Abweichungen, die im vergangenen Jahr erfolgte, ist die Bestimmung der Ahnentyp-Verteilung eines zufällig gewählten gegenwärtig lebenden Individuums in biologischen Multityp-Verzweigungsmodellen.

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   - Bricmont J., DÜRR D., Gallavotti M., Ghirardi G., Petruccione M., Zanghi N.: *Chance in Physics, Lecture Notes in Physics* **574**, 2002
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1.6.3 Betreute wissenschaftliche Arbeiten:

1. **Habilitationsschriften:**
   - ZIEGLER K.: Nonparametric estimation of location and size of maxima of regression functions in the random design case based on the Nadaraya--Watson estimator with data--dependent bandwidths. (2000)
2. **Dissertationen:**
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- A. Martin.: Hyperbolic Stochastic Partial Differential Equations (2002) (Erstgutachter: WINKLER G.)

1.6.4 Eingeworbene Drittmittel:

1. **DFG** (außer Graduiertenkollegien):
   - GEORGII H.-O.: Gibbsmaße für Punktteilchensysteme im Phasenübergangsbereich, Projekt im Schwerpunktprogramm ‘Interagierende stochastische Systeme von hoher Komplexität’’, Geschäftszeichen Ge 803/2, 1999-2001: DM 5000,- Reise- und Gästemittel (bewilligt und erhalten), 2001-2003: Personalmittel für 1 BAT IIa Stelle (bewilligt), 2002 erhalten ca. EUR 52.000, 2003 erhalten ca. EUR 16.000.
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   - SCHWEIZER M.: Bis 2001 Teilprojektleiter (gemeinsam mit Prof. H. Föllmer) im SFB 373, ‘‘Quantifikation und Simulation Ökonomischer Prozesse ‘‘, an der HU Berlin; Anteil der eingeworbenen Mittel für 1999: 20.693 Euro, 2000: 46.016 Euro, 2001: 48.317 Euro
   - SCHWEIZER M.: Beteiligung am GK ,,Stochastische Prozesse und probabilistische Analysis‘‘ an der TU Berlin, Betreuung mehrer Doktoranden; dafür Stipendien folgender Gesamthöhe: 1999: 44.000 DM = 22.497 Euro, 2000: 32.000 DM = 16.361 Euro, 2001: 44.970 DM = 22.993 Euro, 2002: 19.902 Euro
   - WINKLER G.: SFB 386 ,,Statistische Analyse diskreter Strukturen -- Modellierung und Anwendung in Biometrie und Ökonometrie‘‘, Teilprojekt A5 ,,Räumliche Statistik‘‘. 1999: 120 TEUR, 2000: 120 TEUR, 2001: 120 TEUR, 2002: 120 TEUR.
   - DÜRR D.: Eine BAT IIA/2 Doktorandenstelle für zunächst zwei Jahre + 2000 EUR Reisemittel (2003 bewilligt, genutzt ab 2004)

2. **Förderprogramme der EU:**
   - LIEBSCHER V.,WINKLER G.: EU-TMR Netzwerk ,,Harmonic Analysis and Statistics for Signal & Image Processing‘‘, Leiter eines Knotens 2002- , 150 TEUR (bewilligt)
   - LIEBSCHER V.: INTAS-Projekt 99-00545 ,,Noncommutative probability, infinite dimensional analysis and quantum theory‘‘. 2000: 1.5 TEUR, 2001: 3 TEUR, 2002: 1.5 TEUR.
   - OPPEL U.G.: INTAS 972 - 1441, INTAS 01 - 0239
3. **Sonstige:**
   - LIEBSCHER V.: DAAD-Projektbezogener Austausch ,,Tensor Product Sytems of Hilbert Modules‘‘ mit Indien. 2000: 3 TEUR, 2001: 3 TEUR, 2002: 3 TEUR.
   - LIEBSCHER V., WINKLER G.: Internationales B¸ro, Projekt-Austausch ,,Medical Image Analysis‘‘ mit Indien. 1999: 30 TEUR, 2000: 30 TEUR.
   - LIEBSCHER V.: BMBF-Projekt ,,Bioinformatics for Funktional Analysis of Mammalian Metabolism‘‘, Teilprojekt ,,Mathematics for Functional Genomics‘‘. 2001-2006, 600TEUR
   - OPPEL U.G.: DAAD, PPP Hongkong D/00/08307
   - SCHWEIZER M.: Thuringia-Versicherung, ,,Verein zur Förderung der Versicherungswissenschaft in München e.V.‘‘, TDM 50 = EUR 25565 pro Jahr über 5 Jahre; 2002: EUR 3966 erhalten.
   - SCHWEIZER M.: Industriekooperation mit Firma DCS AG über das Thema ,,Biometrische Identifikation‘‘, insgesamt etwa 11.000 Euro (1999)

1.7 Arbeitsbereich Didaktik der Mathematik

Wissenschaftler mit Dauerstellen: Prof. Dr. R. FRITSCH, Dr. G. STUDENY

1.7.1 Forschungsschwerpunkte:

1.
   - Verantwortlicher: R. FRITSCH
   - Titel: Ebene und höher-dimensionale Elementargeometrie einschließlich Umsetzung im Unterricht der Sekundarstufe.
   - key words (engl.): solid geometry, homogenous coordinates, synthetic and analytic geometry, quadrics, foundations of geometry, mathematical education, vector geometry, house of quadrangles, axioms for spatial geometry
   - Beschreibung: Aus dem Bereich der ebenen Geometrie werden Probleme von Transversalen und deren Kopunktalität. Im Raum interessiert ebenfalls der Satz von Bodenmiller, aber insbesondere die Elementargeometrie des Tetraeders als räumlichem Analogon des ebenen Dreiecks. Dabei geht es vor allem um die Kopunktalität gewisser in Analogie zur Dreiecksgeometrie definierbaren Geradensysteme.

     Im Zusammenhang damit wird der Geometrie-Unterricht in der 8. Jahrgangsstufe von Gymnasien und Realschulen untersucht. Es geht um die unterrichtliche Behandlung der Sätze im Umfeld des Umfangswinkelsatzes, die Klassifikation der konvexen Vierecke im Haus der Viereche und die Grundlegung der räumlichen Geometrie, für die es noch keinen systematischen Aufbau gibt, der über die Behandlung in Euklids Elementen hinausgeht.

2.
   - Verantwortliche: Folkerts M. und FRITSCH R.
   - Titel: Geschichte der Elementarmathematik
   - key words (engl.): roots of elementary mathematics, elementary geometry, biographies
   - Beschreibung: Aktuell geht es um die Bearbeitung des Teilbandes ,,Ebene Geometrie‘‘ im Rahmen der Neuherausgabe des klassischen Werkes von Johannes Tropfke zur Geschichte der Elementarmathematik. Im Zusammenhang damit ergeben sich biographische Arbeiten über die einschlägigen Mathematiker.

3.
   - Verantwortlicher: STUDENY G.
   - Titel: Methodik des Mathematikunterrichts der Grund- und Hauptschule.
   - key words (engl.): problem solving at elementary school level, number concepts, concept of fraction, cognitive processes, understanding, material for geometry-learning, teachers training
   - Beschreibung: Schwerpunktmäßig werden drei Themenbereiche bearbeitet:
     Sachrechnen:

     Für die Grundschule wird nach Einflussfaktoren gesucht, die dafür verantwortlich sind, dass Schüler bei Textaufgaben der Schule weniger leisten als bei gleichartigen Alltagsaufgaben. Der Trainierbarkeit von Fähigkeiten im Sachrechnen wird nachgegangen und an curricularen Vorschlägen gearbeitet, die eine sanfte Ausweitung und Vertiefung des Fähigkeiten- und Wissensumfangs beim Kind in Bezug auf angewandte Mathematik

ermöglichen. Für die Hauptschule wird vor allem versucht, die Forderung nach ,,ehrlichen'' Sachaufgaben durch Entwickeln von geeigneten Vorschlägen in der Schulpraxis zu verwirklichen.

Begriffsbildungsprozesse:

Den Gedanken der Grundvorstellungen aufnehmend, welche im Individuum zum Begriff beitragen, werden Situationen und Veranschaulichungen, die üblicherweise im Unterricht zur Begriffsbildung verwendet werden, analysiert. Die Analyse der Begriffsbildungsfacetten bezieht sich auf die natürliche Zahl, die Zahloperationen, die Bruchzahl, den Dezimalbruch, den Prozentbegriff und die Proporitionalitäten.

Geometrie der Grundschule:

Die Verbindung von Handlung und Sprache stellt eine Herausforderung an den Geometrieunterricht der Grundschule dar, es wird nach Möglichkeiten gesucht, eine Überforderung der Schüler zu vermeiden und gleichzeitig Lernzuwachs und Leistung bei ihnen zu erreichen.

1.7.2 Im Druck erschienene Publikationen:

1. **Zeitschriftenartikel:**
   - FRITSCH R.: Za obuchenieto po matematika vchera, dnes i utre (Zum Mathematikunterricht gestern, heute und morgen), *Matematika i Informatika* **24** (1999), 4-10
   - FRITSCH R.: Überlegungen zur Berechnung der Kreiszahl π , *Der Mathematikunterricht* **48**/1 (2002), 57-63
   - MOTZER, R.: Verschiedene Darstellungen von Exponentialfunktionen, *Mathematik in der Schule* **37** (1999), 146-148
   - MOTZER, R.: Magische 3×3 -Quadrate als Beispiel für einen Vektorraum, *PM Praxis der Mathematik in der Schule - Sekundarstufen 1 und 2* **44** (2002), 129-133
   - SCHÄTZ, U.: Auch vom Mathematikunterricht kann man träumen, *Profil,* Heft 1-2/1999, 18-19
   - SCHÄTZ, U.: Mathematik als Unterrichtsfach in der Schule - Ergebnisse einer Facharbeit in Mathematik, *Profil,* Heft 1-2/1999, 20-21
   - SCHÄTZ, U.: Angstfrei fragen und eigene Fähigkeiten erleben, *Naturwissenschaften im Unterricht / Physik* **49** (1999), 16-19
   - SCHÄTZ, U.: Platonische Körper - Mathematik nicht nur im Klassenzimmer, *Mathematik Lehren* **94** (1999), 20-22
   - SCHÄTZ, U.: Gottfried Wilhelm Leibniz, *Profil,* Heft 1-2/2000, 17
   - SCHÄTZ, U.: Posterpräsentation im Mathematikunterricht, *Mathematik Lehren* **99** (2000), 17-22
   - SCHÄTZ, U.: Ferdinand von Lindemann, *Profil,* Heft 7-8/2000, 27
   - SCHÄTZ, U.: Sofja Kowalewskaja, *Profil,* Heft 9/2000, 24
   - SCHÄTZ, U.: Einführung in die Physik: Beobachten und Messen, *Naturwissenschaften im Unterricht / Physik* **60** (2000), 8-12
   - SCHÄTZ, U.: S matematikou po celý rok, *Ucitel Matematiky* **9** (2001), 226-227
   - SCHÄTZ, U.: Der Bezwinger von p - Ferdinand von Lindemann und die Quadratur des Kreises, *Mecklenburg, Zeitschrift für Mecklenburg - Vorpommern,* Heft 10/2001, 9
   - STUDENY, G.: Der neue Lehrplan - eine Chance für das Sachrechnen, *Lehrplan Aktuell,* Heft 4/2001, 4-9

- Fritsch G. und FRITSCH R.: Der Verkünder und Verbreiter der Mengenlehre / Zum 150. Geburtstag von Arthur Schoenflies (1853-1928) - Rektor der Universität Frankfurt in der zweiten Gründungsphase, *Forschung Frankfurt* **2/2003**, 65-68.
- FRITSCH R.: Hilberts Beweis der Transzendenz der Ludolphschen Zahl π , *Differentsial'naya Geometriya Mnogoobrazij Figur* **34** (2003), 144-148
- LEEB P. und Weide-Gertke, M.: Klappmodell für die Binomischen Formeln, *mathematik lehren* **116** (2003), 42

2. **Beiträge zu Konferenzbänden, Buchkapitel u. ä.:**
   - ALPERS, K.: Ein Problem wird gelöst, *Beiträge zum Mathematikunterricht 2001,* Franzbecker, Hildesheim 2000, 69-72
   - ALPERS, K.: Problemlösendes Lernen am Beispiel der Behandlung von Teilverhältnissen, *Beiträge zum Mathematikunterricht 2001,* Franzbecker, Hildesheim 2001, 65-68
   - ALPERS, K.: Raumgeometrie im Mathematikunterricht, *Beiträge zum Mathematikunterricht 2001,* Franzbecker, Hildesheim 2002, 67-70
   - FRITSCH R.: Tetraeder und Kugeln, *Mathematik - interdisziplinär,* Shaker Verlag, Detmold 2000, 149-156
   - FRITSCH R.: Friedrich Wilhelm Franz Meyer, Arthur Schoenflies, *Altpreußische Biographie* **5**/1, N. G. Elwert Verlag, Marburg 2000, 1648-1650, 1691-1692
   - FRITSCH R.: Moritz Pasch, Johann Friedrich Pfaff, Georg Pick, Maximilian Pinl, *Neue Deutsche Biographie* **20**, Duncker & Humblot, Berlin 2001, 81-82, 291-292, 418-419, und 452-453
   - FRITSCH R. und Fritsch G.: Ansätze zu einer wissenschaftlichen Biographie von Arthur Schoenflies, *Florilegium Astronomicum,* (Algorismus - Studien zur Geschichte der Mathematik und der Naturwissenschaften, **37**), Institut für Geschichte der Naturwissenschaften, München 2001, 141-186
   - FRITSCH R.: Georg Pick und Ludwig Berwald - Zwei Mathematiker an der Deutschen Universität Prag, *Schriften der Sudetendeutschen Akademie der Wissenschaften und Künste* **22** (2001), 9-16
   - FRITSCH R. und Rippl, D.: Alfred Pringsheim, *Schriften der Sudetendeutschen Akademie der Wissenschaften und Künste* **22** (2001), 97-128
   - MOTZER, R.: Was ist das ,,Gegenteil''? - Anmerkungen zu einem Begriff, der auch im Stochastik-Unterricht eine Rolle spielt, *Beiträge zum Mathematikunterricht 2001,* Franzbecker, Hildesheim 2001, 434-437
   - SCHÄTZ, U.: Ruznorodé metody ve vyúce matematiky, *Sborník príspevku ze semináre katedry didaktiky matematiky,* Karls-Universität, Prag 2000, 62 - 64
   - SCHÄTZ, U.: Erfahrungen mit einem Mathematikgrundkurs für Mädchen an einem koedukativen Gymnasium, *Beiträge zum Mathematikunterricht 2001,* Franzbecker, Hildesheim 2001, 532-535
   - SCHÄTZ, U.: Freiräume schaffen - Möglichkeiten zur Förderung hochbegabter Mädchen im Grundschul- und Sekundarbereich, *Hochbegabte Mädchen und Frauen,* K.H. Bock, Bad Honnef 2002, 113-114
   - SCHÄTZ, U.: Erfahrungen mit einem Mädchengrundkurs Mathematik an einem koedukativen Gymnasium, *Hochbegabte Mädchen und Frauen,* K.H. Bock, Bad Honnef 2002, 115-118
   - SCHÄTZ, U.: Mathematik als Unterrichtsfach in der Schule - Ergebnisse einer Facharbeit, *Hochbegabte Mädchen und Frauen,* K.H. Bock, Bad Honnef 2002, 119-121
   - STUDENY G.: Vorwort zu *Erste Sachaufgaben im Zahlenraum bis 20* von Christel

Nocke, Schubi Lernmedien AG, Schaffhausen 2001, II-III

- Fritsch G. und FRITSCH R.: Albert Daniel Mercklein - Naturwissenschaftler und/oder Pfarrer in der ersten Hälfte des 18. Jahrhunderts, *Medium Mathematik - Anregungen zu einem interdisziplinären Gedankenaustausch,* Band 1, div verlag franzbecker, Hildesheim und Berlin 2002, 266-284.
- FRITSCH R.: Die Quadratur des Kreises - Zum 150. Geburtstag von Ferdinand Lindemann. Zum Leben und Werk von Siegfried Heinrich Aronhold, *Doklady mezhdunarodnogo matematicheskogo seminara k 140-letiyu so dnya rozhdeniya Davida Gilberta iz Kenigsberga i 25-letiyu matematicheskogo fakulteta,* Izdatel'stvo Kaliningradskogo Gosudarstvennogo Universiteta, Kaliningrad 2002, 30-51, 51-60.
- FRITSCH R.: Hans Rademacher, Theodor Reye, *Neue Deutsche Biographie* **21**, Duncker & Humblot, Berlin 2003, 91-92, 481-482.
- FRITSCH R.: Bemerkungen zum Schmetterlingssatz, *Beiträge zum Mathematikunterricht 2003,* div verlag franzbecker, Hildesheim und Berlin 2003, 221-225.

3. **Bücher:**
   - SCHÄTZ, U.: Mathe-Bingo 5/6, C.C. Buchner, Bamberg 2001
   - SCHÄTZ, U.: Mathe-Bingo 7/8, C.C. Buchner, Bamberg 2001
   - SCHÄTZ, U.: Mathe-Bingo 9/10, C.C. Buchner, Bamberg 2001
   - SCHÄTZ, U.: Ganz einfach Mathematik - Erfolgreich trainieren in Klasse 5, C.C. Buchner, Bamberg 2001
   - SCHÄTZ U. und andere: *delta 5 / Arbeitsheft - Mathematik für Gymnasien,* C. C. Buchner - Paetec, Bamberg und Berlin 2003
   - SCHÄTZ U. und andere: *delta 5 - Mathematik für Gymnasien,* C. C. Buchner - Paetec, Bamberg und Berlin 2003
   - STUDENY G.: Didaktische Beratung des Schulbuchwerkes *Denken und Rechnen - Mathematikbuch für die Grundschulen Bayerns,* Westermann, Braunschweig 2003

1.7.3 Eingeworbene Drittmittel:

1. **DFG** (außer Graduiertenkollegien):
   - R. FRITSCH: EUR 740 Sachbeihilfe für Kongressreise nach Varna
2. **Sonstige:**
   - FRITSCH R.: DM 11.700 erhalten für die Gastaufenthalte von Prof. Dr. K. S. Latyschew, Doz. Dr. S. A. Ischanow und Doz. Dr. N. W. Malachowskij, alle von Universität in Königsberg, von der Daimler-Benz-Stiftung 1999-2001
   - FRITSCH R.: DM 450 als Zuwendung aus Anlass des MNU-Tages 2000 erhalten vom Deutschen Verein zur Förderung des mathematischen und naturwissenschaftlichen Unterrichts
   - FRITSCH R.: DM 5.000 als Spenden aus Anlass des Tages der Mathematik 2000 erhalten von BMW, Bayerische Landesbank und Münchner Rück
   - FRITSCH R.: DM 14.200 als Spenden aus Anlass des Tages der Mathematik 2001 erhalten von BMW, Siemens AG, Stiftung ,,Für Kinder und Jugendliche unserer Stadt'', Bildungspakt Bayern und Münchner Rück
   - FRITSCH R.: DM 3.000 als Spenden aus Anlass der Landessiegerehrung im Bundeswettbewerb Mathematik 2001 erhalten von der Frankona Rückversicherung AG
   - FRITSCH R.: EUR 1.300 als Unkostenerstattung aus Anlass der Summer School 2001 erhalten von der Technischen Universität München

- FRITSCH R.: EUR 4.500 als Spenden aus Anlass des Tages der Mathematik 2002 erhalten von Siemens AG, Stadtsparkasse München und Münchner Rück
- FRITSCH R.: EUR 4.293 erhalten für die Gastaufenthalte von Doz. Dr. S. S. Klevtsur und Doz. Dr. S. V. Matsievsky, beide von Universität in Königsberg, von der Daimler-Benz-Stiftung 2002
- FRITSCH R.: EUR 2.060 erhalten für die Gastaufenthalte der Aspiranten P. Pallo und O. Rozhkova, beide von Universität in Königsberg, von der Möllgaard-Stiftung 2002
- FRITSCH R.: EUR 8.000 erhalten für die Tafelausstattung der Hörsäle der Mathematischen Fakultät der Universität in Königsberg von der Möllgaard-Stiftung 2002
- FRITSCH R.: EUR 600 Spende der Marga- und Kurt Möllgaard-Stiftung für die Reisekosten zur Entgegennahme der Ehrendoktorwürde der Kaliningrader Staatlichen Universität
- FRITSCH R.: EUR 75 als Zuwendung aus Anlass des MNU-Tages 2002 erhalten vom Deutschen Verein zur Förderung des mathematischen und naturwissenschaftlichen Unterrichts

FRITSCH R.: EUR 6.500 als Spenden aus Anlass des Tages der Mathematik 2003 erhalten von der BMW Group, der Münchner Rück, der Siemens AG und der Stadtsparkasse München

1.8 Graduiertenkolleg Mathematik im Bereich ihrer Wechselwirkung mit der Physik

1. **Laufzeit:** 1. 4. 1993 bis 31. 3. 2002

   Auslauffinanzierung:

   1. 4. 2002 bis 31. 3. 2003

   Ab 1.4.2000 Zusatzförderung (siehe unten, Punkt 5)

2. **Sprecher:**

   Prof. Dr. Martin Schottenloher

3. **Träger des Kollegs** (Mathematisches Institut, soweit nicht anders

   angegeben):

   Prof. Dr. Jürgen Batt
   Prof. Dr. Detlef Dürr
   Prof. Dr. Hans-Otto Georgii
   Prof. Dr. Hubert Kalf
   Prof. Dieter Kotschick, D. Phil.
   Dr. Dieter Maison (MPI für Physik, München)
   Prof. Dr. Bodo Pareigis
   Prof. Dr. Hans-Jürgen Schneider
   Prof. Dr. Martin Schottenloher
   Prof. Dr. Herbert Spohn (TU München)
   Prof. Dr. Heinrich Steinlein
   Prof. Dr. Stefan Theisen (Sektion Physik, LMU München)
   Prof. Dr. Julius Wess (Sektion Physik, LMU München und MPI für Physik)

4. **Ziele, Programm und Struktur des Graduiertenkollegs:**
   1. **Zusammenfassung**

      Mit dem Antrag auf Einrichtung des Graduiertenkollegs ‘‘Mathematik im Bereich ihrer Wechselwirkung mit der Physik’’ wurde beabsichtigt, der Entwicklung eines in neuerer Zeit wieder stärkeren Zusammenwirkens von Mathematik und Physik Rechnung zu tragen und den Trend der gegenseitigen Förderung der beiden Wissenschaften zu verfolgen und diese weiter zu vertiefen. Es wurde dabei aufgebaut auf bereits bestehende Kontakte zwischen Professoren der Mathematik und Physik und auf ihre bisher geleistete Zusammenarbeit. Diese interdisziplinäre Kooperation ist im Rahmen des mittlerweile seit sechs Jahren bestehenden Graduiertenkollegs weitergeführt und in eine neue Organisationsform gebracht worden. Vom Angebot der Forschungsthemen wie der Ausbildungsveranstaltungen her soll das Graduiertenkolleg das Bewußtsein für die vielfältigen Verbindungen und Wechselwirkungen zwischen Mathematik und Physik schärfen. Schließlich wird in dem Graduiertenkolleg eine Vertiefung der Zusammenarbeit der beteiligten Mathematiker und Physiker angestrebt.

Den Graduierten (also Stipendiaten und assoziierten Kollegiaten) soll im Graduiertenkolleg eine über das spezielle Forschungsprojekt hinausgehende breitere Ausbildung vermittelt werden. Besondere Formen des Erfahrungs- und Wissensaustausches werden angeboten, die bewirken sollen, daß der Graduierte zusätzliche Anregungen erhält. Durch das Forschungs- und Ausbildungsprogramm des Graduiertenkollegs wird auch angestrebt, den Doktoranden des Kollegs eine über die übliche Betreuung durch den Doktorvater hinausgehende weitere Beratung und Förderung durch die anderen beteiligten Hochschullehrer oder auch durch Gastwissenschaftler zu geben. Schließlich soll diese zusätzliche Förderung auch eine Straffung und eine intensive Durchführung des Promotionsstudiums bewirken.

2. **Forschungsprogramm**
   - **Ziele des Forschungsprogramms**

     Das gemeinsame Forschungsprogramm ist dem Thema ,,Mathematik im Bereich ihrer Wechselwirkung mit der Physik‘‘ gewidmet. Ziel des wissenschaftlichen Programms ist die Erforschung und Anwendung mathematischer Strukturen, die bei physikalischen Problemen zum Tragen kommen: Für das Graduiertenkolleg relevante Beispiele sind die Differentialgeometrie in der Allgemeinen Relativitätstheorie und der Quantenfeldtheorie, die Operatortheorie in der Quantenmechanik, die Stochastik in der Statistischen Physik, die Hopf-Algebren zur Formulierung von allgemeinen Symmetrien und Differentialgleichungen etwa bei der Behandlung von Bewegungsgleichungen der Physik. Ebenso gehört zum Forschungsprogramm des Graduiertenkollegs die Untersuchung der Anwendungen von Ideen und Prinzipien der Physik in der Mathematik. Solche Anregungen haben in den letzten 20 Jahren immer wieder zu interessanten mathematischen Ergebnissen geführt.

   - **Forschungsschwerpunkte:**

     Das angestrebte Forschungsprogramm wird in den folgenden vier Schwerpunkten realisiert:

     A Differentialgleichungen und Funktionalanalysis (vertreten durch Batt, Kalf, Steinlein),
     B Differentialgeometrie, Komplexe Analysis und Stringtheorie (vertreten durch Kotschick, Maison, Schottenloher, Theisen),
     C Quantengruppen und Nichtkommutative Algebra (vertreten durch Pareigis, Schneider, Wess),
     D Wahrscheinlichkeitstheorie und Statistische Physik (vertreten durch Dürr, Georgii, Spohn).

     A: Differentialgleichungen und Funktionalanalysis

     Ziel dieses Forschungsschwerpunktes ist die Weiterentwicklung abstrakter Methoden der linearen und nichtlinearen Funktionalanalysis und die Anwendung funktionalanalytischer Methoden auf Differentialgleichungen und -operatoren der Mathematischen Physik in den folgenden Arbeitsrichtungen:

1) Theorie der Grundgleichungen der Astrophysik (Stellardynamik), der Plasmaphysik (und der Relativitätstheorie) (am Lehrstuhl Batt). Seit 20 Jahren stehen im Vordergrund der Untersuchungen Fragen der Existenz und Eindeutigkeit klassischer und schwacher Lösungen des Vlasov-Poisson-Systems und des Vlasov-Maxwell-Systems partieller Differentialgleichungen, die die Evolution gravitierender Materie und von Plasmen (mit mehreren Komponenten geladener Teilchen) beschreiben, und von deren qualitativem Verhalten, ferner Fragen der Existenz stationärer Lösungen und deren Stabilität. Nach dem Abschluß des klassischem Existenztheorie durch K. Pfaffelmoser (München) gewinnen neuerdings singuläre Lösungen und ihr Bezug zu verwandten Systemen (wie dem Euler-Poisson-System) großes Interesse (hydrodynamischer Limes). Die behandelten Vlasov-Einstein-Gleichungen stellen einen Bezug her zu Differentialgeometrie (Forschungsschwerpunkt B), numerische Verfahren (Partikel-Methoden) einen solchen zur Wahrscheinlichkeitstheorie und Statistischen Physik (Forschungsschwerpunkt D). Die mathematischen Hilfsmittel entstammen u.a. der Nichtlinearen Funktionanalysis bzw. der Theorie der semielliptischen Gleichungen (die zur Arbeitsrichtung von Steinlein und Kalf desselben Forschungsschwerpunktes A gehören). In Zukunft sollen verstärkt die Hamiltonschen und die Symmetriestrukturen der Gleichungen untersucht werden. Bei diesen Fragestellungen ist eine Kooperation mit Prof. J. Scheurle (TU München) geplant.

2) Spektraltheorie von elliptischen Differentialoperatoren (Schrödingeroperatoren) im Zusammenhang mit der Quantenmechanik, quasilineare elliptische Gleichungen und hyperbolische Systeme von partiellen Differentialgleichungen (bei Kalf): Neuere Resultate betreffen Aussagen über das Spektrum von Schrödingeroperatoren mit rotationssymmetrischem Potential und Aussagen über Lücken im wesentlichen Spektrum (siehe auch die Angaben von Kalf im Anhang 1). Herr Kalf verfolgt seit Jahren die Weiterentwicklung der Arbeitsrichtung 1); semilineare Gleichungen spielen u.a. bei der Konstruktion von stationären Modellen des Vlasov-Poisson- und des Vlasov-Maxwell-Systems die entscheidende Rolle. Die bestehende Zusammenarbeit auf diesem Gebiet wird in das Graduiertenkolleg integriert.

3) Nichtlineare Funktionalanalysis und diskrete dynamische Systeme (bei Steinlein). Im Bereich der nichtlinearen Funktionalanalysis konzentrieren sich die Untersuchungen auf die Theorie des äquivarianten Abbildungsgrades, d.h. eines Abbildungsgrades $\deg_G(f,\Omega)$ für äquivariante Abbildungen *f* zwischen

G-Räumen (*G* eine kompakte Lie-Gruppe). Interessante Fragestellungen sind Beziehungen zwischen verschiedenen Abbildungsgradtheorien, konkrete Berechnungen für spezielle Gruppen *G* und geeignete orthogonale Darstellungen sowie Anwendungen insbesondere auf äquivariante Multiparameterverzweigungsprobleme.

B: Differentialgeometrie, Komplexe Analysis und Stringtheorie

Die Wechselwirkung zwischen Mathematik und Physik ist in der Differentialgeometrie (unter Einbeziehung von Eichtheorie und Differentialtopologie) besonders deutlich. Die Beziehung ist so eng, daß viele der benutzten Begriffe eine eindeutige Zuordnung zu einer der beiden Wissenschaften nicht zulassen. Viele der heute verwendeten Konzepte wurden zunächst in der Physik entwickelt, anschließend mathematisch eingehend untersucht und verallgemeinert und fanden später in ganz neuem Zusammenhang wieder Eingang in die Physik, oder sie führten zu unerwarteten Einsichten in mathematische Theorien. Diese Entwicklung hält unvermindert an.

Eines der eindrucksvollsten Beispiele dafür sind die Anwendungen der Eichtheorie in der 4-dimensionalen Topologie. Diese begannen 1982 mit den Arbeiten von Donaldson, der zeigte, daß die Lösungsräume der nicht-linearen Yang-Mills Gleichungen,

d. h. die klassischen Grundzustände der Yang-Mills Theorie, interessante Information über die Differentialtopologie der zugrunde liegenden Mannigfaltigkeit enthalten. So findet man zum Beispiel exotische differenzierbare Strukturen auf dem 4-dimensionalen euklidischen Raum. Seit 1994 weiß man, daß solche Information in konzentrierter Form auch in den sogenannten Seiberg-Witten Gleichungen enthalten ist, die zu einer zu Yang-Mills dualen Quantenfeldtheorie gehören. Die mathematischen Anwendungen dieser und verwandter Ideen werden im Graduiertenkolleg intensiv untersucht.

Die klassische Allgemeine Relativitätstheorie stellt einen der Höhepunkte der oben beschriebenen Wechselwirkungen dar. Derzeit besteht großes Interesse an der Untersuchung ,,teilchenartiger Lösungen'' der Einstein-Gleichungen (selbst-gravitierende Solitonen, schwarze Löcher). Während für Theorien mit Abelschen Eichfeldern (z.B. Einstein-Maxwell-Theorie) die Lösungsmannigfaltigkeiten mit analytischen Methoden bereits sehr genau untersucht worden sind, liegen für Theorien mit nicht-Abelschen Eichfeldern nur Teilergebnisse vor. Das Spektrum der angewandten mathematischen Methoden reicht dabei von der aus der Theorie der Solitonen bekannten Inversen Streumethode (hier ergeben sich Bezüge zu den Forschungsschwerpunktem A und D) bis zu rein numerischen Lösungsmethoden. Wichtige offene Fragen sind mit Schlagworten wie ,,No Hair Conjecture'' und ,,Cosmic Censorship'' angesprochen.

Ein Ideenbereich, in dem die oben angesprochene Wechselwirkung ebenfalls von besonderem Interesse ist, ist die Konforme Feldtheorie, die außer zur Differentialgeometrie Beziehungen zu vielen anderen aktuellen Bereichen der Mathematik und der Physik aufweist, u. a. zur Statistischen Mechanik (und damit zum Schwerpunkt D), zur Theorie der Quantengruppen (und damit zum Schwerpunkt C), zur Knotentheorie, zur Stringtheorie und zur Komplexen Analysis (mit ihren Riemannschen Flächen, Modulräumen etc.). Die Komplexe Analysis hat in den letzten Jahren in verschiedenen Bereichen der Physik an Bedeutung gewonnen. Das trifft besonders für die Stringtheorie zu, in der Modulräume ein wesentliches Werkzeug geworden sind und in der Kählermannigfaltigkeiten und torische Varietäten eine große Rolle spielen.

Ein weiteres Arbeitsgebiet innerhalb des Schwerpunktes B ist die bereits erwähnte Stringtheorie, bei der zweidimensionale Konforme Feldtheorien eine zentrale Rolle spielen. In einer alternativen Formulierung der Stringtheorie stehen die algebro-geometrischen Aspekte im Vordergrund. Zum Beispiel sind bei der Kompaktifizierung von Raumzeiten in der Stringtheorie die Calabi-Yau-Mannigfaltigkeiten von besondere Bedeutung. Dieser Problembereich hat in den vergangenen Jahren zu einem regen Austausch von Ideen und gegenseitigen Stimulationen von Mathematikern und Physikern geführt (Stichwort: Spiegelsymmetrie) mit bemerkenswerten Resultaten auch für die Algebraische Geometrie. In jüngster Zeit hat man, stimuliert durch die Arbeiten von Seiberg und Witten, Dualitätssymmetrien in der Stringtheorie gefunden, die es erlauben, bisher als verschieden betrachtete Theorien als nichtperturbativ äquivalente Formulierungen ein und derselben Theorie zu betrachten. Bei diesen Identifizierungen spielen die sogenannten D-branes eine zentrale Rolle.

C: Quantengruppen und Nichtkommutative Algebra

Seit den Arbeiten von Drinfel'd über Quantengruppen (1987), von Connes über nichtkommutative Geometrie (1985), von Atiyah und Witten zur Quantenfeldtheorie (1988) und von Jones über Knoten-Invarianten (1985) hat sich ein großes fachübergreifendes Arbeitsgebiet mit den mathematischen Teilgebieten der Kategorientheorie, der Knotentheorie, der Hopf-Algebren (Quantengruppen) und den physikalischen Teilgebieten der Statistischen Mechanik, der Quantenfeldtheorie, sowie der Quantenmechanik etabliert.

Im Rahmen des Graduiertenkollegs wird innerhalb des Schwerpunktes weiterhin an der Erforschung der algebraischen Struktur von Quantengruppen, insbesondere der halbeinfachen und der punktierten Quantengruppen, der Aufdeckung der Zusammenhänge zwischen ihrem Auftreten bei Quasisymmetrie-Bedingungen, z.B. in monoidalen Kategorien, bei den Darstellungen der Zopf-Gruppen oder in der Quanten-Yang-Baxter-Gleichung und ihrem Auftreten als Symmetriegruppen von nichtkommutativen Räumen (Quantenräumen) gearbeitet. Dabei sollen auch physikalisch interessante Eigenschaften untersucht und verstanden werden. Ebenfalls dazu gehört die Untersuchung der Differentialrechnung auf Quantenräumen und ihre Einbettung in Quantengruppen. Es sollen insbesondere drei Bereiche schwerpunktmäßig untersucht werden:

1) Der Zusammenhang zwischen den Darstellungen von Zopf-Gruppen und den dabei auftretenden Knoten-Invarianten, den Quasi-Symmetrien in monoidalen Kategorien, den Lösungen der Quanten-Yang-Baxter-Gleichung und den quasitriangulären Hopf-Algebren (als Symmetriegruppen). Als Komplement hierzu sind in der Physik die Statistische Mechanik, die Theorie der Anyonen und niederdimensionale topologische Quantenfeldtheorien zu untersuchen. In dieses Gebiet gehören u.a. Supersymmetrie, Quantenkommutativität, Vektorsymmetrie, R-Matrix, Band-Graphen und Tannaka-Krein-Dualität.

2) Die aus der (algebraischen) Geometrie bekannte Konstruktion der Symmetriegruppe eines Raumes ist auch in der nichtkommutativen Geometrie möglich und führt zu Quantengruppen. Es soll die algebraische Struktur der Quantengruppen und ihrer homogenen Räume, insbesondere der Hauptfaserbündel mit einer Quantengruppe als Strukturgruppe und der verschränkten Produkte von Quantengruppen untersucht werden. Hierzu gehören die Untersuchung der Quotientenbildung, der Quanten-Deformationen, der Hopfalgebren in der verzopften Kategorie der Yetter-Drinfel'd Moduln über einer abelschen oder nicht-abelschen Gruppe, und der Verallgemeinerungen von Quantengruppen, z.B. Quasi-Hopf-Algebren (im Sinne von Drinfel'd). Für die physikalischen Anwendungen sind die möglichen Deformationen und die Darstellungen der physikalisch relevanten Gruppen besonders interessant.

3) Es bedingen sich gegenseitig die Operation der Quantengruppen auf einem Quantenraum und eine Differentialrechnung auf einem Quantenraum. Hier haben erste Untersuchungen stattgefunden, um die von Manin, Wess, Woronowicz, Zumino und anderen gefundenen Ansätze algebraisch zu verarbeiten und durch gewisse universelle Moduln zu erfassen.

Seit Beginn des Graduiertenkollegs hat sich die fächerübergreifende Zusammenarbeit in dem Forschungsschwerpunkt erfreulich positiv entwickelt. Im gemeinsamen Seminar Pareigis/Wess sowie bei vielen Veranstaltungen mit Gästen kam es zu produktiven gegenseitigen Anregungen.

D: Wahrscheinlichkeitstheorie und Statistische Physik

Das zentrale Problem der Statistischen Physik ist die Erklärung des makroskopischen Verhaltens der Materie aus dem mikroskopischen Verhalten ihrer Atome. Da solch eine Erklärung notwendigerweise stochastischer Natur ist, besteht eine fundamentale Beziehung zwischen Wahrscheinlichkeitstheorie und Statistischer Physik. Wahrscheinlichkeitstheoretische Methoden sind unverzichtbar für die Statistische Physik, und Konzepte der letzteren (wie z.B. die Entropie) sind zum festen Bestandteil der Stochastik geworden. Räumliche stochastische Modelle bilden das geeignete wahrscheinlichkeitstheoretische Werkzeug zur Untersuchung von interagierenden

Vielteilchensystemen im thermodynamischen Gleichgewicht. Die zeitliche Entwicklung solcher Systeme kann durch stochastische Prozesse modelliert werden. Ein konkreter Gegenstand aus der Gleichgewichtstheorie, der im Graduiertenkolleg untersucht werden soll, ist die Theorie der großen Abweichungen, welche die Fluktuationen extensiver Größen beschreibt und auch für das klassische Problem der Äquivalenz der Gibbsschen Ensembles von Bedeutung ist. Dieser Gegenstand soll u.a. auch für ungeordnete Systeme wie die sogenannten Spingläser betrachtet werden. Über die Ergodentheorie, insbesondere die zufälligen dynamischen Systeme, und die zufälligen Schrödinger-Operatoren ergibt sich von hier eine Querverbindung zu Schwerpunkt A.

In der Nichtgleichgewichtstheorie soll die Herleitung von Transportphänomenen aus mikroskopischen Teilchenprozessen im hydrodynamischen Limes im Vordergrund stehen. Notwendig hierzu sind Methoden aus der Theorie der Diffusionsprozesse und der großen Abweichungen. Über die dabei resultierenden Transportgleichungen ergibt sich auch hier eine enge Beziehung zu Schwerpunkt A.

Außer den eben genannten Fragestellungen, die der klassischen Statistischen Physik angehören, sollen auch Grundlagenprobleme der Quantenphysik Gegenstand des Graduiertenkollegs sein. Hier konzentriert sich das Interesse einerseits auf die Untersuchung quantenstatistischer Transportphänomene, andererseits aber auch auf Grundlagenprobleme wie die Beschreibung des Meßprozesses in der Quantentheorie durch Spektralmaße von Operatoren. Über die algebraischen Strukturen von Operatoren ergibt sich ein natürlicher Bezug zu Schwerpunkt C. In diesen Problemkreis gehört auch die Frage nach der geeigneten Formulierung einer relativistischen Quantentheorie. Die damit verbundene Untersuchung von Raum-Zeit-Symmetrien und der allgemeinen Struktur der Raum-Zeit ist auch Gegenstand der Schwerpunkte B und C.

3. Interaktion der Forschungsprojekte

In der Beschreibung der Schwerpunkte in 4.3 werden Bezüge und Vernetzungen genannt, die sich in natürlicher Weise aus den Forschungsprogrammen ergeben. Diese Bezüge werden zum Teil im Graduiertenkolleg eingehend verfolgt und untersucht, so daß sich eine rege Zusammenarbeit zwischen den Schwerpunkten ergibt. Diese manifestiert sich z.B. in der Auswahl der auswärtigen Gäste, in der Teilnahme an Lehrveranstaltungen im Programm des Graduiertenkollegs sowie an Frühjahrs- und Herbstschulen (vgl. 8.1) und in der Betreuung und Beratung der Doktoranden. Dabei ist das Zusammenwirken aufgrund der speziellen Interessen der beteiligten Hochschullehrer zwischen den Schwerpunkten A und D einerseits und B und C andererseits enger als bei den anderen möglichen Kombinationen.

4. Studienprogramm

Die grundsätzlichen Ziele des Studienprogramms sind es,

- die teilnehmenden Graduierten an ihre Forschungsgebiete heranzuführen und ihre (notwendigerweise speziellen) Arbeitsthemen in allgemeinere Forschungszusammenhänge einzuordnen,
- ihnen insbesondere ein Bewußtsein für die Bedeutung der vielfältigen Wechselbeziehungen zwischen Mathematik und Physik zu vermitteln, und sie zu interdisziplinärer Denkweise anzuregen, sowie
- durch fachübergreifende Veranstaltungen zu einem engeren Zusammenwachsen der verschiedenen mathematischen Teilgebiete mit physikalischem Bezug beizutragen und eine gemeinsame Verständnisebene

für Mathematiker und Physiker zu schaffen.

Zur Erreichung dieser Ziele dienen folgende Veranstaltungen:

1. Vorlesungen der Träger, die auf die Bedürfnisse der Graduierten zugeschnitten sind und als solche deklariert werden.
2. Blockveranstaltungen (Kompaktkurse) von Trägern zu besonderen Themen,
3. Seminare (gegebenenfalls mit zwei oder mehr Veranstaltern),
4. Gastvorträge und Blockvorlesungen auswärtiger Wissenschaftler,
5. Frühjahrs- und Herbstschulen, kleinere Tagungen,
6. Teilnahme der Graduierten an Tagungen,
7. Studienaufenthalte der Graduierten an auswärtigen Hochschulen,
8. das Graduiertenkolloquium.

5. **Ergänzungsantrag:**

Auf Anregung von Herrn Prof. Dr. J. Wess wurde im Jahre 1999 ein Ergänzungsantrag gestellt mit dem Ziel, Doktoranden und Postdoktoranden aus dem ehemaligen Jugoslawien zu fördern. Der Antrag wurde zügig behandelt und genehmigt, so dass für die zwei abschließenden Jahre April 2000 - März 2002 (und zum Teil in der Auslauffinanzierungszeit April 2002 - März 2003) zusätzlich zu den vorhandenen Stellen zwei Postdoktoranden und ein Doktorand aus Serbien, Montenegro und Kroatien gefördert werden konnten.

6. **Budget des Kollegs:**
   1. **Mittel für 2000:** 672.300,- DM
   2. **Mittel für 2001:** 718.020,- DM
   3. **Mittel für 2002:** 226.953,- EURO (Ab 1.4.2002

      Auslauffinanzierung)

7. **Im Druck erschienene Publikationen von Stipendiaten (Auswahl):**
   1. **Zeitschriftenartikel:**
      - BOHR C.: *Embedded surfaces and almost complex structures*, Proc. Amer. Math. Soc. **128** (2000), 2147-2154.
      - BOHR C.: *On the relation between lifting obstructions and ordinary obstructions*, Topology Appl. **103** (2000), 283-290.
      - TERZIC S.: *Real cohomology of generalised symmetric spaces* (Russian), Fundamentalnaya i prikladnaya matematika **7** (2001), 131-157.
      - HOBST, D., PAREIGIS, B.: Double quantum groups, *J. Algebra* **242** (2001), 460-494.
      - SCHARFSCHWERDT, B.: *The Nichols Zoeller theorem for Hopf algebras in the category of Yetter Drinfeld modules*, Commun. Algebra **29** (2001), 2481-2487.
      - ADAMS, S.: *Complete equivalence of the Gibbs ensembles for one-dimensional Markov systems*, J. Statist. Phys. **105** (2001), 879-908.
      - JOVANOVIC, B.: *Geometry and integrability of Euler-Poincar?-Suslov equations* Nonlinearity **14** (2001), 1555-1567.
      - HÖVERMANN, F., SPOHN, H., TEUFEL, S.: *Semiclassical limit for the Schrödinger equation with a short scale periodic potential*, Comm. Math. Phys. **215** (2001), 609-629.
      - TERZIC S.: *Pontryagin classes of generalised symmetric spaces* (Russian),

Mat. Zametki **69** (2001), 613-621; translation in Math. Notes **69** (2001), 559-566.

- X. Calmet, B. Jurco, P. Schupp, J. WESS und M. WOHLGENANNT: *The Standard Model on Non-Commutative Space-Time*, Eur. Phys. J. **C 23** (2002), 363
- JOVANOVIC, B.: *On the integrability of geodesic flows of submersion metrics*, Lett. Math. Phys. **61** (2002), 29-39.
- TEUFEL, S.: *Effective N-body dynamics for the massless Nelson model and adiabatic decoupling without spectral gap*. Ann. Henri Poincaré **3** (2002), 939-965.
- TUMULKA, R.: *Comment on ''Time-like flows of energy-momentum and particle trajectories for the Klein-Gordon equation''*, J. Phys. A: Math. Gen. **35** (2002) 7961-7962.
- Kashina, Y., SOMMERHÄUSER, Y., Zhu, Y.: *Self-dual modules of semisimple Hopf algebras*, J. Algebra **257** (2002), 88-96.

8. **Abschlüsse von Stipendiaten (mit Betreuer)**
   - RODEWIS, T.: Partikelmethoden zur numerischen Behandlung des symmetrischen Vlasov-Poisson- und Vlasov-Einstein-Systems (Proff. Batt J. und Petras (TU Braunschweig)) 2000
   - HÖVERMANN, F.: Quantum Motion in Periodic Potentials (Proff. Kalf H. und Spohn H.) 2000
   - SCHARFSCHWERDT, B.: Endlich dimensionale Yetter Drinfeld Hopfalgebren (Proff. Schneider H. und Pareigis B.) 2000
   - BOHR, C.: Embedded Surfaces and the Intersection Forms of non-simply Connected 4-Manifolds (Proff. Kotschick, D. und Kreck, M. (Heidelberg)) 2000
   - ADAMS, S.: Vollständige Äquivalenz der Gibbsensembles für eindimensionale Markov-Systeme (Proff. Georgii, H. und Dürr, D.) 2000
   - ULM, V.: Operationen von Hopfalgebren in Kategorien von Yetter-Drinfeld-Moduln (Proff. Schneider H.-J. und Pareigis B.) 2000
   - LANG, J.: Relative Moduli Spaces of Semi-Stable Sheaves on Families of Curves (Proff. Schottenloher M. und Forster O.) 2000
   - HOSTER, M.: Derived Secondary Classess for Flags of Foliations (Proff. Kotschick, D. und Kamber, F. (Univ. of Illinois)) 2001
   - SCHEIDEGGER, E,: D-branes on Calabi-Yau Spaces (Proff. Theisen, S. und Kotschick, D.)
   - TUMULKA, R.: Closed 3-Forms and Random Worldlines (Proff. Dürr, D. und Zanghi, N. (Genua)) 2001
   - DIETZ, S. (geb. SHEVCHENKO): Flache Lösungen des Vlasov-Poisson-Systems (Proff. Batt, J. und Kalf, H.) 2002
9. **Liste der gegenwärtigen Stipendiaten (mit Betreuer); Stand Dezember 2002**

BAKOVIC, Igor (Wess/Schottenloher)
DIDT, Daniel (Schneider)
ELSNER, Karen (Maison)
GROSSKINSKY, Stefan (Spohn)
HOBST, Daniela (Pareigis)
PICKL, Peter (Dürr)
SCHMIDT, Alexander (Wess)

1.9 Graduiertenkolleg Logik in der Informatik

1. **Laufzeit** 1. 4. 1997 bis 31. 3. 2006
2. **Sprecher** Prof. Dr. Helmut Schwichtenberg
3. **Träger des Kollegs** Prof. Manfred Broy (TU Informatik)
   Prof. François Bry (LMU Informatik)
   Prof. Wilfried Buchholz (LMU Mathematik)
   Prof. Wolfram Büttner (Infineon, Uni Kaiserslautern)
   Prof. Peter Clote (LMU Informatik), bis 30.05.2000
   Prof. Javier Esparza (TU Informatik), ausgeschieden
   Prof. Martin Hofmann (LMU Informatik). seit 24.09.01
   Prof. Fred Kröger (LMU Informatik)
   Prof. Tobias Nipkow (TU Informatik)
   Prof. Hans-Jürgen Ohlbach (LMU Informatik), seit 01.04.2000
   Prof. Klaus Schulz (CIS München)
   Prof. Helmut Schwichtenberg (LMU Mathematik)
   Prof. Martin Wirsing (LMU Informatik)
4. **Ziele, Programm und Struktur des Graduiertenkollegs**
   1. **Umfang und Struktur** Das Graduiertenkolleg umfaßt neben den derzeit 11 Stipendiaten weitere 22 sogenannte assoziierte Kollegiaten, die anderweitig finanziert, aber in das Ausbildungsprogramm und die Arbeit des Graduiertenkollegs eingebunden sind.
   2. **Forschungsprogramm** In den letzten Jahren ist es zunehmend deutlich geworden, dass Begriffsbildungen und Methoden der mathematischen Logik in der Informatik mit großem Nutzen angewendet werden können. Insbesondere die Beweistheorie und die Modelltheorie haben sich hier als sehr fruchtbar erwiesen, erfordern aber noch gezielteren Zuschnitt. Die Arbeit im Kolleg stellt darauf ab, die Anwendbarkeit logischer Methoden beim Entwurf, der Spezifikation, der Verifikation und der Optimierung von Programmen, Programmsystemen und Schaltungen weiter zu verbessern und auszudehnen. Die wichtigsten Forschungsgebiete des Kollegs und der angestrebte Informationsfluß von den Grundlagen hin zu Anwendungen wird durch folgendes Diagramm veranschaulicht. In der Informatik haben in den letzten Jahren Entwicklungen stattgefunden, die zunehmend die Notwendigkeit einer stärkeren theoretischen Durchdringung zentraler Fragestellungen gezeigt haben. In der ersten Zeit der stürmischen Entwicklung der Informatik konnte man die zahlreichen Probleme weitgehend mit auf die speziellen Fragen

      zugeschnittenen Methoden angehen. Gegenwärtig schälen sich immer mehr Problemkreise heraus, die sich einem solchen direkten Zugang entziehen, und für deren Lösung eine größere theoretische Durchdringung des Umfelds erforderlich ist. Beispiele sind etwa

      - die Frage, wie man die Korrektheit umfangreicher Programme und Programmsysteme sicherstellen kann, oder
      - ganz allgemein die Beziehungen zwischen Logik und Programmiersprachen, wie sie etwa in den Bereichen Logikprogrammierung und funktionale Programmierung mit Funktionen höherer Ordnung zum Ausdruck kommt.

      Zur Lösung von Problemen dieser Art können Methoden und Ergebnisse der mathematischen Logik erheblich mehr Beiträge liefern als dies bisher der Fall ist. Dies gilt zunächst in besonderer Weise für die Beweistheorie, die sich aufgrund

ihrer ursprünglichen Fragestellungen schon immer mit der Analyse von Herleitungsmechanismen für syntaktische Gebilde zu befassen hatte, wobei in vielfältiger Hinsicht ähnliche Probleme zu lösen waren, wie sie heute in der Informatik auftreten. Die Beweistheorie hat dabei ein reiches Instrumentarium entwickelt, etwa mittels Umformung von Herleitungen in geeignete Normalformen zunächst unzugängliche, kombinatorisch verwickelte Probleme einer Lösung zuzuführen.

Auch von Seiten der Modelltheorie sind für die genannten Anwendungsfelder wichtige Impulse zu erwarten. Die Entwicklung eingebetteter Systeme stellt eine große Herausforderung für die Sicherstellung der Korrektheit dar, da in allen Anwendungen hohe Anforderungen an die Korrektheit gestellt werden. Die bisher verwendeten Entwurfstechniken (Statecharts - Statemate, SDL, Lotos, Esterelle usw.) haben allesamt gemein, dass sie semantisch nicht voll erschlossen und logisch nicht sauber fundiert sind. Eine vollständige mathematische und insbesondere logische Fundierung ist jedoch nach Stand der Technik heute möglich und, um Korrektheit in hochkritischen Anwendungen sicherzustellen, auch unumgänglich.

i. Praktikabilität
   Nachdem die ersten Ansätze der vollständigen logischen Modellierung von reaktiven Systemen sich vornehmlich mit einfachen Beispielen (,,Spielbeispielen‘‘) auseinandergesetzt haben, um die grundsätzlichen Fragen zu klären, sind mittlerweile einige der formalen, logikbasierten Techniken soweit ausgereift, dass sie sich mit realistischeren, anwendungsnäheren Beispielen beschäftigen. Neben der Spezifikation und Verifikation von verteilten und Zeit-basierten Systemen (remote precedure call - Zugriff auf Speicher, Prozesskontrollaufgaben im Bereich der Haushaltstechnik, Fahrzeugtechnik und Avionik) steht mittlerweile auch die theoretische Fundierung von Programmiersprachen (u.a. Java), sowie die logik-basierte Behandlung von intelligenten Datenbanksystemen und die Bioinformatik im Vordergrund.

   Die auftretenden theoretischen Fragestellungen decken das weite Spektrum der logischen Teildisziplinen (Beweistheorie, Modelltheorie, Rekursionstheorie, Komplexitätstheorie, Typentheorie etc.) ebenso ab wie die der Informatik (model checking, formale Spezifikation und Verifikation, Computer-Aided Reasoning u.v.m.). Die theoretische Tiefe der anstehenden Aufgaben und der benutzten Methoden macht das Forschungsgebiet hervorragend geeignet für Promotionsvorhaben wie sie in den Forschungsprogrammen der Dozenten und Kollegiaten beschrieben sind. Die Integration und Vernetzung der verschiedenen Aktivitäten in dem weitgefächerten Gebiet ist das besondere Anliegen unseres Graduiertenkollegs.

ii. Bedarf der Industrie
   Welch wichtigen Beitrag aus der Sicht der Industrie gerade logische Beschreibungsmethoden für die Beherrschung komplexer reaktiver Systeme leisten können, sieht man daran, dass die Doktoranden aus den einschlägigen Forschungseinheiten, wie sie auch am Graduiertenkolleg beteiligt sind, dringend von der Industrie nachgefragt werden. So ist zu beobachten, dass für junge, frisch promovierte Wissenschaftler mit profunden Kenntnissen logischer Methoden der Informatik eine Fülle von interessanten Tätigkeiten in der Industrie besteht und dass sie in der Regel unter mehreren hochdotierten Angeboten wählen können. Dank der Kontakte zur Industrie (Siemens, BMW u.a.) kann das Graduiertenkolleg den notwendigen Praxisbezug der aktuellen

Forschung herstellen und neue Probleme verzögerungsfrei angehen.

iii. Forschungsschwerpunkte

- Logische Grundlagen, insbesondere Lambda-Kalkül, Gleichungslogik, Temporale Logik, Model Checking, logik-basierte Wissensrepräsentation, minimale Implikation, nichtmonotones Schließen. (Bry, Buchholz, Büttner, Hofmann, Kröger, Nipkow, Schulz, Schwichtenberg)
- Rechnergestütztes Beweisen / Theorembeweiser, insbesondere Integration von Gleichungstheorien auch höherer Ordnung, Kombination von Theorembeweisern und Spezialverfahren, Anwendungen zur Wissensverarbeitung. (Bry, Buchholz, Nipkow, Ohlbach, Schulz, Schwichtenberg)
- Modellierung insbesondere wissensbasierter und verteilter Systeme, Model Checking Automaten. (Broy, Bry, Büttner, Hofmann, Kröger, Wirsing)
- Semantik und Logik für Programme und Programmiersprachen, insbesondere Ressourcenkontrolle, Objektorientierung. (Broy, Hofmann, Kröger, Nipkow, Wirsing)
- Grundlagen der Software-Technik, insbesondere Modularisierung und Wiederverwendung von Programmeinheiten, Verwendung von Kalkülen beim Entwurf und bei der Optimierung von Programmen, Programmsystemen und Schaltungen. (Broy, Büttner, Wirsing)
- Anwendungen, Umsetzung und Praktikabilitätsstudien, insbesondere im Bereich logischer Programmierparadigmen. (Broy, Bry, Hofmann, Ohlbach, Wirsing)

Zwischen diesen Arbeitsgebieten gibt es offensichtlich zahlreiche Überlappungen. Die sich daraus ergebenden Kooperationen sind erklärtes Ziel des Graduiertenkollegs und haben in der Vergangenheit einen besonderen Niederschlag in den folgenden Schwerpunktbereichen gefunden.

A. Formale Fundierung der Programmiersprache JAVA: In Fortsetzung laufender Arbeiten soll die formale Korrektheit des vollen Java-Kerns inklusive Multithreading bewiesen werden. Ziel ist es, auf die sicherheitsrelevante Internet-Programmierung neuere Techniken der Spezifikation und Verifikation anzuwenden. Es sollen auch Erweiterungen insbesondere um Typinformationen und Korrektheitsbeweise diskutiert und implementiert werden. Die Organisation dieses Kooperationsschwerpunktes liegt bei den Arbeitsgruppen Clote, Nipkow und Wirsing.

B. Spezifikation und Verifikation verteilter und reaktiver Systeme: Die Modellierung von parallel arbeitenden und interagierenden Systemen stellt auch unter praktischen Gesichtspunkten eine große Herausforderung dar. Die gemeinsamen Grundlagen der verschiedenen theoretischen Zugänge sowie die Schwierigkeiten in der industriellen Umsetzung stehen im Vordergrund der integrierten Bemühungen im Graduiertenkolleg. Alle Arbeitsgruppen, insbesondere auch die Forschungsgruppen von Siemens und BMW, sind direkt mit Forschungsprojekten an dem gemeinsamen Schwerpunktprojekt beteiligt.

C. Syntaktische und semantische Aspekte der Typentheorie und ihrer Erweiterungen (um Unifikation, (Ko-)Induktion, ...): Als formale Grundlage des Computer-Aided-Reasoning sowie konstruktiver Modellierung von

Programmiersprachen steht die Typentheorie seit mehreren Jahren im Brennpunkt der Erforschung formaler Methoden. Dabei sind Fragen der denotationellen und operationellen Semantik für mächtige Erweiterungen um Induktion und Koinduktion, Termersetzungssysteme, Unifikation u.a. zu beantworten. Andererseits werden bei der Identifikation und Behandlung geeigneter Teile der Typentheorie komplexitäts- und rekursionstheoretische Fragestellungen verfolgt. Besonders beteiligt sind hier die Forschungsgruppen Buchholz, Clote, Kröger, Nipkow, Schulz, Schwichtenberg, Wirsing.

iv. Studienprogramm

- Das Graduiertenkolloquium findet während des Semesters mindestens alle zwei Wochen, meist jedoch wöchentlich statt. Es dient als Forum, in dem die Doktoranden den Fortgang ihrer Arbeit auseinandersetzen und diskutieren können. Im Vordergrund steht hierbei der Austausch und Kontakt mit anderen Kollegiaten und den Professoren des Kollegs. Auf diese Weise treten Berührungspunkte zwischen den verschiedenen Forschungsbereichen zutage und können in gemeinsamen, die Grenzen der Spezialbereiche übergreifenden Diskussionen und Arbeiten nutzbar gemacht werden. Ziel des Kolloquiums ist es, die Doktoranden an den Forschungsgebieten aller ihrer Kollegen zu interessieren und dergestalt einer blinden Spezialisierung entgegen zu wirken. Das Graduiertenkolleg arbeitet eng zusammen mit den Graduierten-Veranstaltungen der einzelnen Arbeitsgruppen und Institute (Oberseminare, Typen-Club, Mathematisches Kolloquium). Insbesondere werden einschlägige Vorträge in das Curriculum des Graduiertenkollegs mit aufgenommen und andererseits einzelne Graduiertenkolloquien in den Rahmen der Oberseminare oder des Typen-Clubs gestellt.
- Das Vorlesungs- und Seminarangebot der im Graduiertenkolleg eingebundenen Professoren und Privatdozenten berücksichtigt die Themenstellung des Graduiertenkollegs. Insbesondere werden einzelne Themenschwerpunkte in fachübergreifenden Seminaren bearbeitet. In das Curriculum des Graduiertenkollegs werden einschlägige Veranstaltungen aufgenommen. Von den Doktoranden wird erwartet, dass sie im Verlauf ihres Promotionsprojektes Einführungsvorlesungen und womöglich weiterführende Seminare in den wesentlichen Schwerpunktgebieten des Kollegs besuchen, um eine breit gefächerte Ausbildung als Grundlage für den wissenschaftlichen Austausch im Kolloquium zu erwerben.
- In den Überschneidungsbereichen der einzelnen Arbeitsgruppen, die sich in der Arbeit des Graduiertenkollegs als besonders fruchtbar erwiesen haben, werden gemeinsame, fachübergreifende Seminare veranstaltet, so etwa im Sommersemester 1999 ein gemeinsames Seminar von Berger, Clote und Schwichtenberg über Komplexitätstheorie.
- Sommerschulen renommierter internationaler Art werden schon seit längerer Zeit von einigen der Antragsteller (M. Broy, M. Nipkow und H. Schwichtenberg) in Marktoberdorf bei München organisiert. Das Generalthema ist die Methodologie des Programmierens; Themen aus dem Bereich Anwendungen der Logik in der Informatik werden jedes zweite Jahr gewählt. Titel der letzten Sommerschulen sind
  A. Logic, Algebra and Computation (1989),
  B. Programming and Mathematical Method (1990),
  C. Logic and Algebra of Specification (1991),

D. Program Design Calculi (1992),
E. Proof and Computation (1993),
F. Deductive Program Design (1994),
G. Logic of Computation (1995),
H. Mathematical Methods in Program Developement (1996),
I. Computational Logic (1997),
J. Calculational System Design (1998),
K. Foundations of Secure Computation (1999),
L. Engineering Theories of Software Construction (2000),
M. Proof and System-Reliability (2001),
N. Models, Algebras and Logic of Engineering Software (2002),
O. Proof Technology and Computation (2003).

Hier bietet sich eine exzellente Gelegenheit für die Kollegiaten, mit herausragenden Fachvertretern direkte Kontakte anzuknüpfen. Vom Graduiertenkolleg selbst werden Kompaktkurse und -seminare in den Semesterferien als Winter- und Sommerschulen durchgeführt. Neben den bereits aufgeführten Veranstaltungen der Vergangenheit sind geplant

- die jährlich stattfindende Arbeitstagung Bern-München
- Arbeitstreffen des Graduiertenkollegs in der Internationalen Universität Venedig (Frühjahr 2004)

- Das Vorlesungsprogramm des Graduiertenkollegs wird zu einem Teil von auswärtigen Gastwissenschaftlern durchgeführt. Soweit deren Forschungsgebiete besonders gut zu vorangegangenen Vorträgen von Doktoranden im Graduiertenkolleg passen, werden Gastvorträge auch im Kolloquium gehalten. Dazu kommen kürzere Gastaufenthalte und Gastvorträge auswärtiger Kollegen, sowie kleinere Tagungen. Diese dienen nicht nur dem notwendigen wissenschaftlichen Austausch, sondern eröffnen den Kollegiaten zusätzliche Möglichkeiten, Kontakte für einen auswärtigen Studienaufenthalt zu knüpfen. Solche Studienaufenthalte im Ausland leisten einen wichtigen Beitrag zur Förderung der Doktoranden, der über die Betreuung durch den Doktorvater hinausgeht.

v. Bedeutung Eine bemerkenswerte Tatsache ist die starke Verflechtung und fortschreitende Annäherung zwischen Informatik und mathematischer Logik. Hier sind weitere wichtige Entwicklungen zu erwarten. Für die Graduierten ist eine breite Kenntnis der Methoden auf diesen Gebieten eine hervorragende Grundlage für eine industrielle oder wissenschaftliche Laufbahn. Zu betonen ist die entscheidende Bedeutung, die ein Transfer der in den letzten Jahren erreichten theoretischen Fundierung der Software-Technik in die industrielle Praxis hat. Auch von Seiten der Industrie besteht ein starkes Interesse daran, das Potential der Anwendung von logischen Methoden auf bestimmte Bereiche der Informatik - etwa im Rahmen von Promotionsprojekten - auszuloten. Die Anzahl der Promotionen in der Informatik ist im Vergleich mit der in anderen Fächern immer noch viel zu gering. Dies ist nicht zuletzt darauf zurückzuführen, dass viele Informatiker in Projektarbeiten verstrickt sind und es in dieser Situation schwierig ist, genügenden Abstand für die Arbeit am eigenen Promotionsprojekt zu gewinnen. Hier leistet das Graduiertenkolleg einen wichtigen Beitrag, indem die Gesamtzahl der Promotionen erhöht und der dafür nötige Zeitaufwand verkürzt wird. Ferner bildet das Graduiertenkolleg eine Plattform, auf der die bisher mehr individuell gewachsene Zusammenarbeit der mathematischen Logiker am Mathematischen Institut und der Informatiker an

den Instituten für Informatik der Universität München und der TU München organisiert ist und nach außen wirksam werden kann. Wie im Arbeitsbericht erläutert, ergeben sich vielfältige Anregungen für die jeweiligen Gebiete: Für die Logik etwa des Auffinden lohnender Anwendungsfelder, und für die Informatik Hinweise auf die angemessene Gestaltung der formalen Sprachrahmen und deduktiven Apparate, wie sie bei der Spezifikation und Verifikation insbesondere von komplexen Systemen benötigt werden.

5. **Budget des Kollegs**
   - Mittel für 1999: 401’738,- DM
   - Mittel für 2000: 502’429,- DM
   - Mittel für 2001: 525’790,- DM
   - Mittel für 2002: 273’588,- Euro
   - Mittel für 2003: 287’467,- Euro
6. **Erschienene Publikationen von Stipendiaten**
   1. **Zeitschriftenartikel**

1

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2. **Beiträge zu Konferenzbänden, Buchkapitel u. ä.**

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AEHLIG K and Johannsen J. An Elementary Fragment of Second-Order Lambda Calculus (ICC '02)

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7. **Abschlüsse von Kollegiaten**
   - Matthias EBERL: Normalization by Evaluation, Januar 2002 (Prof. Schwichtenberg)
   - Felix JOACHIMSKI: Reduction Properties of IE-Systems, Dezember 2001 (Prof. Schwichtenberg)
   - Alexander KURZ: Logics for Coalgebras and Applications to Computer Science, Juli 2000 (Prof. Wirsing)
   - Monika MAIDL: Model-checking used for system verification, August 2000 (Prof. Schwichtenberg)
   - Dirk PATTINSON: Expressivity Results in the Modal Logic of Coalgebras, Juni 2001 (Prof. Wirsing)
   - Leonor PRENSA NIETO: Verification of Parallel Programs with the Owicki-Gries and Rely-Guarantee Methods in Isabelle/HOL, Oktober 2001 (Prof. Nipkow)
   - Harald STöRRLE: Models of Software Architecture, Dezember 2000 (Prof. Wirsing)
   - Klaus WEICH: Improving Proof Search in Intuitionistic Propositional Logic, Juli 2001 (Prof. Schwichtenberg)
   - Wolfgang ZUBER: Bereichstheoretische Semantik der Linearen Logik, November 2000 (Prof. Schwichtenberg)
   - Klaus AEHLIG : On Fragments of Analysis with Strengths of Finitely Iterated Inductive Definitions, 2003. (Prof. Buchholz)
8. **Gegenwärtige Stipendiaten in alphabetischer Reihenfolge**
   - Andreas ABEL (LMU Informatik, Prof. Hofmann, Prof. Pfenning)
   - Freiric BARRAL (LMU Informatik, Prof. Soloviev, Prof. Hofmann,

Prof. Schwichtenberg)
- Silvia GEBELLATO (LMU Mathematik, Prof. Schwichtenberg)
- Dan HERNEST (LMU Mathematik, Prof. Schwichtenberg)
- Steffen JOST (LMU Informatik, Prof. Hofmann)
- Paula-Lavinia PATRANJAN (LMU Informatik, Prof. Bry, Prof. Ohlbach)
- Stephanie SPRANGER (LMU Informatik, Prof. Bry, Prof. Ohlbach)
- Tjark WEBER (TU Informatik, Prof. Nipkow)
- Júlia ZAPPE (LMU Informatik, Prof. Kröger)

9. **Postdoktoranden**
   - Dr. Laura CROSILLA (September 2000 - August 2002; ab September 2002 wiss. Mitarbeiterin)
   - Dr. Isabel OITAVEM (September 2002 - Juli 2003)
   - Dr. Josef BERGER (Juni 2003 - August 2004)
   - Dr. Felix JOACHIMSKI (April 2003 - Mai 2003)
   - Dr. Sebastian SKALBERG (September 2002 - August 2003)

2 Institute for Informatics

The Department "Institute for Informatics" is highly reputed for its research. In the first ranking of Computer Science departments at German Universities performed by Professor Dr. B. Nebel in 2001 (cf. Informatik Spektrum, August 2001), the Institute for Informatics scored rank 2 out of 50 institutions in the category average number of research publications per professor and scored rank 4 out of 50 in the category average number of citations in CITESEER (http://citeseer.nj.nec.com/cs) per professor.

During the last few years, several prestigious research awards and research employment offers at well-known institutions were received by members of the Institute for Informatics: ACM-SIGMOD Best Paper Award 1997, IFIP/IEEE Dan Stokesberry Memorial Award 2001, offer to lead a research group at AT&T research labs, offer for a full professorship (chair) at the United Nations University.

Furthermore, 3 professors of the Institute for Informatics are members of the Informatics Commission of the Bavarian Academy of Sciences and 2 professors of the Institute for Informatics are co-ordinators of (thematics or excellence) networks of the EU commision. An additional indicator for the high quality research of the department is the high and yearly increasing amount of external research funds spent by the Institute for Informatics: 933.000 Euro in 2000, 1.106.000 Euro in 2001, and 1.521.000 Euro in 2002.

The Institute of informatrics consists of 7 units:

1. Unit "Distributed Systems, Computer Networks and Systems Programming" [see page 72]
2. Unit "Database Systems" [see page 86]
3. Unit "Programming and Software Engineering" [see page 102]
4. Unit "Programming and Modelling Languages" [see page 126]
5. Unit "Theoretical Computer Science" [see page 139]
6. Unit "Media Informatics" [see page 149]
7. Unit "Practical Computer Science and Bioinformatics" [see page 153]

2.1 Unit "Distributed Systems, Computer Networks and Systems Programming"

Prof. Dr. Heinz-Gerd Hegering, full professor

Prof. Dr. Claudia Linnhoff-Popien, full professor

		1998	1999	2000	2001	2002	2003
Full professor(s):		1	1	1	1	1	1
Associate professor(s) :		1	1	1	1	1	1
Research and teaching assistant(s) (*)		5	5	5	5	6	6
Research assistant(s) (without teaching duties) (**) employed at (***)	LMU	3	4	4	5	5	8
	LRZ/TUM	4	4	4	4	4	4
	elsewhere	1	1	1	1	5	2

Research Staff

(*) "Wissenschaftlicher Mitarbeiter auf Landesstelle mit Lehrverpflichtung"
(**) "Wissenschaftlicher Mitarbeiter aud Drittmittelstelle oder mit Promotions- oder Postdoc-Stipendium ohne Lehrverpflichtung"
(***) LMU: University of Munich, LRZ: Leibniz Supercomputing Centre, TUM: Technische Universität München

In addition to his profession as a professor, Dr. Hegering is chairman of the board of directors at the Leibniz Supercomputing Centre of the Bavarian Academy of Sciences.

The following topics characterise the main focus of research and teachings:

- communications systems and protocols
- Internet-based services, middle ware and grids
- ubiquitous, pervasive and contextual computing
- design of IT-systems/networks-structures
- concepts and methods of IT-management
- system programming, operating systems, distributed systems

At present, especially the research areas below are addressed that also lead to several long-term third-party funded projects.

The research work of this unit is strongly international oriented. Prof. Hegering for example received the IFIP/IEEE Dan Stokesberry Memorial Award "for his outstanding contribution to the field of Integrated Network Management" in 2001.

2.1.1 IT-Management Concepts and Methods

As a consequence of global-wide networking and new forms of tele-cooperations the commercial relevance of networked systems, distributed applications and distributedly provided IT-services is increasing. As one of the first groups in Germany this research unit is engaged in questions of the network-, system-, application-, enterprise- and service-management. Research is done in tight cooperation with international developers and users and in consideration of standards and best-practice-guides like ITIL, eTOM and others. This topic is intertwined with economic questions of business process modeling and the foundation of virtual organisations.

2.1.1.1 Service Management

Service management mainly is concerned with the development of new concepts and a universal architecture (service-management platform) to form the basis for an all-embracing service-management. Subquestions are the specification of service dependencies, the development of a universal service model, the modeling of customer-provider-interactions at the service access interface and the modeling of service level agreements (SLAs).

Policy-based Management. Policies enable the transition from purely imperative management approaches to a declarative paradigm and therefore provide better support for distributed management. These policy-based techniques are predestinated for highly dynamic and mobile environments. Research is done with cooperation partners to analyse how far these concepts are suitable for the management of, e.g., mobile networks of the 4th generation. Another research topic is the development of a methodology to support business and management processes using policy techniques with the objective to realize them automated in concrete management architectures. With the distributed specification of policies and their refinement into operational policies (machine-executable) conflicts can occur. There are two basic approaches to treat these conflicts: The preventive detection of potential conflicts and the reactive solution of conflicts that already have occurred. For both possibilities formal IT-management-models are analysed and specified to find invariances that are applicable to conflict-treatment.

Management of customer-provider-interactions. Utilising and provisioning of services as well as their quality are negotiated between customer and provider in a service level agreement (SLA). The unambiguous specification of quality attributes that are monitored and enforced during the operation of a service is a precondition for meaningful SLAs. Therefore formal and all-purpose description and modeling techniques based on existing standards are developed. In today's systems customers increasingly demand a technical interaction-interface to the management-system of the service-provider. At the so called customer-service-management (CSM) interface the customer shall be granted a uniform, but client-specific, view to the service, its current state, its current quality of service (QoS) as well as to the reporting of the service. Above all the customer shall be able to adapt the service to his current needs within the limits that were negotiated before.

In order to realise a CSM the provider has to change its component-based management system, thereby paving the way for a customer-based and service-specific paradigm. This leads to new questions. To identify the quality of a service customer-specific parameters have to be declared and monitored. Therefore, methods have to be found to map the quality-of-service-parameters on the several layers of the management hierarchy, which is to map customer-specific QoS-parameters on system- and component-specific

QoS-parameters and vice versa. Today complex services are not offered by a single provider but by a chain of several providers, therefore mappings on the several QoS-architectures of each provider are also necessary (difficulty of mapping in the provider hierarchy).

Similar difficulties exist within the fault- and problem-management. The provider is forced to consider his infrastructure and his components from the point of view of the customer. In this context the question occurs how component-driven error-messages (events) could be associated to a specific service or customer. On the other hand there is the need to find the causative component as fast as possible after receiving an error report (trouble ticket) from a customer concerning a specific service. Both mappings, bottom-up as well as top-down are subject of research work.

Architectures and Concepts for the Support of process-oriented Service-Management. Process-oriented Service-Management allows a technology-independent view to the operational realisation of IT-management. Present tools and architectures for the support of IT-management either deal with the monitoring and controlling of the technical infrastructure exclusively or only with single processes of service-management. Up to now, there are no architectures or concepts that would be able to integrate these tools and to offer an all-embracing support of all processes. Though the TeleManagement-Forum within NGOSS (New Generation Operations Systems and Software) that includes eTOM is engaged in this problem field, there is no respective framework in sight for the ITIL that is more widely-spread in Europe. The definition of appropriate information models as well as the difficulties concerning workflow-controlling and communication among distributed management-applications are subject of the research work of this unit.

Publications on the above-mentioned and/or related issues are [3], [5], [9], [11], [13], [14], [15], [16], [17], [19], [21], [22], [23], [24], [25], [31], [32], [33], [35], [36], [38], [39], [41], [42], [43], [44], [45], [48], [49], [50], [52], [53], [54], [55], [57], [58], [59], [60], [62], [65], [67], [69], [70], [71], [72], [73], [74], [78], [81], [82], [83], [85], [87], [88], [89], [90], [91], [95], [99], [104], [106], [108], [109], [113] and [118].

Contributing researchers:	Heinz-Gerd Hegering, Michael Brenner, Vitalian Danciu, Gabi Dreo-Rodosek, Christian Ensel (until June 2002), Markus Garschhammer, Boris Gruschke (until November 1999), Andreas Hanemann, Rainer Hauck (until July 2001), Stephen Heilbronner (until January 2000), Thomas Kaiser (until April 1999), Alexander Keller (until December 1998), Bernhard Kempter, Michael Langer (until March 2001), Stefan Loidl, Michael Nerb (until March 2001), Thomas Paintmayer (until May 1999), Igor Radisic (until February 2003), Helmut Reiser, Harald Roelle, Martin Sailer, Holger Schmidt (until July 2001), David Schmitz, Norbert Wienold (until June 2001)
Cooperations:	BMW Group, T-Systems, Siemens ICN, Siemens CT, Cisco, IBM Research Labs Rüschlikon, INRIA Nancy,Hewlett-Packard Research Labs Bristol, Frauenhofer Fokus, German Research Network (DFN), DZ Bank, RWTH Aachen, Imperial College London, University of Pretoria
Research Grant:	Seven full-time researcher positions by DFN, Siemens ICN and T-Systems

2.1.1.2 Security Concepts for distributed Management

An essential ancillary condition for a successful distributed management is the security of the management system. Management systems are increasingly operated inter-organisational. Because of the vital relevance of a management system for the operation of distributed IT-infrastructures concepts are necessary which incorporate security aspects in an all-embracing way. Threat analyses or security risk analyses deliver requirements a secure distributed management system has to meet. Research is done on how a system that is operated by several organisations could integrate all aspects of security (e.g. authentication, authorisation, access control, abuse treatment etc.) and what services are needed therefore. Subquestions are among other things how the security of critical management functions could be increased with the use of federative security concepts and extended authorisation mechanisms. And how single management tasks could be delegated in an efficient and secure way. All this aims towards a security architecture for federative and interorganisational management systems.

Publications on the above-mentioned and/or related issues are [8], [10], [28], [34], [37], [68], [73] and [92].

Contributing researchers:	Heinz-Gerd Hegering, Helmut Reiser, Gerald Vogt (until March 2003)
Cooperations:	Dr. Matthias Scherf, Genomatics; Prof. Dr. Thomas Seidl, RWTH Aachen; Prof. Dr. Thomas Meitinger and Dr. Holger Prokisch, Institute of Human Genetics, GSF National Research Center, Neuherberg, Germany.
Cooperations:	IBM Research Labs Zürich, Bundesamt für Sicherheit in der Informationstechnik (BSI)
Research grant:	One full-time researcher position funded by the Graduiertenkolleg TU Munich

2.1.1.3 System Preconditions and Architectures for IT-Outsourcing

IT-outsourcing is the relocation of IT-services to external service providers who are not part of the own company. The provisioning of complex application services via a network (ASP) holds particular challenges for the IT-management. In addition to classic difficulties of QoS-management, these challenges also include the addressing of security concerns on the part of the customer and the provisioning of controlling tools for the customer (e.g. for ad-hoc ordering of standard services or requesting accounting-information), because outsourcing leads to the customer losing direct control over service provisioning. Additional questions concerning this topic arise against the background of increasing trends towards a partial dynamic composition of services (e.g. with Web Services) across several domain boundaries.

Publications on the above-mentioned and/or related issues are [29], [30], [36], [40], [56], [62], [86], [93], [94], [103], [105], [111], [115], [119], [120] and [121].

Contributing Researchers:	Heinz-Gerd Hegering, Markus Garschhammer, Michael Langer (until March 2001), Michael Nerb (until March 2001), Harald Roelle
Cooperations:	German Research Network (DFN), BMW Group, T-Systems
Research Grant:	Two full-time researcher positions funded by the German Research Network (DFN)

2.1.2 Mobility and context-aware Services

New challenges arise because of mobility and context-awareness. Users access services of multiple providers with manifold end devices via heterogeneous access networks (e.g. GSM/UMTS, WLAN, Bluetooth etc). This leads to highly dynamic relations between involved service components and organisations. To achieve an efficient service management in mobile environments, decentralised and self organising management approaches are increasingly considered. Together with industry partners this unit currently develops a policy-based management system tailored to the needs of mobile networks. Due to the heterogeneity of end devices and access networks, services as well as content must be adaptable. Also under examination is how adaptation functionality could be integrated in so called Content Delivery Networks and be combined with the distribution of content and services.

As a consequence of mobility new applications become possible. One example are context-aware services that are adapted depending on context-information like the user's position or current profile information. In consideration of aspects like efficiency, security, accounting and fault tolerance, strategies and infrastructure services are developed that allow the provisioning, processing and using of context information in cellular and ad-hoc-networks. Because context-aware services will apparently affect the economy and society, this unit is engaged in an interdisciplinary project with the business administration and communication science departments. Here, in addition to technical issues, business models and their influence on existing value chains in the media industry are examined as well as the users' acceptance and the effects of context-aware services on society.

Publications on the above-mentioned and/or related issues are [1], [2], [6], [7], [47], [51], [77], [93], [107], [110], [114] and [122].

Contributing Researchers:	Heinz-Gerd Hegering, Claudia Linnhoff-Popien, Thomas Buchholz, Vitalian Danciu, Caroline Funk, Iris Hochstatter, Michael Krause, Axel Küpper, Michael Samulowitz (until July 2002), Michael Schiffers, Thomas Strang
Cooperations:	Prof. Alexander Schill, TU Dresden; Björn Schiemann, Siemens Corporate Technology; Andre Varney, Apollis Interactive; Prof. Arnold Picot, LMU; Prof. Hess, LMU, Prof. Brosius, LMU; Prof. Wirth, ETH Zürich
Research Grant:	Two full-time researcher positions funded by the BMBF within the project "Internetökonomie". Two full-time researcher positions funded by the Bayerische Staatskanzlei within the project "Kontextsensitive Dienste für globale UMTS-Netze"

2.1.3 Platforms for distributed Learning and Teaching

New Internet and web-based technologies lead to new chances and difficulties in teaching. This unit examines concepts of virtual learning and teaching for lectures as well as for practical courses. The lecture "Telecommunication Systems" was broadcasted between Munich and the RWTH Aachen (Aix-la-Chapelle) and the lecture "Computer Networks" between Munich and Garching via interactive video-conferences.

An interactive, multimedia-based practical course was offered for the first time in the summer term 2003 in cooperation with the RWTH Aachen. Through distributed access to learning material via the Internet the students gained more flexibility with respect to the time and place of their learning activities. This flexibility requires an integrated organisation of students, teachers and learning material. Current research work concentrates on the support of practice-related learning with simulation-based learning material, which emulates the highly dynamic behaviour of communication networks. This learning material is offered via a web-based interface for a distributed, interactive and self organising learning.

Publications on the above-mentioned and/or related issues are [4], [12], [46], [64], [76] and [102].

Contributing Researchers:	Claudia Linnhoff-Popien, Mang Li
Cooperations:	Prof. Dr. Otto Spaniol, RWTH Aachen; Prof. Dr. Uwe A. Michelsen, RWTH Aachen; Michael R. Kunzi, Cisco Systems
Research Grant:	One full-time researcher funded by the BMBF within the project "Entwicklung und Evaluierung eines Virtuellen Informatik Praktikums"

2.1.4 Achievements

Since 1998, the following theses have been completed by the members of the Unit:

- Igor Radisic: [11] (PhD Thesis)
- Gabriele Dreo Rodosek: [17] (Habilitation Thesis)
- Christian Ensel: [18] (PhD Thesis)
- Helmut Reiser: [28] (PhD Thesis)
- Rainer Hauck: [42] (PhD Thesis)
- Holger Schmidt: [43] (PhD Thesis)
- Michael Langer: [52] (PhD Thesis)
- Michael Nerb: [53] (PhD Thesis)
- Axel Küpper: [55] (PhD Thesis)
- Stephen Heilbronner: [77] (PhD Thesis)
- Boris Gruschke: [82] (PhD Thesis)
- Thomas Paintmayer: [92] (PhD Thesis)
- Thomas Kaiser: [95] (PhD Thesis)
- Alexander Keller: [104] (PhD Thesis)

2.1.5 Publications

1. Hegering, H.-G., Küpper, A., Linnhoff-Popien, C., Reiser, H., **Management Challenges of Context-Aware Services in Ubiquitous Environments**, In Self-Managing Distributed Systems; 14th IFIP/IEEE International Workshop on Distributed Systems: Operations and Manage-ment, DSOM 2003, Heidelberg, Germany, October 2003, Proceedings, (LNCS 2867), 246-259, Springer, Heidelberg, Germany, October, 2003.
2. Buchholz, T., Buchholz, S., **Adaptive Content Networking**, In International Symposium on Information and Communications Technologies (ISICT 03), 2003, Dublin, Ireland, September, 2003.
3. Dreo Rodosek, G., Feridun, M., **Management of IT Services, Special Issue**, In Computer Networks - The International Journal of Computer and Telecommunications Networking, 2003(1), 43, September, 2003.
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5. Hanemann, A., Schmitz, D., **Approaching Automated Workflow Support for the Application of Generic Service Management Models**, 2003, HP OpenView University Association, Geneva, Switzerland, July, 2003.
6. Brenner, M., Schiffers, M., **Applying Web Services Technologies to the Management of Context Provisioning** , In 10th International Workshop of the HP OpenView University Association (HPOVUA 2003), Geneva, Switzerland, July, 2003.
7. Buchholz, T., Küpper, A., Schiffers, M., **Quality of Context Information: What it is and why we need it**, In Proceedings of the 10th HP-OVUA Workshop, 2003, Geneva, Switzerland, July, 2003.
8. Garschhammer, M., Hegering, H.-G., Schiffers, M., Broy, M., Picot, A., **Kommunikations- und Informationstechnik 2010+3**, 2003, Bundesamt für Sicherheit in der Informationstechnik, Bonn, Germany, May, 2003.
9. Dreo Rodosek, G., **A Generic Model for IT Services and Service Management**, In Integrated Network Management VIII - Managing It All, 2003, 171-184, Kluwer Academic Publishers, IFIP/IEEE, Colorado Springs, USA, March, 2003.
10. Vogt, G., **Multiple Authorization - A Model and Architecture for Increased, Practical Security**, In Proceedings of the IFIP/IEEE Eighth International Symposium on Integrated Network Management (IM 2003), 109-112, Kluwer Academic Publishers, IFIP/IEEE, Colorado Springs, USA, March, 2003.
11. Radisic, I., **Ein prozessorientierter, policy-basierter Ansatz für ein integriertes, dienstorientiertes Abrechnungsmanagement**, PhD-Thesis, Ludwig-Maximilians-University Munich, February, 2003.
12. Li, M., Linnhoff-Popien, C., **Interactive Simulation in E-Learning**, In The IASTED International Conference - Applied Modelling and Simulation (AMS 2002), IASTED, Cambridge, USA, November, 2002.
13. Brenner, M., Radisic, I., Schollmeyer, M., **A Criteria Catalog based Methodology for Analyzing Service Management Processes**, In Feridun, M., Kropf, P., Babin, G., editors, Proceedings of the 13th IFIP/IEEE International Workshop on Distributed Systems: Operations & Management (DSOM 2002), Lecture Notes in Computer Science (LNCS) 2506, 145-156, Springer, IFIP/IEEE, Montreal, Canada, October, 2002.
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Distributed Systems: Operations & Management (DSOM 2002), Lecture Notes in Computer Science (LNCS) 2506, 82-93, Springer, IFIP/IEEE, Montreal, Canada, October, 2002.

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28. Reiser, H., **Sicherheitsarchitektur für ein Managementsystem auf der Basis Mobiler Agenten**, PhD Thesis, Ludwig-Maximilians-University Munich, December, 2001.
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46. Immhoff, F., Linnhoff-Popien, C., **Internet-based Teleteaching using the IP-based German Broadband Science Network**, In International Conference on Intelligent Multimedia and Distance Education, Fargo, ND, USA, June, 2001.
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56. Hegering, H.-G., **IP Networks, Carrier and Enterprise Solutions**, (Congressband III), Online 2001, Online-Verlag, Velbert, ISBN 3-89077-221-8, February, 2001.
57. Hegering, H.-G., Langer, M., Nerb, M., **Kunde vs. Dienstleister: Die unterschiedlichen Sichten auf Dienstqualität und SLA-Management**, In Proceedings Online Congress 2001, Congressband III, C320.1-C320.13, Düsseldorf, February, 2001.
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2.2 Unit "Database Systems"

Prof. Dr. Hans-Peter Kriegel, full professor

Prof. Dr. Christian Böhm, associate professor

	1998	1999	2000	2001	2002	2003
Full professor(s):	1	1	1	1	1	1
Associate professor:			1	1	1	
Research and teaching assistant(s) (*)	7	7	7	8	8	8
Research assistant(s) (without teaching duties) (**)	1	2	2	3	3	3

Research Staff

(*) "Wissenschaftlicher Mitarbeiter auf Landesstelle mit Lehrverpflichtung"
(**) "Wissenschaftlicher Mitarbeiter aud Drittmittelstelle oder mit Promotions- oder Postdoc-Stipendium ohne Lehrverpflichtung"

2.2.1 Research Topics

- Design and implementation of database systems, particularly for the application areas biology, biochemistry, medical and life sciences, multimedia, geography and engineering
- Knowledge Discovery in Databases
- Information Filtering for E-business
- Similarity Search in Databases
- Access Methods for High-Dimensional Data Spaces
- Spatial Data Management in CAD Databases
- Molecular Bioinformatics

Hans- Peter Kriegel and Christian Böhm received the internationally prestigious "SIGMOD Best Paper Award 1997" for the publication and prototype implementation "Fast Parallel Similarity Search in Multimedia Databases" together with three members of their research team. This prize ranks as one of the highest awards for research in database systems.

The projects described in more detail below led to several grants by the Deutsche Forschungsgemeinschaft (DFG), by the Bundesministerium für Bildung und Forschung (BMBF) and by industrial partners.

2.2.1.1 Knowledge Discovery in Databases

Modern methods in application domains such as molecular biology, astronomy, geography, etc. produce a vast amount of data. Since all this data can no longer be managed without the help of automated analysis tools, there is an ever increasing need for efficient and effective data mining methods to make use of the information contained implicitly in that data. One of the main tasks of data mining is clustering which is intended to help a user discovering and understanding the natural structure or grouping in a data set. Clustering real-world data sets is often hampered by the so-called curse of dimensionality, since many real-world data sets

consist of a very high dimensional feature space. In this case, traditional clustering algorithms often fail to generate meaningful results. We are currently working on subspaces clustering algorithms and advanced feature selection methods for clustering high-dimensional data.

Web content mining is the application of data mining techniques to automatically extract relevant content from the world wide web. While many established methods are targeted to retrieve relevant web pages, there are various applications which target whole web sites. A web site is a set of web pages serving a common purpose, e.g. to represent an organisation. We develop techniques for classification, focused crawling and clustering to enable users to query the web for specific web sites.

Another important aspect is the development of data mining algorithms for complex objects. Since representing complex objects as single feature vectors might loose vital information, we develop methods that are capable to handle sets and tuples of feature vectors. Applications of this approach are biomolecular databases and CAD-databases which provide multiple representations for the data objects.

Traditional KDD methods require full access to the data which is going to be analysed. All data has to be located on a single site. Nowadays, large amounts of heterogeneous, complex data reside on different, independently working computers which are connected to each other via local or wide area networks, e.g. mobile and sensor networks, supermarket chains, and cannot be made available in a centralised location due to bandwidth limitations, scalability problems or security/privacy considerations. We develop methods for analysing data in a distributed fashion. Thus, the data is analysed locally, where it has been generated and stored. Afterwards, we combine these local models to a global one. For large data sets, scaling up the speed of the KDD process is crucial. Thus we further develop techniques for parallel knowledge discovery.

Publications on the above-mentioned and/or related issues are [1], [5], [6], [8], [13], [15], [16], [18], [19], [20], [21], [22], [23], [27], [28], [29], [32], [33], [34], [36], [37], [43], [45], [48], [50], [51], [52], [53], [56], [57], [61], [63], [65], [66], [68], [70], [71], [72], [73], [75], [76], [77], [78], [79], [87], [88], [89], [90], [91], [96], [97], [98], [99].

Contributing researchers:	Hans-Peter Kriegel, Christian Böhm, Mihael Ankerst (until March 2001), Stefan Berchtold (until July 1997), Bernhard Braunmüller (February 2001), Markus Breunig (until February 2001), Martin Ester (until October 2001), Eshref Januzaj, Karin Kailing, Daniel Keim (until March 1998), Florian Krebs (until August 2001), Peer Kröger, Martin Pfeifle, Jörg Sander (until August 2001), Stefan Schönauer, Thomas Seidl (until August 2002), and Matthias Schubert, Xiaowei Xu (until June 1998)
Cooperations:	Prof. Dr. Jiawei Han, University of Illinois, Urbana Champaign, USA; Prof. Dr. Raymond Ng, University of British Columbia, Vancouver, Kanada; Dr. Mihael Ankerst, Boeing, Seattle, USA; Prof. Dr. Martin Ester, Simon Fraser University, Vanouver, Kanada; Prof. Dr. Jörg Sander, University of Alberta, Edmonton, Kanada.
Research grant:	one full-time researcher position funded by the Deutsche Forschungsgemeinschaft (DFG) within the project "Methods for cluster structure analysis and KDD database primitives for efficient (semi-) automatic knowledge extraction in very large high-dimensional databases"

2.2.1.2 Information Filtering for E-business

The explosive growth of digital data has opened great challenges to the area of E-business. A family of technologies, summarized as "Information Filtering", emerges to assist users to find desired information from large amount of available data. Applications include recommender systems, image retrieval, spam email filtering, news filtering, personalized web browsing and others. It has become a vivid research area that focuses on learning users' profiles of information need. Existing approaches either infer individuals' profiles by exploring their connections to other users, known as collaborative filtering, or learn the profile from the descriptive contents of examples given by the users, known as content-based filtering. This project studies various novel statistical learning approaches to modeling user profiles, namely collaborative filtering, content-based filtering and hybrid filtering.

Publications on the above-mentioned and/or related issues are [51], [52], [69], [76], [85], [90], [91].

Contributing researchers:	Hans-Peter Kriegel, Martin Ester (until October 2001), Xiaowei Xu (until June 1998), Zhao Xu, Kai Yu, Shipeng Yu
Cooperations:	Prof. Dr. Bernd Schürmann, Dr. Volker Tresp, Siemens AG München Corporate Technology
Research grant:	three doctoral scholarships funded by Siemens AG, Corporate Technology

2.2.1.3 Similarity Search in Databases

Modern database applications are characterised by two major aspects: the use of complex data types with internal structure and the need for new data analysis methods. The focus of database users has shifted from simple queries to complex analysis of the data, known as knowledge discovery in databases. Important tasks in this area are the grouping of data objects (clustering), the classification of new data objects or the detection of exceptional data

objects (outlier detection). Most algorithms for solving those problems are based on similarity search in databases.

On the other hand, similarity search is also directly important in many application domains. In molecular biology and pharmaceutics, finding geometrically similar or geometrically complementary molecules is essential for computer-aided drug design. In engineering, enormous cost reductions are possible by the identification of similar parts and a following reduction of part diversity.

All this makes efficient similarity search in large databases of structured objects an important basic operation for modern database applications. Consequently, similarity search plays an important role in several of our research projects and is investigated from different view points in those projects.

In the past few years, we developed several successful similarity search methods for different applications. A very general approach is based on a histogram representation of objects and the use of quadratic form distance functions. We applied this approach in such diverse application domains as image retrieval, bio informatics and CAD databases. The use of the quadratic form distance function allows the flexibility to adapt the similarity search method to the needs of different applications and users. This extends even to a point where the user is able to adapt the similarity measure between two queries without loosing interactive response times. The necessary performance is achieved through several generally applicable techniques like multi-step query processing architectures, an optimal k-nearest-neighbour algorithm, dimension reduction and efficient index structures.

We also developed efficient similarity search methods for graph- and tree-structured data. The edge matching distance for such data uses a matching between edge sets to derive a measure for the similarity of graph structures. It is characterised by a moderate computational complexity and high adaptability to user and application needs. Additionally, a multi-step query processing architecture for this measure was created to ensure good query response times. For tree-structured data, a similar query processing architecture was developed, also showing very good performance results.

All our similarity search techniques have been implemented prototypically and tested with data from various real-world applications. Additionally, several demos of the techniques are available on our web site.

Publications on the above-mentioned and/or related issues are [2], [3], [7], [9], [11], [12], [25], [30], [33], [36], [39], [40], [42], [47], [54], [55], [57], [63], [64], [65], [83], [86], [88], [93], [94], [103], [104], [105].

Contributing researchers:	Hans-Peter Kriegel, Christian Böhm, Mihael Ankerst (until March 2001), Bernhard Braunmüller (until February 2001), Stefan Brecheisen, Markus Breunig (until February 2001), Eshref Januzaj, Karin Kailing, Daniel Keim (until March 1998), Florian Krebs (until August 2001), Peer Kröger, Martin Pfeifle, Marco Pötke (until September 2001), Jörg Sander (until August 2001), Stefan Schönauer, Matthias Schubert, Thomas Seidl (until August 2002)
Cooperations:	Dr. Mihael Ankerst, Boeing, Seattle, USA; Prof. Dr. Thomas Seidl, RWTH Aachen.

2.2.1.4 Access Methods for High-Dimensional Data Spaces

The most well-known method for similarity search in various application domains such as CAD databases, time sequence analysis, molecular biology etc. is the so-called feature transformation. This transformation associates the objects of the database with vectors of numerical features which characterise the objects. Similarity search is thus translated into a search for neighbouring vectors in a usually high-dimensional feature space. The specific advantage is that using a single methodology, i.e. neighbourhood search upon feature vectors, a broad variety of application domains can be handled. One of the most important index structures for neighbourhood search in low dimensional spaces, the R*-tree, has been developed in the LMU database group. Our extension for high-dimensional spaces, the X-tree has become one of the milestones and yardsticks for similarity search. Due to a number of effects commonly referred to as the "curse of dimensionality", even the performance of the X-tree and other specialised index structures for high dimensions deteriorates when facing feature spaces of too high dimensionality. To gain a deep understanding of the related problems, a cost model for query processing based on index structures like the R*-tree or the X-tree was developed in a first step. This cost model was then used to identify numerous parameters for optimisation. A number of optimisation techniques such as the dynamic block size optimisation, optimal dimension assignment, optimal index scan techniques, and an optimising data compression technique for index structures have been proposed. The IQ tree, into which we integrated many of these techniques, has become one of the most efficient index structures today.

Publications on the above-mentioned and/or related issues are [4], [10], [12], [14], [22], [23], [24], [31], [33], [35], [36], [39], [40], [41], [42], [45], [46], [47], [49], [50], [56], [57], [63], [64], [65], [66], [68], [70], [71], [72], [75], [77], [78], [80], [81], [82], [84], [95], [101], [102].

Contributing researchers:	Hans-Peter Kriegel, Christian Böhm, Bernhard Braunmüller (until February 2001), Daniel Keim (until March 1998), Florian Krebs (until August 2001), Peter Kunath, Martin Pfeifle, Marco Pötke (until September 2001), Matthias Renz, Matthias Schubert, Thomas Seidl (until August 2002)

2.2.1.5 Spatial Data Management in CAD Databases

The development, design, manufacturing and maintenance of modern engineering products is a very expensive and complex process. Today, thousands to millions of CAD files of a car or an air plane may occupy terabytes of distributed secondary and tertiary storage. The main objective of this project is to find techniques to manage effectively and efficiently huge enterprise-wide amounts of spatial data and to evaluate them in an industrial environment. As a main application, we focus on collision detection and within-distance queries for digital mockup and on similarity search in large CAD databases. For an efficient query processing, conservative approximations of the CAD models are stored in a database in order to support geometric queries like collision or within-distance queries in a multi-tiered fashion. A selective and complete filtering mechanism determines only a small amount of the CAD parts to be downloaded from the database into main memory for exact geometric analysis. The efficiency is in particular realized by index structures we developed, which can be easily integrated into industrial strength object-relational database systems. To reduce the query times when dealing with high resolution spatial data, we apply data compression techniques to lower the high I/O cost. Special care is taken to find a good compromise between I/O- and CPU cost. In addition, we analyse which degree of redundancy is most suitable for high

resolution spatial objects. Collision detection and within-distance queries, which are very important for digital mockup (DMU), can be carried out interactively using our approach, instead of running time-consuming batch jobs on the whole database overnight. Furthermore, our approach for the efficient management of spatially extended objects can be applied on many other modern database applications including geographic information systems (GIS), medical imaging, computer- aided design (CAD), molecular biology or time-critical virtual reality applications, e.g. haptic rendering. Our industrial partners Boeing, Volkswagen and the German Aerospace Centre (DLR) use and evaluate the methods developed by us.

Publications on the above-mentioned and/or related issues are [3], [4], [9], [24], [38], [58], [59], [60], [62], [67], [74], [82], [83], [84], [86], [92], [94], [95], [100], [101], [102], [103].

Contributing researchers:	Hans-Peter Kriegel, Christian Böhm, Mihael Ankerst (until March 2001), Stefan Brecheisen, Peer Kröger, Peter Kunath, Martin Pfeifle, Marco Pötke (until September 2001), Matthias Renz, Matthias Schubert, Thomas Seidl (until August 2002)
Cooperations:	Dr. Andreas Müller, Volkswagen AG; Dr. Bob Abarbanel, Boeing; Prof. Dr. Gerd Hirzinger and Carsten Preusche, DLR; Dr. Marco Pötke, sd&m.

2.2.1.6 Molecular Bioinformatics

Modern analysis methods in molecular biology produce a tremendous amount of data. To make the full use out of this data, automatic tools for knowledge discovery and data analysis are needed. Our project "Molecular Bioinformatics" tries to address this task of supporting the automatic analysis of molecular biology data. The first sub-project aims at supporting the 1:n protein docking problem, i.e. given a query protein P find all proteins in a database that interact physically with P. A typical application is the prediction of the effect of specific drugs and their side effects to the human immune system. To predict the docking partners, potential docking sites are located on the surface of all proteins in a database for a given query molecule. Specific shape descriptions of these sites enable an efficient search in the database. The second sub-project deals with the cluster analysis of gene expression data. Micro array chip technology allows monitoring the expression level of thousands of genes synchronously. From the expression level of a gene, biologists are able to make implications about the amount of the gene product, it codes for (e.g. a protein). To analyse which genes are co-expressed under which conditions, tools for clustering are used. Since the raw data is very high-dimensional and genes typically cluster (are co-expressed) differently under varying conditions, the development of new clustering methods is required, for example algorithms for subspace clustering.

Publications on the above-mentioned and/or related issues are [2], [9], [17], [25], [26], [30], [87].

Contributing researchers:	Hans-Peter Kriegel, Mihael Ankerst (until March 2001), Karin Kailing, Peer Kröger, Stefan Schönauer, Thomas Seidl (until August 2002)
Cooperations:	Dr. Matthias Scherf, Genomatics; Prof. Dr. Thomas Seidl, RWTH Aachen; Prof. Dr. Thomas Meitinger and Dr. Holger Prokisch, Institute of Human Genetics, GSF National Research Center, Neuherberg, Germany.
Research grant:	two full-time researcher positions funded by the BMBF within the joint project: "Bioinformatics for the Functional Analysis of Mammalian genomes (BFAM)"

2.2.2 Dissertations, Habilitations and other Achievements

Since 1998, the following eight members of the unit for database systems graduated with a PhD in Computer Science:

- Mihael Ankerst
- Markus Breunig
- Christian Böhm
- Bernhard Braunmüller
- Andreas Miethsam
- Marco Pötke
- Jörg Sander
- Xiaowei Xu

During this period, four members of the unit received a habilitation in Computer Science from our faculty:

- Christian Böhm
- Martin Ester
- Daniel Keim
- Thomas Seidl

The following former members of the unit for database systems are now professors at various institutions:

- Stefan Conrad, Full Professor, Universität Düsseldorf
- Daniel Keim, Full Professor, Universität Konstanz
- Bernhard Seeger, Full Professor, Universität Marburg
- Thomas Seidl, Full Professor, RWTH Aachen
- Christian Böhm, Associate Professor, 2001-2003: UMIT Innsbruck, since 2003: LMU München
- Martin Ester, Associate Professor, Simon Fraser University, Vancouver, Canada
- Xiaowei Xu, Associate Professor, University of Arkansas, Little Rock, USA
- Jörg Sander, Assistant Professor, University of Alberta, Edmonton, Canada

During the report period, Hans-Peter Kriegel received an offer for the position of technology leader for the database group, AT&T Labs Research, USA, as well as offers for chairs in database systems with the Universität Augsburg and Cardiff University, GB. All offers were

declined.

2.2.3 Publications

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2.3 Unit "Programming and Software-Engineering"

Prof. Dr. Martin Wirsing, full professor

Prof. Dr. Fred Kröger, associate professor

	1998	1999	2000	2001	2002	2003
Full professor(s):	1	1	1	1	1	1
Associate professor(s) :	1	1	1	1	1	1
Research and teaching assistant(s) (*)	6	6	6	7	7	7.5
Research assistant(s) (without teaching duties) (**)	10	9	14	13	11	7.5

Research Staff

(*) "Wissenschaftlicher Mitarbeiter auf Landesstelle mit Lehrverpflichtung"
(**) "Wissenschaftlicher Mitarbeiter aud Drittmittelstelle oder mit Promotions- oder Postdoc-Stipendium ohne Lehrverpflichtung"

See below [see page 124] for a more detailed table with researcher's names.

2.3.1 Research activities

The research and teaching unit on Programming and Software Engineering (PST) is focussing on practical applications and theoretical foundations of object-oriented software engineering methods, new generation CASE systems, and new programming languages. A prime topic of the R&D activities of PST is the development of methods to improve software quality. Formal methods involve making mathematical models of software and deriving properties of the software from the models. This parallels practice in other areas of engineering, but is more difficult for software, due to the extreme complexity of modern software systems, and the unfamiliarity of engineers with the complex discrete mathematics required. The key for this task is to integrate semiformal engineering methods and notations, such as UML, with formal methods in order to provide a basis for mathematical analysis, validation, maintenance and verification of requirements, design specifications and software systems. A second central theme is the development of new techniques for object-oriented, constraint based, functional programming. This includes the study of foundational aspects of programming languages, such as semantics, correctness, specification construction, and design and development calculi as well as the application of these methods and principles to the design and implementation of software systems.

Actual application areas are concurrent and distributed programming, global computing, Internet programming and multimedia systems. PST has particular competence in object-oriented software development of mobile systems, in Java programming and the design of web based software systems. PST researchers have developed the first formal semantics for multi-threading in Java and the first provably correct code generation algorithm, generating concurrent Java programs from UML designs. Tools developed by PST comprise an adaptive hypermedia training system (SMEX-Web), a workflow driven CASE tool for software engineering (PUSH) and for Web applications (OpenUWE), a model checker

for UML real-time state and interaction diagrams (HUGO), a semantic meta editor for diagrammatic languages (RECOPLA), the language EPKML for high level design and rapid development of electronic product catalogues, and an editor for visual construction of Multi-Agent-Systems (Agent Component).

Currently, PST is coordinating the FET Global Computing project AGILE on developing software architecture of mobile systems; in addition, PST runs several sponsored research projects on formal foundations of object-oriented software engineering (InOpSys), web and hypermedia engineering (MMiSS), software development for distributed and mobile systems, test generation from design, and the development of a distributed web-based decision support for global change of climate (GLOWA).

In the following the actual research topics are presented in more detail.

- Formal Software Development
  - Formal Object-Oriented Software Development
  - Modelchecking
  - Temporal Logic of Actions
  - Theoretical Foundations of Systems Specifications
  - Semantics of Programming Languages
- Software Engineering
  - Mobile Computing, Agents
  - Web-Engineering, E-Learning
  - Software Architecture and Software Development Processes
  - Software-Techniques for Analysis and Simulation of Global Climate Change
- Innovative Programming Techniques
  - Constraint Programming
  - View-Oriented and Generative Programming

2.3.1.1 Formal Software Development

2.3.1.1.1 Formal Foundations of Object-Oriented Software Development

Since the end of the eighties object-oriented development techniques have become popular in software engineering. Not only modern programming languages like C++ and Java have been developed but also object-oriented analysis and design methods together with accompanying graphical modeling languages like the UML which is the de-facto standard in object-oriented software development. For safety-critical systems pragmatic methods must be enhanced by well-founded, formal notations which allow the unambiguous interpretation of specifications and which provide the basis for the verification of program correctness. Typically, object-oriented specifications contain invariants for classes which restrict the (visible) state space of their objects and pre- and postconditions for the given operations. These ideas have been incorporated already in the assertion language of Eiffel and have been developed further in languages like JML (Java Modeling Language) and OCL (the Object Constraint Language which is part of the UML). However, there is still a wide range of open questions concerning, for instance, the semantics of object-oriented specifications and component-based development with precise interface specifications. Our research results in this area comprise

- the mathematical semantics for diagrammatic modeling languages such as UML including the object constraint language OCL and other diagrammatic languages such as SDL and Message Sequence Charts,
- the extension of class specifications to object-oriented components and the development of a semantically well-founded component interconnection language,
- object-oriented refinement concepts and corresponding proof methods,
- assertion-based proof calculi for Java programs and
- tool support, in particular for the generation of proof-obligations.

Publications on the above-mentioned and/or related issues are [15], [62], [49], [79], [47], [107], [10], [9], [25], [67], [23], [66], and [95].

2.3.1.1.2 ModelChecking

Model checking is an established technique for fully automatic proving temporal properties of reactive systems. The main limitation of model checking applications is its restriction to finite state systems. By using abstraction techniques, this limitation can be ameliorated to a certain degree. Consequently, model checking techniques have also been applied more recently to checking software and programs.

In our research, we aim at applying model checking to software designs rather than implementations. On the one hand, software models in the early design phases tend to be more abstract and thus more amenable to model checking. On the other hand, development costs can be greatly reduced by finding errors as early as possible. We use the "Unified Modeling Language" (UML) as the software modeling notation. A tool, called HUGO, has been developed for translating UML state machines and UML interactions over UML static structures into off-the-shelf model checkers. For un-timed systems we use the model checker SPIN, for models involving timing annotations we employ UPPAAL. HUGO can be used for consistency checks between the dynamic views of UML interactions and UML state machines. Moreover, UML interactions can be viewed as defining desired or forbidden runs of collaborating UML state machines, thus defining properties in an easy-to-use language.

Development of the application-oriented tool HUGO is complemented by theoretical research in abstraction techniques. Predicate diagrams pave the way for specifying and proving abstractions of infinite state systems diagrammatically and thus directly lend themselves for inclusion in the UML-based model checking tool HUGO.

Publications on the above-mentioned and/or related issues are [27], [45], [46], [63], [84], and [83].

2.3.1.1.3 Temporal Logic of Actions for Reactive and Mobile Systems (TLA, MTLA)

Work in the area of Temporal Logic of Actions (TLA) investigates a diagram-based formalism to verify temporal properties of reactive systems. Diagrams integrate deductive and algorithmic verification techniques for the verification of finite and infinite-state systems, thus combining the expressive power and flexibility of deduction with the automation provided by algorithmic methods. We show that the concept of predicate diagrams can be used to verify not only discrete systems, but also some more complex classes of reactive systems such as real-time systems and parametrised systems. We prove the completeness of predicate diagrams and study an approach for the generation of predicate diagrams. We develop

prototype tools that can be used for supporting the generation of diagrams semi-automatically.

We have proposed an extension of Lamport's Temporal Logic of Actions by spatial modalities for the specification and verification of systems involving mobile code. Similar as in the Ambient Calculus due to Cardelli and Gordon, we model the topological structure of a mobile system as a tree whose edges are labelled by names. The mobility of objects is reflected in the dynamical reconfiguration of this tree. The main novelty of our approach is a study of notions of refinement appropriate for mobile systems that guide the selection of the spatial modalities of the logic. Specifically, we use names to refer to locations at arbitrary nesting depth rather than just below the current node. In this way, a single agent may be decomposed into a hierarchy of sub objects during a refinement step. A first paper on the logic and its use for the specification and refinement of mobile systems has been published at FASE 2003. The logic has meanwhile been applied to the specification of an active traceroute protocol, and we have proved the decidability of its satisfiability and model checking problems.

Publications on the above-mentioned and/or related issues are [27], [96], and [117]

2.3.1.1.4 Theoretical Foundations of Systems Specifications

Work in the area of theoretical foundations of systems specifications centres around the mathematical theory of formal models for systems specification, development, transformation and verification. We investigate the algebraic and coalgebraic foundations of specifications and their relationships. An interesting application is the use of domain theory for computing provably correct solutions of ordinary differential equations.

In the area of algebraic specifications and term rewriting we have designed Timed Rewriting Logic and the language Timed Maude for specifying real-time object-oriented systems and we have developed techniques for extracting programs from proofs of structured specifications.

Timed Rewriting Logic (TRL) is a new variant of Rewriting Logic, an algebraic formalism which allows the dynamic behaviour of systems to be axiomatised using rewrite rules. In TRL rewrite rules can be labelled with time constraints and this provides a means of reasoning about time elapse in real-time systems. The object-oriented specification language Timed Maude is based on TRL. Timed Maude has been successfully applied to the specification of several pragmatic modeling languages including Message Sequence Charts and SDL.

Extraction of Structured Programs Our technique for obtaining correct programs from proofs produces correct high-level programs from parameterised specifications written in a subset of CASL. The technique is based on a combination of standard constructive mathematical proof methods (due to Curry and Howard) together with structural modifications deriving from the proof calculi for structured specifications. Although programs extracted by the Curry-Howard process can be very cumbersome, we use a number of simplifications that ensure that the programs extracted are in a language close to SML.

The notion of coalgebras for a functor on a concrete category provides a general framework which captures various types of state transition systems and process calculi. On this level of generality, we are interested in formal logics, which can be used to specify and reason about coalgebraically modeled systems. Our line of research follows three main threads, detailed below:

Duality Theory This branch exploits the fact that coalgebras are the formal duals of algebras, and tries to build bridges between both areas. The problem lies in the fact that coalgebras over a category C are dual to algebras over the category C^op, which is in general different from C. Therefore, the goals are the formulation of coalgebras and their logics in a category-independent manner, and use this description to dualise results which are already known in the algebraic setting, e.g. Birkhoff's variety theorem.

Formal Systems for Coalgebraic Logics Here, we are investigating proof systems which can be used along with coalgebraic logic. This requires that the logic is equipped with a concrete syntax, and that the relevant proof rules are isolated. The focus of research here is soundness, completeness, and the expressiveness of the logics.

Specification Logics The portion of the research concerned with specification logics tries to apply the general results obtained in the other two branches to the problem of specifying properties of concretely presented state based systems. The main contribution lies in a synthesis of the algebraic / coalgebraic approach, which enables to reason about observable properties, while at the same time retains a certain amount of compositionality, described by the algebraic aspect of the system.

Apart from providing denotational semantics for programming languages, domain theory can also be used as a foundation for exact computation in analysis. The translation of classical theorems of analysis into domain theory then provides exact and provably correct algorithms for computations in analysis. This general paradigm is substantiated with case studies in several areas, including the provably correct solution of ordinary differential equations and the implicit function theorem.

Publications on the above-mentioned and/or related issues are [13], [1], [92], [105], [18], [14], [44], [73], [118], [106], [7], [36], [93], [119], [19], [120], [58], [59], [5], [6], [24], [41], [42], [68], [43], and [65].

2.3.1.1.5 Semantics of Programming Languages

The programming language Java combines the object-oriented programming paradigm with the concurrent programming paradigm through tightly integrated support for multi-threaded programming. In particular, Java features a full-fledged memory consistency protocol for synchronising the local working memories of threads and the main memory. Java thus poses the challenge to integrate the low-level description of the memory model with the high-level language constructs into a modular, operational semantics which is parameterised in the details of the memory protocol.

We defined a mathematical structure, called event spaces, that declaratively captures the memory model specification. An operational semantics for the Java language constructs is combined with the event spaces by memory action primitives. In fact, the parameterisability of the approach has been proved by showing that an optimisation by so-called prescient store action is correct with respect to the original memory model. Moreover, event spaces have been demonstrated to provide a rich mathematical structure, viz. forming a prime-algebraic, consistently complete Scott domain, that clearly expresses the concurrent features of Java.

The event-based, operational semantics of Java does not answer the question for specifying and proving properties of Java programs directly and sufficiently. On the side of event spaces the logic of configuration theories, which is currently under thorough investigation, can be used to reason on the properties of memory models. For object-orientation itself, object specifications define rules for recursive object behaviour generalising the approach by Abadi and Leino.

Publications on the above-mentioned and/or related issues are [3], [8], [16], [20], [38], and [33].

Contributing researchers:	Hubert Baumeister, Pietro Cenciarelli (until 1999), Rolf Hennicker, Stephan Janisch, Alexander Knapp, Piotr Kosiuczenko (until 2003), Alexander Kurz (until 2000), Stephan Merz (until 2002), Dirk Pattinson, Axel Rauschmayr, Bernhard Reus (until 2000), Martin Wirsing, Julia Zappe (until 2003).
Co-operations:	Japan Institute of Science and Technology, JAIST (Kanazawa, Japan), Protos Software GmbH (München), Software Research Associates (Tokyo), Michel Bidoit (Ecole Normale Supérieure de Cachan), Manfred Broy (TU München), Pietro Cenciarelli (Università di Roma "La Sapienza"; since 1999), Corina Cirstea (Southampton, UK), John N. Crossley (Monash University Melbourne), Abbas Edalat (Imperial College, London), Clemens Kupke (Amsterdam, Netherlands), Stephan Merz (INRIA Nancy; since 2003), Jose Meseguer (Univarsity of Illinois at Urbana Champaign), Bernhard Möller (Universität Augsburg), Ataru Nakagawa (Software Research Associates, Tokyo), Tobias Nipkow (TU München), Iman Poernomo (Monash University Melbourne), Kokichi Futatsugi (Japan Institute of Science and Technology, JAIST) Wolfgang Reif (Universität Augsburg), Bernhard Reus (University of Sussex; since 2000), Toshiki Sakabe (Nagoya University, Japan), Mingsheng Ying (Tsinghua University, Beijing).

2.3.1.2 Software Engineering

2.3.1.2.1 Mobile Computing, Agents

Architecture-based approaches have been promoted as a means of controlling the complexity of system construction and evolution, namely for providing systems with the agility required to operate in turbulent environments and adapt very quickly to changes in the enterprise world. Recent technological advances in communication and distribution have made mobility an additional factor of complexity, one for which current architectural concepts and techniques are not prepared for.

As part of the EU project AGILE we have developed extensions to the UML to model mobile systems. In a first step an extension of UML activity diagrams was defined to model the location of objects and how mobility primitives change the location of objects. How the thread of control is affected by objects changing their location is visualised by using the extension of UML sequence diagrams. To model the dynamic evolution of the interaction structure between multiple objects, UML state charts were extended by multiple input queues and by the notion of localities.

A new logic, extending the Temporal Logic of Actions (TLA) by Lamport, has been proposed for considering spatio-temporal issues in the specification and the analysis of the behaviour of mobile systems. The logic extends TLA by providing operators for the description of properties of trees, as well as changes in their structure, intuitively representing the hierarchical structure of administrative domains.

In the research area of Agent-Technology we have introduced an new approach (AgentComponent) that integrates software component features into agent technology. Component concepts like encapsulation, interfaces, parametrisation have been found useful for integration. Using this technology combination agents grow up to be reusable and parametrisable in different contexts. According to this approach a visual editor (AgentComponent Tool (http://www.pst.informatik.uni-muenchen.de/projekte/agentcomponent)) for AgentComponents has been developed and is still in development. This editor is based on the JADE Java Agent Development Framework and enables the user to visually create Multi-AgentComponent-Systems. Moreover AgentComponent-Systems can be visually parametrised and changed during runtime. This is a very useful feature to test the designed AgentComponent-Systems without having to stop the whole application.

Also in the research area of Agent-Technology we have designed and implemented BABSy, an accounting system that helps automate payment in an agent-based electronic commerce environment.

Publications on the above-mentioned and/or related issues are [103], [104], [97], [117], [89], [39], [113], [116], [115], [126], and [124].

2.3.1.2.2 Web-Engineering

Web-Engineering is a new upcoming discipline that focuses on systematic, disciplined and quantifiable approaches to the cost-effective development and evolution of high-quality Web-based systems and applications. The discipline of Web Engineering tries to prevent a new software crisis that may occur due to the omnipresence of Web applications and their strong cross-dependency. Web Engineering incorporates some of the well-known and successful traditional software engineering principles and practices, adapting them to the particular requirements of Web applications. But Web Engineering is inherently different from software engineering in that it must also take many aspects of other disciplines into account, such as:

- document orientation and content-drivenness of the Web
- focus on the look and feel and a strong bond between art and science
- diverse skills and capabilities of users demanding highly personalised services
- fast-changing technology and constantly evolving standards
- emerging legal and security issues
- need for ubiquitous access through mobile devices
- integration with pre-existing logic of legacy systems for quick entrance to the market

In our research, we aim at supporting the modeling of Web applications and the model-driven implementation of Web systems. We developed a methodology - called **UWE** (UML-based Web Engineering) - to cover the life-cycle of Web application development proposing an object-oriented and iterative approach based on the standard UML and the Unified Software Development Process. UWE uses “pure” UML notation and UML diagram types as far as

possible for the analysis and design of Web applications, i.e. without extensions of any type. Special aspects of the Web domain are addressed defining a so called “lightweight” UML profile. The UWE profile includes stereotypes and tagged values defined for the modeling elements needed to model the different aspects of Web applications, such as navigation, presentation, Web processes and adaptation aspects. The UWE design approach for workflow-based Web applications consists of introducing specific process classes that are part of a separate process model with a clear interface to the navigation model.

To support the systematic design the CASE-tool **ArgoUWE** has been implemented for Web information systems and is currently being extended for workflow-based Web applications. ArgoUWE is integrated in the **OpenUWE** tool suite environment to achieve a model-driven generation of such Web applications.

Publications on the above-mentioned and/or related issues are [12], [31], [32], [56], [52], [53], [55], [85], [87], [90], [75], [86], [88], [110], [111], [109], and [123].

2.3.1.2.3 E-Learning

SmexWeb (http://smexweb.pst.informatik.uni-muenchen.de/) (Student Modeled Exercising on the World Wide Web) is a modular framework for the development of adaptive Web-based systems. An instance of Smex Web has been implemented to give students the possibility to practice and deepen their knowledge in a time- and local independent fashion. At present SmexWeb offers a lesson on the topic of EBNF (Extended Backus-Naur Formalism).

The aim of the MMiSS (http://www.mmiss.org/) project is to set up a multimedia Internet-based adaptive educational system, covering the whole subject of Safe Systems. The area of "Safe Systems" has in the last few years become increasingly important. Software is increasingly used to control security-critical embedded systems, in aeroplanes, spaceships, and cars; and electronic trading over the Internet, with its associated security risks, is rapidly expanding. All this requires qualitatively and quantitatively better training in Safe Systems. To go with the planned deployment at universities, a number of well-known German companies have already expressed, through the various industrial contacts of the project partners, an interest in measures for further training in their own workforce.

Publications on the above-mentioned and/or related issues are [4], [11], [26], and [112]

2.3.1.2.4 Software-Techniques for Analysis and Simulation of Global Climate Change

An important issue of global climate change concerns changes in the hydrological cycle and the investigation of ways for sustainable future water use. To improve the quality of predictions and global change simulations one has to take into account that many processes of various fields are involved and influence each other. Hence, a key challenge for integrative simulation and analysis is the integration of the various simulation models of the different disciplines ranging from natural sciences, such as meteorology, hydrology, remote sensing, ground- and surface water management, glaciology, and plant ecology, to social sciences, such as environmental psychology and economy, agriculture and tourism.

Within the GLOWA-Danube project - being part of the GLOWA initiative of the German Ministry of Education and Research - we design the Internet based platform DANUBIA as a tool for integrative simulations and support of decision making for a sustainable environmental management in the Upper Danube Basin. Many water-related conflicts arise in

this area of almost 80.000 square kilometres concerning, for instance, water quality and water utilisation, environmental protection, flood risks, tourism and vulnerability of mountain environments due to climatic change.

The development of DANUBIA is based on object-oriented software engineering and Web engineering methods and on the Unified Modeling Language UML which is used by all partners as a common graphical notation for modeling the integrative aspects of the system. The crucial concepts behind the design of DANUBIA concern the network and interface structure, the modeling of space and layered simulation areas and the temporal coordination of local models by a global time controller which constitutes the heart of any integrative DANUBIA simulation.

Publications on the above-mentioned and/or related issues are [30], [50], [51], [91], [78], [114], [100], [125].

2.3.1.2.5 Software-Architecture and Software Development Processes

The architecture of a software system is now widely recognised as the key success factor when it comes to devising, maintaining, and reusing software components, and evolving large scale software systems. One important part of software architecture is the communication between all stakeholders of a software system. Another is to achieve a sound fundament for the software in order to achieve maintainability for the system and re-usability for its parts.

Our research is based on two main strands: the modeling aspect and the technical realisation aspect. Modeling of software systems, especially in the early development phases, involves much effort in communicating with the stakeholders to investigate all requirements and needs the stakeholders have. To communicate results the Unified Modeling Language (UML) is a first choice, as it is the current de facto standard modeling language for software. Integration architectural concepts in the UML meta-model allows us to share the methods and tools for the UML.

The technical realisation aspect is another crucial step to achieve a software that meets all stakeholders' needs and is maintainable and yet extensible. Currently we are extending Java by architectural concepts (Java/A). In this way we achieve a smooth crossover from architectural models to an implementation by providing architectural concepts as fundamental parts in a programming language. Furthermore, Java/A improves the re-usability of software components as it assists programmers in developing them as independent parts.

Lately agile software development processes gained a lot of attention. In contrast to traditional software development processes, these processes promise to provide business value faster than traditional processes and to better cope with changes coming from changing and unclear requirements.

We have successfully applied these processes in the context of the EU project CARUSO, whose objective was the design and implementation of a framework for customised customer relationship management (CRM) applications. Further, we have started to integrate formal methods with these processes.

Performance assessment of software from the early design phase through the implementation has been subject to a great variety of approaches in the past. Performance aspects have to be considered and laid down in certain documents. Thus typical artifacts are created and have to be integrated in the software design as well as in the software development process.

We use UML diagrams to describe all essential aspects of a software and its environment. Dynamic properties of a software are laid down in activity diagrams. The environment that will execute the software is modeled by class diagrams. Finally a simulating software configured by the environment description rates the software model.

Publications on the above-mentioned and/or related issues are [21], [22], [40], [64], [77], [72], [69], [70], [71], [98], and [99].

Contributing researchers:	Michael Barth, Hubert Baumeister, Rolf Hennicker, Stephan Janisch, Alexander Knapp, Piotr Kosiuczenko (until 2003), Andreas Kraus, Matthias Ludwig, Philipp Meier, Stephan Merz (until 2002), Bernhard Reus (until 2000), Martin Wirsing, Gefei Zhang
Cooperations:	ATX Software (Lissabon), DataCall Systems (München), FAST GmbH (München), FJA GmbH (München), ImCon GmbH (München), sd&m Research (München), Remu (Utrecht, Niederlande), Softlab GmbH (München), Soluzione (München), Don Batory (University of Texas at Austin), J. Bendix (Fachbereich Geographie; Phillipps-Universität Marburg), J. Braun (Institut für Wasserbau; Universität Stuttgart), Cristina Cachero (Universidad de Alicante, Spain since 2001), Andrea Corradini (University of Pisa), S. Dabbert (Institut für Landwirtschaftliche Betriebslehre; Universität Hohenheim), Rocco De Nicola (University of Florence), J. Egger (Institut für Meteorologie; LMU), A. Ernst (Wiss. Zentrum für Umweltsystemforschung; Universität Kassel), H. Escher-Vetter (Kommission für Glaziologie der Bayerischen Akademie der Wissenschaften), Jose Fiadeiro (University of Leicester), Stefania Gnesi (Istituto di Scienza e Tecnologie della Informazione "A. Faedo" Pisa), Jaime Gomez (Universidad de Alicante, Spain since 2001), Heinrich Hußmann (LFE Medieninformatik; LMU), H.-B. Kleeberg (IAWG; Institut für Angewandte Wasserwirtschaft und Geoinformatik), H. Kobus (Institut für Wasserbau; Universität Stuttgart), Piotr Kosiuczenko (University of Leicester, since 2003), M. Kuhn (Institut für Meteorologie und Geophysik; Universität Innsbruck), Diego Latella (Istituto di Scienza e Tecnologie della Informazione "A. Faedo" Pisa), Antonia Lopes (University of Lisbon), Wolfram Mauser (Dept. für Geographie und Umweltwissenschaften; LMU), Stephan Merz (INRIA Nancy, since 2002), Ugo Montanari (University of Pisa), Rupert Rockinger(FAST, since 2000), Gustavo Rossi (Universidad de La Plata, Argentinien since 2000), J. Schmude (Institut für Geographie; Universität Regensburg), Wieland Schwinger (Universität Linz, Austria since 2002), R. Sprenger (Ifo-Institut für Wirtschaftsforschung), Andrzej Tarlecki (University of Warsaw), J. Tenhunen (Lehrstuhl für Pflanzenökologie; Universität Bayreuth), Michel Wermelinger (University of Lisbon), J. Wackerbauer (Ifo-Institut für Wirtschaftsforschung), W. Willems (IAWG; Institut für Angewandte Wasserwirtschaft und Geoinformatik), V. Wirth (Institut für Physik der Atmosphäre; Johannes-Gutenberg-Universität Mainz), Julia Zappe (INRIA Nancy, since 2003),

2.3.1.3 Innovative Programming Techniques

2.3.1.3.1 Constraint Programming

Constraint Programming is an established paradigm for solving a wide class of problems. Constraint Programming languages allow the programmer to specify a set of relations (constraints) that hold between entities; a constraint solver computes possible values for those entities that satisfy all constraints.

One focus of our work was the declarative specification of constraint solvers. This can be achieved with Constraint Handling Rules (CHR), a programming language based on a committed-choice rewriting system with guarded rules. CHR allow the introduction of user defined constraints into the language. Recent work focused on automatic analysis of properties of CHR programs like termination or complexity. A further area of research was the integration of soft constraint propagation into CHR. We also built several applications using CHR, for example a rent advisor or a program to compute the optimal placement of base stations in wireless indoor communication networks.

Constraint Languages are usually integrated into a logic programming language, giving rise to Constraint Logic Programming languages (CLPs). In recent years there has been interest in combining constraint languages with other programming paradigms to address insufficiencies of CLPs for certain problem domains. We have developed a family of formal calculi (the Constraint Lambda Calculi) that provide a foundation for integrating functional programming languages and constraint solvers, proved confluence properties for the constraint lambda calculi and introduced a denotational semantics. The constraint lambda calculi are parametric in the constraint domain over which they operate and allow the meta-level specification of search and result strategies. They provide most of the facilities of CLPs but can also address problems that are difficult to solve in logic programming languages like the interaction of side effects and constraint solving. Furthermore they allow new advanced programming techniques like hierarchical constraint solver determination. On this foundation we have developed and implemented the ConS/* family of programming languages which extend languages like Scheme, Dylan or Common Lisp with the facilities of the constraint lambda calculi.

Publications on the above-mentioned and/or related issues are [76], [74], [48], [29], [28], [54], [82], [80], [81].

2.3.1.3.2 View-Oriented and Generative Programming

In *View-Oriented Programming*, we look at a software system from several angles which has the benefit of aiding construction and comprehension of such a system. Each such angle represents an aspect (or *view*) of a system and is expressed in a formal language (visual or other). This allows one to perform consistency checks between the views or to query them for further information.

We have taken three approaches towards solutions in this area: The first one is to model-check consistency in UML state machines and interactions (see section on model-checking, project *Hugo*). The second one is algebraic and formalises views as sentences in a language. We allow views to be expressed in different languages and semantics and compare them for consistency using a heterogeneous pull-back construction. The third approach is an extension of Hyperspaces that allows individual methods to be partially distributed into several different Hyper-slices.

Generative Programming is about improving programmer productivity by raising the level of abstraction: Programming usually means translating a specification from a *problem domain* (which can be expressed in human language or in a notation used by domain experts) to one in the *solution domain* (usually an executable program expressed in a programming language). Generative programming aids abstraction and communication between domain experts and programmers by letting the latter develop in a notation that is close to the problem domain and by translating it to a language in the solution domain. A related problem

is that of *Software Product Lines* (SPLs): Very often, one needs to produce a family of software systems that are very similar. SPLs is a technique for constructing this family from a common set of base resources.

Work in this area started with a diploma thesis on an editor for a generative programming infrastructure that would later be named *AHEAD*. AHEAD automatically synthesises members of a product line that can contain a wide array of artifacts (written in human language, domain expert notation, programming language etc.). Furthermore, we developed a formal foundation for AHEAD, *Graft* to more precisely define its concepts and to analyse software systems developed with it. An analysis can check for semantic and formal correctness and provide information about the system to the programmer.

Publications on the above-mentioned and/or related issues are [94], [108], [61], [102], [101], [121] and [122]

Contributing researchers:	Thom Frühwirth (until 2001), Matthias Hölzl, Alexander Knapp, Stephan Merz, Bernd Meyer (until 1999), Christopher Rauh, Axel Rauschmayer, Timm Schäfer
Cooperations:	Prof. Don Batory (University of Texas at Austin), John Newsome Crossley (CSSE, Monash University), Stephan Merz (INRIA Nancy since 2003), Wolfgang Reif (Universität Augsburg),

2.3.2 Achievements

Since 1998, the following seven members of the unit PST graduated with a PhD in Computer Science:

- Alexander Kurz: Logics for Coalgebras and Applications to Computer Science, LMU München, 2000, [35].
- Alexander Knapp: A Formal Approach to Object-Oriented Software Engineering, LMU München, 2000, [33].
- Nora Parcus de Koch: Software Engineering for Adaptive Hypermedia Systems: Reference Model, Modeling Techniques and Development Process, LMU München, 2000, [34].
- Harald Störrle: Models of Software Architecture, LMU München, 2000, [40].
- Nataly Lyabakh: Design and Rigorous Prototyping of Object-Oriented Modeling with Syntropy, LMU München, 2000, [37].
- Dirk Pattinson: Expressivity Results in the Modal Logic of Coalgebras, LMU München, 2001, [60].
- Matthias Hölzl: Constraint Lambda Calculus, LMU München, 2001, [54]

During this period, two members of the unit received a habilitation in Computer Science from our faculty:

- Thom Frühwirth: A declarative language for constraint systems, LMU München, 1998,[2].
- Stephan Merz: Logic-Based Analysis of Reactive Systems: Hiding, Composition, and Abstraction, LMU München, 2001, [57].

The following former members of the unit PST are now professors at various institutions:

- Thom Frühwirth, Professor Universität Ulm
- Bernd Meyer, Senior Lecturer, Monash University Melbourne
- Piotr Kosiuczenko, Lecturer, University of Leicester
- Alexander Kurz, Lecturer, University of Leicester
- Stephan Merz, Director of Research, INRIA, Nancy
- Bernhard Reus, Lecturer, University of Sussex, Brighton
- Thomas Streicher, Professor Universität Darmstadt

The following conferences and workshops have been organized by members of PST:

- Semi-Formal and Formal Specification Techniques for Software Systems. **Dagstuhl Seminar**, 1998.
- Neue Horizonte im neuen Jahrhundert. **Informatik**, 2000.
- Integrating Diagrammatic and Formal Specification Methods.**GI/ÖCG Jahrestagung,** 2001
- Algebraic Development Techniques.**WADT,** 2002
- Radical Innovations of Software and Systems Engineering in the Future.**Monterey,** 2002

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2.3.4 Research Staff

	1998	1999	2000	2001	2002	2003
Full professor(s):	Prof. Wirsing	Prof. Wirsing	Prof. Wirsing	Prof. Wirsing	Prof. Wirsing	Prof. Wirsing
Associate professor(s):	Prof. Kröger	Prof. Kröger	Prof. Kröger	Prof. Kröger	Prof. Kröger	Prof. Kröger
Research assistant(s):	R. Hennicker, T. Frühwirth, V. Cengarle, S. Merz, B. Reus, A. Knapp	R. Hennicker, T. Frühwirth, V. Cengarle, S. Merz, B. Reus, A. Knapp	R. Hennicker, T. Frühwirth, V. Cengarle,P. Kosiuczenko (since 1.10.00), S. Merz, B. Reus, A. Knapp,	R. Hennicker, T. Frühwirth, P. Kosiuczenko, M. Hölzl, A. Knapp, S. Merz, D. Pattinson,	R. Hennicker, A. Knapp, P. Kosiuczenko, S. Merz, D. Pattinson, M. Hölzl, F. Hacklinger	R. Hennicker, A. Knapp, P. Kosiuczenko (until 30.9.03), D. Pattinson, M. Hölzl, F. Hacklinger, M. Barth (since 1.10.03), Nora Koch (halbe Stelle)
Research fellow(s):	H. Baumeister, P. Kosiuczenko, M. Hölzl, N. Koch, A. Kurz, N. Lyabakh, B. Meyer, D. Pattinson, H. Störrle, P. Cenciarelli	H. Baumeister, P. Kosiuczenko, M. Hölzl, N. Koch, A. Kurz, N. Lyabakh, B. Meyer,D. Pattinson, H. Störrle	H. Baumeister, P. Kosiuczenko (until 1.10.00), M. Barth, M. Hölzl, N. Koch, A. Kurz, M. Ludwig, N. Lyabakh, C. Nugraheni, D. Pattinson, J. Rottler, H. Störrle, T. Ströse, J. Zappe	H. Baumeister, M. Barth, F. Hacklinger, N. Koch, A. Kraus, A. Kurz, M. Ludwig, N. Lyabakh, C. Nugraheni, J. Rottler, H. Störrle, T. Ströse, J. Zappe	H. Baumeister, M. Barth, N. Koch, A. Kraus, M. Ludwig, P. Meier, C. Nugraheni, A. Rauschmayr, J. Rottler, J. Zappe, G. Zhang	H. Baumeister, N. Koch (halbe Stelle), M. Ludwig, A. Kraus, P. Meier, C. Nugraheni, A. Rauschmayr, G. Zhang

2.4 Unit "Programming and Modelling Languages"

Prof. Dr. François Bry, full professor

Prof. Dr. Hans Jürgen Ohlbach, associate professor

	1998	1999	2000	2001	2002	2003
Full professor(s):	1	1	1	1	1	1
Associate professor(s) :			1	1	1	1
Research and teaching assistant(s) (*)	4	4	4	4	4	4
Research assistant(s) (without teaching duties) (**)	2	2	2	2	1	3

Research Staff

(*) "Wissenschaftlicher Mitarbeiter auf Landesstelle mit Lehrverpflichtung"
(**) "Wissenschaftlicher Mitarbeiter aud Drittmittelstelle oder mit Promotions- oder Postdoc-Stipendium ohne Lehrverpflichtung"

2.4.1 Research activities

The Unit "Programming and Modeling Languages" investigates, applies, and develops logic-based programming and data modeling methods currently focusing on Web and Semantic Web applications. The Unit has manifold connections to national and international research teams. This has led to the launching in 2002 and 2003 of a Network of Excellence (in the 6th Framework Programme of the EU Commission) "REWERSE" on "Reasoning on the Web" under the co-ordination of François Bry. During the period of reference (1998 -- 2003), the Unit has investigated the following research topics:

- Querying and Indexing XML Data
- Web Data Modeling and Reasoning
- Analysis, Optimisation, and Generation of Rule-Based Constraint Solvers
- Selected Issues in Automated Reasoning (related to the above-mentioned subjects)
- Applications (related to the above-mentioned subjects)

2.4.1.1 Querying and Indexing XML Data (since 2000)

A deductive Web query language, called Xcerpt, is under development [49] [52] [58] [59]. Xcerpt is based on a novel form of unification, called "simulation unification" [57]. A first prototype has been completed and is used with an original visual programming interface [59] [63]. Elements for a formalisation of the declarative semantics of Xcerpt are given in [62]. The procedural semantics and the run time system of Xcerpt are based on constraint reasoning [57]. Temporal types and operations for Xcerpt are discussed in [60]. First experiments with Xcerpt point to the conciseness and simplicity of Xcerpt programs compared to e.g. XQuery programs and suggest that Xcerpt might considerably ease the implementation of adaptive Web systems.

The novel notion "complete answer aggregates" of aggregated answer to queries against XML and/or semistructured data is described in [3] and [35]. The notion aims at sharing subparts common to the various answers to a same query. A prototype system has been developed that computes complete answer aggregates to queries expressed in an XPath-like language and using which a user can "browse" aggregated answers. The prototype, its application to test beds, and its visual user interface are described in [55].

A method called SPEX for evaluating continuous XPath queries against XML data streams is presented in [69]. The approach first translates general XPath queries into equivalent XPath queries without so-called reverse axes such as "parent" or "ancestor" [47]. Then, such XPath expressions are translated into networks of push-down automata. The method has a polynomial combined complexity. A prototype and its evaluation on bench marks are reported about in [53].

Building upon the Data Guide approach to indexing the structure of XML or semistructured data, a method called "Content Aware Data Guide (CADG)" for an indexing of both, structure and textual content has been developed. The method, its implementation, and its performances on bench marks are described in [68].

Further publications on the above-mentioned and/or related issues are [31] [40] [42].

Contributing researchers:	François Bry, Norbert Eisinger, Hans Jürgen Ohlbach, Dan Olteanu, Sebastian Schaffert, Stephanie Spranger, and Sacha Berger.
Co-operations:	Klaus U. Schulz (Centre for Information and Language Processing, University of Munich) and Holger Meuss (European Southern Observatory).
Research Grants:	Two full time positions (Stephanie Spranger since January 2003 and Paula Pàtrânjan since November 2003) funded by the DFG (http://www.dfg.de/) within the doctoral programme "Graduiertenkolleg Logik in der Informatik" (http://www.mathematik.uni-muenchen.de/~gkli/)

2.4.1.2 Web data modeling and reasoning (since 2000)

Logic provides with a convenient basis for declarative languages such as Xcerpt. However, pure logics provide little means for modeling real world notions and objects. In project WebTNSS a logic is developed that has such means. The focus is on the modeling of "common sense" time and calendric and location notions [66]. These notions are becoming more and more important on the Web with the emergence of mobile Web applications. A related project is devoted to integrating elementary arithmetics in description logics and ontology languages [36]. The goal of both projects is to enrich logics and logic-based languages with numerical aspects of sets such as price, age, duration, etc.

The implementation of adaptive Web systems using Web query languages is investigated [48] [56] [67]. First investigations suggest that the approach should considerably simplify the implementation of adaptive Web systems.

Contributing researchers:	François Bry, Bernhard Lorenz, Hans Jürgen Ohlbach, Stephanie Spranger
Co-operations:	Michael Kraus (Keio University, Tokyo) and Kazuhiro Kitagawa (W3C Kyoto).
Research Grant:	55 000 Euro from the Max Plank Institute for running expenses in 2000

2.4.1.3 Analysis, Optimisation, and Generation of Rule-Based Constraint Solvers (up till 2002)

The analysis, integration, optimisation, and automatic generation of rule-based constraint solvers has been investigated focusing on constraint solvers implemented in the rule-based language CHR. Methods for the analysis and optimisation of constraint solvers are presented in [1] [24]. Methods for an automatic generation of constraint solvers from complete, incomplete, and intentional specifications are described in [9] [28] [41] [45] [46] [54] [70] [65]. The integration of constraint solvers is addressed in [64].

Related results and constraint programming tools tools are presented in [8] [23] [29] [37] [43] [51].

Contributing researchers:	Slim Abdennadher and Michael Marte.
Co-operations:	Henning Christiansen (Roskilde University), Thom Frühwirth (University of Ulm), and Christophe Rigotti (ENSA Lyon, France)
Research Grant:	One full time position (Michael Marte from February 1999 to January 2002) funded by the DFG (http://www.dfg.de/) within the doctoral programme "Graduiertenkolleg SIL (Sprache, Information, Logik)" 14 000 Euro for travel from the BFHZ-CCUFB (http://www.ccufb.uni-muenchen.de/accueil.html) in 1999 und 2000

2.4.1.4 Selected Issues in Automated Reasoning

Various applications of logic, e.g. type theory, to programming and software maintenance are investigated in [34] [38].

A formalisation of a (refinement of the) stable model theory in terms of a is given in [39]. The salient aspect of this formalisation is that it is expressed in the manner of classical model theory in terms of a truth-function function defined recursively on the structure of formulas. This definition makes it possible to evaluates logic programs according to the (refined) stable model semantics using standard proof methods such as resolution.

Several contributions to the theorem proving framework introduced with the SATCHMO prover have been investigated up till 1998. A deduction method complete for both refutation and finite satisfiability is presented in [2] [10]. Such a method is useful for artificial intelligence applications such a processing natural and/or controlled language specifications [25]. The generation of minimal models, an issue of importance for artificial intelligence applications such as planning, is addressed in the framework of the SATCHMO theorem prover in [30].

The application of a model generation prover to problem solving and to the specification of database integrity constraints is addressed in [11] [13] [19]. Implementations of provers are described in [12] [15]

Further reports on related issues are [20].

Contributing researchers:	François Bry, Norbert Eisinger, and Reinhard Kahle.
Co-operations:	Peter Baumgartner and Ulrich Furbach (both University of Coblence, Germany), and Adnan Yahya (Bir Zeit University, Palestine).
Research Grants:	Three full time positions (Sunna Torge from November 1995 to August 1999, Thomas Brüggemann from December 1995 to April 1998 and Reinhard Kahle from 2000 to 2001) funded by the DFG (http://www.dfg.de/) within the doctoral programme "Graduiertenkolleg SIL (Sprache, Information, Logik)" and one full time position (Heribert Schütz from November 1996 to April 1999) funded by the Bavarian Ministery for Education and Research

2.4.1.5 Applications

Timetabling issues have been investigated in various contexts, e.g. high school, universities, and hospital. Timetabling systems have been developed using constraint logic programming and extensively tested on benchmarks [6] [7] [17] [18] [22] [33] [5] [26]. Constraint logic programming has been applied for implementing a 'rent advisor' according to German city office regulations fixing upper bounds to apartment rents. Constraint programming makes it very easy to reason with interval and/or missing data instead of exact data [14] [21] [27]. Knowledge assimilation in deductive databases has been investigated in [16]. The interactive analysis of high-dimensional association structures has been investigated in [32]. An overview of current Bioinformatics databases is given in [50]. An approach to Web-based co-operative work has been specified, implemented, and tested. Web services for teaching are addressed in [61]. Proposals for an enhanced modeling of electronic books are made in [44].

Contributing researchers:	François Bry, Norbert Eisinger, Hans Jürgen Ohlbach, Sunna Torge.
Co-operations:	Hendrick Decker (Siemens, Munich, Germany, and Instituto Tecnológico de Informática, Valencia, Spain) and Iris Pigeot (Institute for Statistics, University of Munich).

2.4.2 Conference Organisation

Members of the Unit have been organisers or co-organisers of the following conferences:

- Workshop on Principles and Practice of Semantic Web Reasoning (PPSWR 2003) (http://www.kbs.uni-hannover.de/~henze/ppswr03/) at the 19th International Conference on Logic Programming (ICLP 2003) (http://www.tcs.tifr.res.in/~iclp03/) , 9-13 December 2003, Mumbay (India)
- 10th International Workshop on 'Knowledge Representation meets Databases'

(KRDB2003)
(http://www.pms.informatik.uni-muenchen.de/publikationen#PMS-FB-2003-9),
September 15-16, 2003, Hamburg

- Dagstuhl Seminar 01411 on 'Proof Theory in Computer Science' (http://www-ls.informatik.uni-tuebingen.de/logik/PTCS.html), October 7 - 12, 2001, Dagstuhl
- Intensionality Workshop (http://www.cis.uni-muenchen.de/sil/tagung/), October 27 - 92, 2000, München
- CP 2000 Workshop on 'Analysis and Visualization of Constraint Programs and Solvers' (http://www.pms.informatik.uni-muenchen.de/ereignisse/debug.html), September 22, 2000, Singapore
- CP 2000 Workshop on 'Rule-Based Constraint Reasoning and Programming' (http://www.informatik.uni-muenchen.de/~fruehwir/cp2000r.html), September 22, 2000, Singapore
- CL 2000 Workshop on 'Rule-Based Constraint Reasoning and Programming' (http://www.informatik.uni-muenchen.de/~fruehwir/cl2000r.html), July 24 - 28, London
- 15th Workshop on 'Logic Programming and Constraint Systems' (WLP 2000) (http://wdp.first.gmd.de:8080/glp/wlp2000.html), Collocated with ECAI2000 (http://www.ecai2000.hu-berlin.de/), August 25 - 27, 2000, Berlin
- 14. WLP -- Workshop Logische Programmierung (http://wdp.first.gmd.de:8080/glp/wlp99.html), 26. - 28. Januar 2000, Julius-Maximilians-Universität Würzburg
- International Conference on Deductive and Object-Oriented Databases (DOOD'97) (http://www.cs.uni-bonn.de/~dood97/), 8.-12. Dezember 1997, Montreux, Schweiz
- 12th Workshop Logische Programmierung (WLP'97) (http://www-info1.informatik.uni-wuerzburg.de/wlp97/), 17. - 19. September 1997, Ludwig-Maximilians-Universität München

In addition, members of the Unit have contributed to several additional conferences as program committee members or as reviewers.

2.4.3 Achievements

Since 1998, the following four members of the unit "Programming and Modeling Languages" obtained a PhD in Computer Science:

- Slim Abdennadher: [1]
- Sunna Torge: [2]
- Holger Meuss: [3]
- Michael Marte: [5]

Since 1998, one member of the unit "Programming and Modeling Languages" received a habilitation in Computer Science from our faculty:

- Slim Abdennadher: [4]

Slim Abdennadher has a full professorship (since September 2003) at the German University in Cairo (http://www.guc.edu.eg/), Egypt.

Two former members of the Unit, Tim Geisler and Dr. Heribert Schütz, have founded in 2000 a start-up company, webXcerpt (http://www.webxcerpt.de/), developping Software and offering services in the areas of Web data retrieval and querying.

2.4.4 External Funding

Between 1998 and 2003, external funding has been acquired by the unit for five full-time PhD Students in the framework of PhD programs (or "Graduiertenkollegs") of the German Foundation for Research "DFG" (http://www.dfg.de/).

In 2001 and 2003 an application for a Network of Excellence "REWERSE" on "Reasoning on the Web" in the 6th Framework Programme of the EU Commission has been successfully prepared under the co-ordination of François Bry. REWERSE will start in 2004 and last over 4 years, involves about 100 researchers from about 30 institutions, and has an overall budget of 5,5 Million Euro of which 1,6 Millions are assigned to the Unit "Programming and Modelling Languages".

In 1999 and 2000 the unit has received 14000 Euro from the BFHZ-CCUFB (http://www.ccufb.uni-muenchen.de/accueil.html) (Bayerisch-Französisch Hochschulzentrum - Centre de Coopération Universitaire Franco-Bavarois) for joint research activities with colleagues from France.

2.4.5 Literature

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2.5 Unit "Theoretical Computer Science"

Prof. Dr. Martin Hofmann, full professor

	1998	1999	2000	2001	2002	2003
Full professor(s):	1	1	1	1	1	1
Associate professor(s) :						
Research and teaching assistant(s) (*)	3	3	4	4	3	3
Research assistant(s) (without teaching duties) (**)			2	4	5	6

Research Staff

(*) "Wissenschaftlicher Mitarbeiter auf Landesstelle mit Lehrverpflichtung"
(**) "Wissenschaftlicher Mitarbeiter aud Drittmittelstelle oder mit Promotions- oder Postdoc-Stipendium ohne Lehrverpflichtung"

This report covers the period from **September 2001** because the chair holder, Professor Martin Hofmann took up his position only then. Publications of those current members who have been employed before September 2001 are included as are publications of Martin Hofmann in case they are of importance for the current activities of the unit.

The former chair Peter Clote is now full professor of biology at Boston College, the former assistant Thorsten Altenkirch is lecturer in computer science at the University of Nottingham, and the former assistant Rolf Backofen is full professor for bioinformatics at the University of Jena.

Prizes: Martin Lange received the Best Student Paper Award at the 13th Int. Conference on Concurrency Theory in Brno, Czech Republic, for his paper "Local Model Checking Games for Fixed Point Logic with Chop" (2002). The program committee of the int. conference "Typed Lambda Calculi and Applications 2001" in Kraków, Poland, chaired by Samson Abramsky (University of Oxford), awarded Ralph Matthes with the prize for the "most promising paper, TLCA 2001".

2.5.1 Main Research Topics

- Complexity Theory
  - complexity of circuits and propositional proof systems
  - resource-free characterisations of complexity classes
- Type Theory and Lambda Calculi
  - programming with infinite datatypes (streams, reals, continuations, infinitely-branching trees)
  - higher-order syntax
- Computer-Aided Theorem Proving
  - semiautomatic tools for the verification of distributed algorithms (abstract model checking)
  - logics for object-oriented programming languages
- Declarative Programming

    - memory management in functional languages
    - resource prediction and certification
    - parallel functional programming
- Combinatorial Optimisation
    - scheduling
    - dynamic memory allocation

2.5.2 Projects

Apart from the research projects below, there are two important project involvements:

- The chair coordinates the Thematic Network "Applied Semantics II", contract no: IST-2001-38957 in the 5th Framework Program of the European Union, 2003-2005, involving 30 universities and research institutes as well as industrial partners.
- The SIGNAL project, co-funded by the European Commission and the "Bayerisches Staatsministerium für Wissenschaft, Forschung und Kunst", where teachers are qualified for the new major subject informatics in Bavarian gymnasiums. (It also finances the project by Jäger described below.)

2.5.2.1 Mobile Resource Guarantees

Contributing Researchers:	Martin Hofmann (contact person), Steffen Jost, Hans Wolfgang Loidl, Olha Shkaravska
Cooperations:	Cooperation with University of Edinburgh (project partners)
Research Grant:	Funding as project IST-2001-33149 (European Commission’s Fifth Framework Programme)

The project members are developing the foundations for guaranteeing bounded resource consumption of mobile code. The goal of this effort is to enhance the security of large-scale distributed systems by preventing third-party code from exhausting available resources. A proof-carrying-code infrastructure is used, where resource certificates are shipped together with mobile code. Key techniques used in this project are automated theorem proving (currently using Isabelle), for validating the resource certificates, and high-level type-systems [52,10,11], which extend classical types for functional languages with information on resource consumption.

2.5.2.2 Complexity of Propositional Proof Systems and Monotone Circuits

Contributing Researchers:	Jan Johannsen
Cooperations:	with University of Toronto (Alasdair Urquhart, Toniann Pitassi), Universitat Polytecnica de Catalunya (Albert Atserias, Maria Luisa Bonet, Juan Luis Esteban, Nicola Galesi)
Research Grant:	Funding as Independent Junior Research Group in the DFG Emmy-Noether-Programme, under grant no. Jo 291/2-1 and Jo 291/2-2, 10/1999-6/2003, employed: N.S. Narayanaswamy, Ulrich Rührmair

In this project the complexity of proof systems for classical propositional logic is studied. In particular we investigate the minimal lengths of proofs in refinements and extensions of the Resolution calculus. Lower bounds on the proof lengths in these systems imply runtime lower bounds for certain types of backtracking algorithms, e.g. for satisfiability testing. Another goal is to study the complexity of monotone boolean circuits, which can be a useful tool for the main project objective above. Publications: [50,39,19,20]

2.5.2.3 Implicit Characterisation of Computational Complexity Classes

Contributing Researchers:	Martin Hofmann (contact person), Jan Johannsen
Cooperations:	with LMU Department of Mathematics (Helmut Schwichtenberg, Klaus Aehlig), Universidade Nove de Lisboa (Isabel Oitavem), University of Ottawa (Phil Scott), Brandeis University (Harry Mairson), INRIA Nancy (Jean-Yves Marion)
Research Grant:	Partially funded by the EU working group Applied Semantics II, coordinated by Martin Hofmann.

The goal of this project is to find characterisations of computational complexity classes that do not rely on a specific model of computation and explicit resource bounds, but on more conceptual means, e.g. characterisations by type systems, programming languages or logical systems. Apart from insights into structure of complexity classes this has applications to resource certification of programs [10] and code optimisation, in particular of space usage [52]. Publications: [38,9,52,21,10,11,1]

2.5.2.4 Nested Datatypes

Contributing Researchers:	Andreas Abel, Ralph Matthes (contact person)
Cooperations:	with Tarmo Uustalu, Senior Researcher at Tallinn Technical University, Estonia
Research Grant:	Partially funded by the EU working group "TYPES", project no. 29001 in IST programme, and by the "Graduiertenkolleg Logik in der Informatik" of TU and LMU.

Nested datatypes, as introduced by Bird (Oxford) and his coworkers, can be understood semantically as initial algebras of endofunctors on a functor category. In this framework, notions of substitution for very general data structures can be represented [15]. The project is mainly concerned with a programming language approach: For higher-order typed lambda calculi, schemes of iteration and primitive recursion for inductively defined families of datatypes are identified and the programs expressible in these formalisms proven terminating, also for infinite datatypes. Typical examples are representations of terms involving binding such as lambda abstraction and explicit substitution operators. References: [42,13,14,15]

2.5.2.5 The Complexity of Program Logics

Contributing Researchers:	Jan Johannsen, Martin Lange

Verification of hardware or software systems is often done using logics that are interpreted over program behaviours, i.e. modal, temporal or dynamic logics, etc. Even though most of them are known since the ’70s or even earlier, there are still interesting fragments or variants of the standard logics with decision problems whose exact complexity bounds are still unknown. The aim of this research is to determine these bounds. Reference: [8]

2.5.2.6 Parallel Functional Programming

Contributing Researchers:	Hans-Wolfgang Loidl
Research Grant:	Funding as project ARC D/03/20257 of the DAAD with Philipps-University Marburg, Heriot-University Edinburgh, and St Andrews University.

The goal of parallel functional programming is to speed-up computations in functional languages by executing them on several processors in parallel. In contrast to conventional parallel languages, no detailed specification of the coordination between the parallel processes has to be given. It is only necessary to annotate those expressions in the program that might be evaluated in parallel, and a sophisticated runtime environment automatically manages the coordination and distribution of work and data. We have developed a parallel extension of Haskell98, called GpH (http://www.cee.hw.ac.uk/~dsg/gph/), and are studying program analyses and program development in this high-level parallel language [22], the efficient implementation of the runtime-environment on a range of parallel architectures [12,23] and extensions for mobile code [24].

2.5.2.7 Program Extraction from Proofs in Systems of (Co)inductive Definitions

Contributing Researchers:	Favio Miranda
Research Grant:	PhD project funded by DAAD and CONACYT (Mexico’s National Science and Technology Council)

This research is a chapter of the synthesis problem. In our case the specifications are given by formulas of a logical system of (co)inductive definitions which is an extension of second order logic with equality (AF2) whereas the programming language is a strongly normalising system of (co)inductive types which is an extension of the second order polymorphic lambda calculus. Using a realisability interpretation we can automatically transform the proof of the specification into a proof of the fact that the program realizes it and therefore additional program verification methods are not needed. The new contribution consists in extending the method to specifications that include inductive definitions like lists and trees and even co-inductive definitions like streams or infinite trees. The paper [26] reports early stages of this research.

2.5.2.8 CSCL (Computer Supported Cooperative Learning) in postgraduate professional education

Contributing Researchers:	Hans Dietmar Jäger
Research Grant:	PhD project funded by "Bayerisches Staatsministerium für Wissenschaft, Forschung und Kunst" within the SIGNAL project, see above

Today learning is rather a life-long process than a one-time task. In this regard media and PC competence is a key qualification. Keeping that in mind this project is about relating prerequisites of learners to their learning process in distance learning postgraduate professional education. We centre our main focus on media and PC competences in a virtual learning environment with extremely heterogeneous participants. Future work will deal with setting up a virtual learning environment with specific functions. A didactical, pedagogical and social concept will be made to support learners in a cooperative learning process. Main goal of this project is to observe the influence of deficits in handling new media and computers on learning progress and to map out a strategy to countervail this behaviour. Reference: [7]

2.5.2.9 Verification of Non-Regular Properties

Contributing Researchers:	Martin Lange
Cooperations:	Humboldt-University Berlin

Most logics used for verification purposes turn out to be embeddable into the Modal mu-Calculus, a modal fixpoint logic that is often said to be very expressive. However, due to a very important result by Janin/ Walukiewicz - Modal mu-Calculus is equi-expressive to the bisimulation invariant fragment of Monadic Second Order Logic - its expressive power is rather limited. All properties defined by formulas of the Modal mu-Calculus are regular in the language theoretic sense. Thus, it is not even possible to express that something behaves like a bounded stack. This research aims at logics beyond the Modal mu-Calculus and suitable model checking algorithms for them. Reference: [25]

2.5.2.10 Lambda Calculus and Classical Logic

Contributing Researchers:	Ralph Matthes
Cooperations:	with LMU Department of Mathematics (Helmut Schwichtenberg)

Typed lambda calculi are the notation systems of choice for proofs in intuitionistic natural deduction. Since classical logic can be embedded into intuitionistic logic, also the former can be studied by the operational techniques available for lambda calculi. The operational reading of classical logic is of deep interest in programming language theory as an idealised functional programming language with control. This project aims at novel termination proofs for programs in these language fragments (such as Parigot's lambda-mu-calculus) and tries to incorporate complex datatypes. An alternative technique to CPS translations has been discovered. References: [43, 5]

2.5.3 Conferences

Organised since September 2001:

- "Ein Bogen von der Beweistheorie zur Informatik", international colloquium in Munich, April 6, 2002, co-organized by Ralph Matthes
- "Typed Lambda Calculi and Applications", 6th International Conference, TLCA 2003, Valencia, Spain, June 10-12, 2003, with Martin Hofmann as PC chair and proceedings volume editor
- "Dependently Typed Programming", international seminar no.04381 at Schloss Dagstuhl, September 2004, co-organized by Martin Hofmann

2.5.4 Publications

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2. M. Lange, **Satisfiability and completeness of converse-PDL replayed**, In Proc. 26th German Conf. on Artificial Intelligence, KI'03, volume ?? of LNAI, page ??, Hamburg, Germany, 2003. Springer. (to appear).
3. David Aspinall, Martin Hofmann, **Dependent Types**, In Benjamin C. Pierce, editor, Advanced Topics in Types and Programming Languages MIT Press, to appear 2004.
4. M. Escardó, Martin Hofmann and T. Streicher, **On the non-sequential nature of the interval-domain model of exact real-number computation**, To appear in Math. Struct. Comp. Sci.
5. Ralph Matthes, **Non-Strictly Positive Fixed-Points for Classical Natural Deduction**, accepted for publication in APAL, 2004.
6. Jan Johannsen, **Satisfiability problems complete for deterministic logarithmic space**, Accepted for the 21st International Symposium on Theoretical Aspects of Computer Science (STACS 2004), 2004.
7. H. D. Jäger, **Improving learning progress with learning technologies in postgraduate professional education with extreme heterogeneous participants**, For ED-MEDIA 2004-World Conference on Educational Multimedia, Hypermedia & Telecommunications, Lugano 2004.

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62. Martin Hofmann, **Semantics of linear/modal lambda calculus**, Journal of Functional Programming 9(3):247-277, 1999.
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64. Martin Hofmann, **Linear types and non size-increasing polynomial time computation**, In Logic in Computer Science (LICS), pages 464-476. IEEE, Computer Society Press, 1999.
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66. Ralph Matthes. **Extensions of System F by Iteration and Primitive Recursion on Monotone Inductive Types**, Doktorarbeit (PhD thesis), University of Munich, 1998.
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2.6 Unit "Media Informatics"

Prof. Dr. Heinrich Hußmann, full professor

	1998	1999	2000	2001	2002	2003
Full professor(s):						1
Associate professor(s) :						
Research and teaching assistant(s) (*)						4
Research assistant(s) (without teaching duties) (**)						1

Research Staff

(*) "Wissenschaftlicher Mitarbeiter auf Landesstelle mit Lehrverpflichtung"
(**) "Wissenschaftlicher Mitarbeiter aud Drittmittelstelle oder mit Promotions- oder Postdoc-Stipendium ohne Lehrverpflichtung"

2.6.1 Projects

2.6.1.1 Project: Media of the Future, Media++

In the project Media of the Future we investigate the use of new types of media and devices for presentation and interaction with information. In the course of the project we investigate commercially available products as well as technologies available in the research community and assess their applicability for specific application domains. The focus is on input and output devices for virtual and augmented reality, technologies for mobile multimedia applications, and physical user interface. Beyond that we investigate technologies and methods that can be used for implicit user interfaces; of particular interest are sensors for capture and ambient media for peripheral information provision. The evaluation of technologies lead to a laboratory setup where specific technologies can be tested and assessed in detail with regard to specific application domains and user’s needs. Examples of technologies that are available in the lab are an interactive whiteboard (Smart-Board), a 3D head-mounted display unit, data gloves for input, and prototypes of physical user interfaces (Smart-Its). This is complemented by software and development tools for these systems.

Contributing researchers: Heinrich Hußmann, Albrecht Schmidt, Arnd Vitzthum

2.6.1.2 Project: Software Models and Development Support for Multimedia Applications

Multimedia applications are widely used for presentations, learning systems, and teaching tools. Currently development support and authoring tools are tailored to very specific application domains. The development of complex interactive multimedia applications is inadequate. Model driven development, reusable components, and interface abstractions - standard practice in software engineering - are poorly supported. In this project it is investigated how methods and tools successfully used in software engineering can be applied to improve the development process of complex multimedia applications. We are interested how such applications are developed, especially the cooperation of designer and

software engineers is investigated. Existing development system for conventional software and authoring tools for multimedia applications have been studied and compared. These results are the basis for the development of new tools and methods for modelling and creating of multimedia applications.

Contributing researchers: Heinrich Hußmann, Andreas Pleuß

2.6.1.3 Project: Digital Media Production

In more and more domains the production of audiovisual media is done entirely based on digital technology. Images, Sounds, and Video are captured, recorded, communicated, and stored in digital form. Additional processing steps are also carried out digitally. The approach changes work processes and allows new forms of media production. In the project digital media production a concept for a research laboratory was created and currently the installation is on its way. The lab allows us to do investigate all steps that are involved in the process of digital media production. We investigate processes where video, animation, and 3D graphics merge. A further topic is digital audio production and distribution channels. We are especially interested in new models and data formats for digital radio and in particular Internet radio. Based on these technologies we investigate new approach and technologies for digital media production.

Contributing researchers: Heinrich Hußmann, Albrecht Schmidt, Siegfried Wagner

2.6.1.4 Project: Intermedia - UML modelling of business processes

The entire project is third party funded by the federal ministry of education and research (BMBF). Intermedia is an interdisciplinary project at the LMU and is part of the BMBF's program "Internet economy". Within Intermedia six research groups cooperate, namely Hußmann and Linnhoff from Computer Science, Picot and Hess from Business Studies, Brosius and Wirth from Communication Science. The overall objective of sub-project 4 - Intermedia - is model-based application development for information intermediaries (Modellbasierte Anwendungs-entwicklung für Informationsintermediäre). The aims of the project are the development of description language for business processes and supporting tools and infrastructure. The description language will be based on UML (Unified Modeling Language) and is designed to be appropriate for modelling complex business process on an abstract level. The language will be the basis for analysing business processes with regard to economic aspects. In the course of the project a prototypical reference implementation of an application that processes the description language will be designed and implemented. The main function of this application is to transform descriptions of business processes into executable programs. These generated programs will be web applications using HTML as mechanism for creating the user interface.

Contributing researchers: Heinrich Hußmann, Richard Atterer

2.6.2 Publications

2.6.2.1 Books

1. A.K. Dey, A. Schmidt, J. McCarthy(Eds.) **UbiComp 2003: Ubiquitous Computing; 5th International Conferenc**., Seattle, WA, USA, October 12-15, 2003, *Proceedings Series: Lecture Notes in Computer Science* , Vol. 2864 2003, XVII, ISBN: 3-540-20301-X

2.6.2.2 Journal Papers

2. T. Engel, H. Granzer, H. Hußmann, B. F. Koch, F. Ricciato, S. Salsano, P. Sampatakos, I. S. Venieris, M. Winter, **Adaptive Resource Control for QoS Using an IP-based Layered Architectur**. *IEEE Communication Magazine*, January 2003.
3. K. Van Laerhoven, N. Villar, A. Schmidt, H.-W. Gellersen, M. Håkansson, L. E. Holmquist. **In-Home Networking - Pin&Play: The Surface as Network Medium**. *IEEE Communications Magazine*, no. 4, April 2003
4. Florian Michahelles, Peter Matter, Albrecht Schmidt and Bernt Schiele. **Applying Wearable Sensors to Avalanche Rescue: First Experiences with a Novel Avalanche Beacon**. In *Computers & Graphics*, Vol. 27, No. 6, 2003.
5. N. Villar, H-W. Gellersen, A. Schmidt, G. Kortuem. **Interacting with Proactive Community Displays**. *In Computers & Graphics*, Vol. 27, No. 6, 2003

2.6.2.3 Conferences/Workshops

6. B. F. Koch, H. Hußmann. **Overview of the Project AQUIL**. (IST-1999-10077) *Architectures for Quality of Service in the Internet.* International Workshop (Art-QoS 2003) Warsaw, Poland, March 24-25, 2003 pp. 154 - 164
7. K. Van Laerhoven, N. Villar, A. Schmidt, G. Kortuem and H.-W. Gellersen. **Using an Autonomous Cube for Basic Navigation and Input**. In *Proceedings of ICMI/PUI 2003.* ISBN: 1-58113-621-8; ACM Press. Vancouver, Canada. 2003, pp. 203-211. PDF
8. F. Michahelles, P. Matter, A. Schmidt and B. Schiele. **Applying Wearable Sensors to Avalanche Rescue: First Experiences with a Novel Avalanche Beacon**. *Int. Workshop on Mobile Computing (IMC Workshop)*, Rostock, Germany, Juni 2003. (extended version in Computers & Graphics)
9. N. Villar, H-W. Gellersen, A. Schmidt, G. Kortuem. **Interacting with Proactive Community Displays**. *Int. Workshop on Mobile Computing (IMC Workshop)*, Rostock, Germany, Juni 2003. (extended version in *Computers & Graphics*)
10. N. Kern, B. Schiele, A. Schmidt. **Multi-Sensor Activity Context Detection for Wearable Computing**. In *European Symposium on Ambient Intelligence (EUSAI)*, Eindhoven, The Netherlands, 2003.
11. A. Schmidt, F. Siegemund, M. Beigl, S. Antifakos, F. Michahelles, and H. Gellersen. **Mobile Ad-hoc Communication Issues in Ubiquitous Computing: The Smart-Its Experimentation Platforms**. *Personal Wireless Communications. IFIP-TC6 8th International Conference*, PWC 2003 Venice, Italy, September 23-25, 2003. Proceedings. Springer LNCS Volume 2775/2003. September 2003, Venice, Italy. pp. 213 - 218

2.6.2.4 Posters/Demos

12. Poster: F. Michahelles, S. Antifakos, J. Boutellier, A. Schmidt and B. Schiele **Instructions immersed into the real world - How your Furniture can teach you**. In *The Fifth International Conference on Ubiquitous Computing (Ubicomp)*, Seattle, USA 2003
13. Demo: M. Beigl, A. Krohn, C. Decker, P. Robinson, T. Zimmer, H. Gellersen, A. Schmidt. **Context Nuggets: A Smart-Its Game**. *Ubicomp 2003*, Oct. 12-15, Seattle, USA

2.6.2.5 Community Involvement (Selection)

- A. Pleuß. Co-organizer of the *5th GPCE Young Researchers Workshop 2003*, in conjunction with Net.ObjectDays 2003 (NoDE 2003), September 2003, Erfurt, Germany
- A. Pleuß. Co-organizer of the Workshop *Correctness of Model-based Software Composition (CMC)*, European Conference on Object-Oriented Programming (ECOOP 2003), July 2003, Darmstadt, Germany
- H. Hußmann. Co-organizer of the Workshop *OCL 2.0 - Industry standard or scientific playground?*, 6th International Conference on the Unified Modeling Language (UML 2003), October 2003, San Francisco, Califormia, USA.
- A. Schmidt. Program co-chair of the *Fifth International Conference on Ubiquitous Computing (Ubicomp2003)*, October 2003, Seattle, Washington, USA.
- A. Schmidt. Co-organizer of the Workshops *Physical Interaction (PI03) - Workshop on Real World User Interfaces*, Fifth International Symposium on Human Computer Interaction with Mobile Devices and Services (Mobile HCI 2003), September 2003, Udine, Italy.
- A. Schmidt. Co-Organizer of the Tutorial *Physical and Tangible User Interfaces*, Mensch & Computer 2003 Conference, September 2003, Stuttgart, Germany.

2.7 Unit "Practical Computer Science and Bioinformatics"

Prof. Dr. Ralf Zimmer, Full Professor
Prof. Dr. Volker Heun, Associate Professor

	1998	1999	2000	2001	2002	2003
Full professor(s):				1	1	1
Associate professor(s) :						1
Research and teaching assistant(s) (*)				1	5	6
Research assistant(s) (without teaching duties) (**)						3

Research Staff

(*) "Wissenschaftlicher Mitarbeiter auf Landesstelle mit Lehrverpflichtung"
(**) "Wissenschaftlicher Mitarbeiter aud Drittmittelstelle oder mit Promotions- oder Postdoc-Stipendium ohne Lehrverpflichtung"

2.7.1 Research Activities

The unit "Practical Computer Science and Bioinformatics" started in the winter term 2001/2002 with Prof. Zimmer and one PhD student (Florian Sohler), Prof. Heun started in April 2003. Currently, the unit consists of three postdocs and six PhD students (plus additional three PhD students employed at the Fraunhofer Institute SCAI, Sankt Augustin). The activities concentrate on the establishment of the Bioinformatics Initiative Munich (BIM) and algorithmic aspects of bioinformatics. In computer science the unit focuses on areas relevant for bioinformatics applications:

- Algorithms and complexity
- Machine learning and statistical learning algorithms
- Discrete and combinatorial optimisation
- String and sequence analysis methods
- Graph and Petri Net modeling
- Probabilistic modeling, Bayesian Networks
- Text Analysis and Mining

Research Topics:

- Protein sequence and structure analysis, protein structure prediction, and structural genome analysis
- Expression data analysis and biochemical (metabolic and regulatory) networks
- Representation of biological knowledge and extraction from databases and scientific texts
- Genomics, Trancriptomics, Proteomics
- Cheminformatics, Molecule Design and Dynamics
- Clustering of Gene-Expression Data

- Combinatorial Models for Protein Structure Prediction
- Algorithmic Aspects of Genome Rearrangements
- Algorithms for Biological Networks

In all research topics scientists and students are funded via third party funding.

2.7.1.1 Protein sequence and structure analysis, protein structure prediction, structural genome analysis

Currently, work in this area is organised in two projects: DFG project PROSEQO and PSY. The goal of the DFG funded PROSEQO (Protein sequence structure optimisation, 2 years, 2 full time scientists and 2 students) within the DFG focus program "Verfahren zur Analyse großer genomischer Datenmengen" is the development of fast, accurate and flexible algorithms and software for protein structure prediction, i.e. the computation of the three dimensional structure models for genomic or amino acid sequences ("The second half of the genetic code"). The problems involved are hard from an algorithmic viewpoint (NP complete) and difficult with respect to modeling aspects (protein folding).

The project PROSEQO develops and implements heuristic combinatorial optimisation methods for protein structure prediction, determines good and efficiently computable bounds for structure prediction, exploits appropriate biological constraints, defines a formal language for the specification of such constraints (e.g. using a XML based markup language) and uses it in optimisation methods. The project constructs feature based views of the protein sequence structure space, works on multi-criteria clustering of sequences and structures at the same time and develops methods for classification and alignment of proteins based on various criteria and scoring functions. The effective and discriminative construction and evaluation of those criteria and scoring systems are also done in the project.

The project PSY (protein structure analysis) aims at integrating advanced students and student staff into a collaborative effort to implement a competitive protein structure prediction server. This involves the development of new methods and derived data resources, the exploitation of available programs, databases and web services, the intelligent combination of these methods, and the effective use of various supercomputer and workstation cluster computer facilities.

Related publications: [4, 5, 6, 7, 13, 15, 21, 22, 26, 27, 29, 30, 35, 36, 37, 52, 55, 56, 58, 60, 63, 64, 65, 66, 68, 69, 74, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 97, 99, 102, 104, 105, 106, 107]

Contributing researchers:	Dipl.-Inform. Alessandro Macri (since 08/2002), Dipl.-Inform. Jan Erik Gewehr (since 04/2003), Ralf Zimmer.
Collaborations and external PhD students:	FhI SCAI, Sankt Augustin, BioSolveIT GmbH, Sankt Augustin. Dipl.-Inform. Heinz-Theodor Mevissen (FhI), Dipl.-Inform. Daniel Hanisch (FhI), Dipl.-Math. Niklas von Öhsen (FhI). Dr. Ingolf Sommer (MPI Informatik, Saarbrücken).
Research grant:	DFG, two years, two full time researcher positions, two student positions
Thesis work:	Andreas Spitzmüller (ongoing)

2.7.1.2 Expression data analysis and biochemical networks, knowledge extraction

Within several projects funded by Aventis (BEX, two years, 2 full time scientists) and by the BMBF (BOA, 3 years, 2 scientists) new innovative methods for the analysis of expression data and of metabolic and regulatory networks are being developed. High throughput data obtained via DNA chips allow the genome wide measurement of cellular activities at the molecular level and thus, the comparison of different cell types, cell states and of normal/diseased tissue. In particular, graph and Petri net models and algorithms combine network analysis and statistical evaluation for the combined interpretation of expression data. Goal is the construction of disease models, the identification of new drug target molecules as starting points for new drug candidates, therapies and diagnostic means. Methods for mining metabolic and regulatory relationships from scientific texts and data extraction from appropriate databases are developed and used to generate large networks building the basis of new hypotheses concerning diseases and molecular mechanisms. The methods are applied for experimental data and measurements from several disease groups of the pharmaceutical company Aventis (Frankfurt). In addition, methods to design and equip new taylor-made DNA-chips.

The project BEX concentrates in this area on the development and implementation of new algorithms and tools. The project BOA focuses on the application and tuning of the methods as well as the development of new concepts for expression data analysis, in particular for osteoarthritis research. BOA provides bioinformatics analysis tools for and within the BMBF molecular medicine Leitprojekt "Therapie und Diagnose der Osteoarthrose" in collaboration with about 20 partners from pharmaceutical industry, Biotech companies, start-ups, research institutes and university hospitals for the analysis of expression data and networks of osteoarthritis. In the BEX and BOA projects two successful software tools have been developed: ProMiner and ToPNet. ProMiner allows for a sensitive and accurate search for gene and protein names in large scientific text bodies (such as the about 15 millions of PubMed abstracts) and to construct simple co-occurrence networks from the searches. ToPNet allows for visualisation and analysis of networks of various types, e.g. text mining co-occurrence networks, interaction networks derived from databases such as DIP or Swissprot, or detailed reaction or regulation networks as listed in specialised biochemical databases such as Transpath. In contains a broad range of interactive selection, visualisation, searching and analysis tools for such networks and associated annotations. Theses annotations can be all kinds of functional data, mappings to classifications and ontologies, or measurement data such as DNA-chip expression data or proteomics measurements. ToPNet uses a set of mapping files that facilitates the connections of the various network nodes, genes and proteins, and the annotations and measurements. A couple of new algorithms have been developed, published and integrated into ToPNet, which allow to identify interesting genes/proteins and pathways/subnetworks based on the network structure and the respective experimental data. These methods include pathway scoring, co-clustering (of network and expression data), significant area search, pathway queries, and clustering (of expression data). Thus, ToPNet allows for efficient and interactive interpretation of experimental data based of automatically and/or semi-automatically assembled contexts of biological knowledge.

Related publications: [1, 2, 3, 14, 23, 24, 25, 31, 32, 33, 34, 54, 57, 59, 74, 75, 76, 92, 93, 94, 95, 96, 97, 98, 103]

Contributing researchers:	Dr. Roger Abseher (04/2002 - 04/2003), Dipl.-Biotech. Katrin Fundel (since 04/2002), Dr. Robert Küffner (since 09/2003), M.Sc. (computer science), Florian Sohler (since 10/2001), Ralf Zimmer.
Collaborations and external PhD students:	Dipl.-Inform. Daniel Hanisch and Dipl.-Inform. Heinz-Theodor Mevissen, FhI SCAI (Sankt Augustin); Dr. Sabine Trochim, BioSolveIT GmbH (Sankt Augustin); Bioinformatics group Aventis Pharma GmbH (Frankfurt); Disease group DG Thrombosis & Degenerative Joint Diseases, Aventis Pharma GmbH (Frankfurt), GPC Biotech (Martinsried); BioSolveIT GmbH (Sankt Augustin); Fraunhofer Institut SCAI (Sankt Augustin); GSF München; BioTez Berlin; Invitek Berlin; University Erlangen; University Münster; University Mainz; University Frankfurt; Hospital Rummelsberg.
Research grant:	Aventis (BEX), Aventis+BMBF+FhI (BOA): three years, two (+ two) research positions, four student positions, Server (58 TEUR), software and travel funds.
Thesis work:	Cornelia Donner (8/2003 [14]), Caroline Friedel (8/2003 [23]), William Holton (11/2003 [54]), Simon Tietze (ongoing)

2.7.1.3 Genomics, Transkriptomics, Proteomics

The BMBF funded project ProBio/MAMS develops methods and bioinformatics tools for the construction and analysis of protein chips in co-operation with several universities, research institutes, as well as companies. The protein chips developed in the project are based on a innovative detection method for bound protein molecules via mass spectrometry and new binding mechanisms for these proteins via chip-attached RNA molecules (so called aptamers). The new chip will be applied to data from the application areas blood coagulation (U. Bonn) and viral infections (U. Cologne) for the identification of new targets and the validation of target candidates. The goal of the LMU project is the development of methods for the joint and combined analysis of networks, mRNA expression and protein expression data.

The PROBIO project is part of a larger BMBF funded project for the development of an aptamer based protein chip. Aptamers are short nucleic acid sequences that have been selected for their specific binding to a given (protein) target. The aim of PROBIO is to provide the bioinformatics support for finding suitable candidate target and perform the analysis of the results. A number of different research topics are being addressed within the scope of this project:

1. Protein Domain Prediction. Development of new methods for the identification of protein domains.
2. New methods for the analysis of protein expression. Crossreactivity and saturation of protein spots are expected to be two major problems limiting the quality of specific protein detection in chip based approaches. We are developing linear and non linear models to address this issue. Since at the time being the available data is very scarce, theoretical development is tested on artificial data produced via reasonable models.
3. Prediction of gene function from biological networks. The availability of different types of data sources makes it necessary to find ways to combine data of various type and quality. In the case where part of the data is limited precision it becomes necessary, to

either derive quantitative measures from qualitative data, or to abstract the quantitative measures into a binary information. We are addressing this issue in both ways and use success of gene function (process) prediction to evaluate the different approaches.

4. Text and information mining. We take a rather pragmatic approach to text mining, using simple methods for the identification of gene names in scientific texts and relying on manual analysis of the results. To this end we are developing a text mining browser that supports scientists in the analysis of hits from text mining and the optimisation of keyword and synonym lists. The text mining activity forms a part of a larger platform that aims at the flexible, efficient and accurate information retrieval for proteins and genes. The idea here is to build an extensible platform for formulating queries that can be answered by the best available methods on the world wide web.

Related publications: [8, 9, 10, 11, 12, 17, 18, 19, 20, 24, 25, 28, 32, 33, 51, 52, 53, 59, 60, 62, 67, 73, 76, 79, 80, 87, 88, 89, 97, 98, 99, 100, 101, 103]

Contributing researchers:	Dr. Joannis Apostolakis, Dr. Christoph Best, Dipl.-Biotech. Katrin Fundel, Ralf Zimmer
Collaborations and external PhD students:	Dipl.-Math. Niklas von Öhsen (FhI SCAI); Stiftung caesar, Bonn; FhI SCAI, Sankt Augustin; University Bonn, Institute for experimental hematology and transfusion medicine; University Cologne, Institute of Virology; Qiagen GmbH, Hilden; NascaCell AG, Tutzing; Bruker Daltronic GmbH, Bremen.
Research grant:	BMBF, FhI: three years, two (+ one) research positions, two student positions, Server (58 TEUR), software and travel funds.
Thesis work:	Thomas Obkircher (11/2003 [72]), Daniel Güttler (ongoing)

2.7.1.4 Cheminformatics, Molecule Design and Dynamics

Cheminformatics deals with theoretical models and computer science methods and to address problems and data obtained in chemistry applications. One problem is the prediction of binding free energies and optimisation of energy/scoring functions for the prediction of molecular structures and properties [11, 12, 67, 73]. A second interest is in developing machine learning methods for classification, regression and feature extraction [10, 51]. A third problem is the understanding and simulation of the dynamics of molecular and cellular processes. Work done on this topic involves the dynamics of Vancomycin, the analysis of co-operativity effects in binding and on protonation states. A major problem concerns protein folding: research is on the development and application of methods for calculating folding trajectories, conformational transitions and predicting protein structures of peptides and small proteins. [8, 9, 17, 18, 19, 20]

The DFG funded Template project (co-operation with MPI Saarbrücken and University of Düsseldorf) has as its main aim the development of methods for artificial receptor design. Artificial receptors are relatively low molecular weight molecules that nevertheless can bind a specific ligand with high affinity and specificity.

Future efforts will be focused on a simple theoretical framework for the analysis of gene expression and cellular gene expression dynamics. Chem- and bioinformatics methods and models will be combined to obtain novel insights into biological processes and find possible

applications in the field of drug design and biotechnology.

Related publications: [8, 9, 10, 11, 12, 17, 18, 19, 20, 28, 51, 62, 67, 71, 73, 97]

Contributing researchers:	Dr. Joannis Apostolakis,
Collaborations and external PhD students:	Dr. Philippe Ferrara, NIH; Dr. Andreas Kämper, MPI Saarbrücken; Prof. Dr. Christel Marian, University of Düsseldorf.
Research grant:	DFG, template project: two years, one researcher position

2.7.1.5 Combinatorial Models for Protein Structure Prediction

The prediction of the spatial structure of a protein is one of the most important open problems in molecular biology. For the standard combinatorial model (the so-called HP model proposed by Kenneth Dill), only a few simple approximation algorithms are known, which achieve poor approximation ratios and produce rather artificial conformations. To overcome the artificial predictions, different and more appropriate relaxed discretisation of the 3-dimensional space as well as the relaxation of the embedding constraints have to be studied.

In the 3-dimensional extended cubic lattice we proposed a general folding algorithm which achieves for all protein sequences an approximation ratio of 59/70. A more sophisticated folding algorithm which can be applied to a restricted subset of HP-sequences yields an approximation ratio of 37/42. Although it is difficult to compare the approximation ratios for protein structure prediction algorithms on different lattice models, it should be mentioned that this is the best known approximation ratio for such algorithms. On the other hand, this is the first time that folding algorithms for a ‘natural’ subclass of HP-sequences have been investigated. A strong indication that the considered subclass of HP-sequences is a ‘natural choice’ is the fact that more than 99.5% of all sequences in protein data base SWISS-PROT belong to the considered subclass. Finally, the running time of both approximation algorithms are linear.

Related Publications: [38, 39, 44, 45, 47, 48, 49, 50]

Contributing researchers:	Volker Heun, Dipl.-Inf. Johannes Fischer (since 10/03), Dipl.-Inf. Simon W. Ginzinger, M.Sc. (since 10/03)
Research grant:	DFG (BIM) 2+3 years.

2.7.1.6 Clustering of Gene-Expression Data

One step in the analysis of gene expression data is the clustering of co-expressed genes. Due to the large amount of generated data and due to the fact that the data are perturbed by noise, rigid mathematical models for the analysis as well as efficient algorithms are necessary to overcome the involved problems. We presented a sound mathematical model dealing with the large error rates and proposed two algorithms (one based on probabilistic methods, the other based on spectral graph theory) to solve the involved clustering problem efficiently. These algorithms recognise perturbed cluster structures assuming that the noise is identically and independently distributed. The algorithms are completely analysed and

experimental results on synthetic data as well as on real data demonstrate their capability to solve the clustering problem efficiently.

Related publications: [16]

Contributing researchers:	Volker Heun.
Collaborations:	Dr. Jens Ernst, Prof. Dr. Ernst W. Mayr, Dr. Ulrich Voll (Technische Universität München).

2.7.1.7 Algorithmic Aspects of Genome Rearrangements

An important algorithmic problem is to develop efficient genome comparison methods to find the minimum number of global mutation operations to transform one genome sequence into another and thereby characterising the evolutionary relationship between the corresponding organisms. This approach guarantees with a high degree of certainty that existing evolutionary relationships will be discovered.

This combinatorial problem is of particular interest to theoretical computer science because it has been shown to be NP-complete and therefore, in full generality, not solvable efficiently due its high inherent complexity. On the one hand this motivates the search for efficient approximation algorithms guaranteeing high quality results and short running times in real life experimental settings. And on the other hand it justifies attempts to achieve a reduction of complexity through modifications to the underlying formal model making the biological problem accessible to computer science.

We study the complexity of different versions of the genome rearrangement problem and evaluate existing formal models in terms of their computational feasibility - most of the questions arising in this context are currently open. In the same context we aim at designing new and realistic models which should still allow algorithmic solutions. The main focus, however, is on developing efficient combinatorial methods yielding either exact or approximate results with a high guaranteed approximation quality.

Contributing researchers:	Volker Heun, Dipl.-Inf. Johannes Fischer (since 10/03), Dipl.-Inf. Simon W. Ginzinger, M.Sc. (since 10/03)
Research grant:	DFG (BIM) 2+3 years,

2.7.1.8 Algorithms for Biological Networks

Visualisation of biological networks (e.g., metabolic or regulatory networks) is important for their better understanding. Such networks will usually be modeled with graph-theoretic concepts like Petri nets or attributed (hyper-)graphs. Due to the large amount of data, it is not useful to generate a single map representing it. Hence, algorithmic methods are needed for organising data in different layers representing different levels of abstraction. Therefore, on the one hand, methods are sought for structuring and partitioning graphs and their underlying data, and on the other hand, methods to reveal similarities within the same layer of abstraction as well as between different levels.

Provided suitable computational models of biochemical networks, our goal is to develop efficient algorithms to detect similarities for structuring given graphs as well as to find close relationships between parts of the given graph. Although this problem is in general NP-hart (subgraph isomorphism), the additional biological information stored as attributes at nodes and (hyper-)edges might be helpful to design efficient algorithms. On the other hand, specific models for graph similarity are required (like edit-distances) to quantify the similarity of graphs. Such models are useful if the induced similarity measures can be determined efficiently.

Another aspect is the investigation of fluxes or pathways within biochemical networks. Here we are interested in the decomposition of a given network or fluxes into fundamental ones under the constraints of involved products or enzymes. Such algorithms are required as a first step of analysing the function of a given biochemical network and to find possible alternative pathways of a given flux or to inhibit certain pathways.

Contributing researchers:	Volker Heun, Dipl.-Inf. Johannes Fischer (since 10/03), Dipl.-Inf. Simon W. Ginzinger, M.Sc. (since 10/03)
Collaborations:	Dipl.-Biol. Arno Buchner, Dr. Jens Ernst, Jan Griebsch, M.Sc., Prof. Dr. Ernst W. Mayr, Dipl.-Inf. Hanjo Täubig (Technische Universität München).

2.7.2 Education, Bioinformatics Initiative Munich (BIM)

The DFG and BMBF projects (BIM, 2+3 years, 1750 TEUR + 1750 TEUR) and BFAM (6 years, 1 full time scientist) fund the establishment of a bioinformatics centre and university programs within the Bioinformatics Initiative Munich, a joint venture of the LMU and TU Munich as well as the GSF research centre and the Max-Planck-Institute for Biochemistry. Overall, BIM funds four junior research groups consisting of one associate professor and two scientists each. The groups are associated with the respective faculties for computer science and biology at the two universities. In the BFAM project a goal is to establish a graduate program for graduates of either computer science/mathematics or biology/chemistry. Here graduates will study via an individual study plan to receive an additional bachelor degree in bioinformatics within three semester terms. At the research unit for practical computer science and bioinformatics, a junior research group (Associate professor Heun (Stiftungsprofessur) and two scientists) is funded via BIM for a five year period (2003-2008).

Related publications: [40, 41, 42, 43]

2.7.3 Conference Organization

Members of the Chair have been organisers of the following conferences: German Conference on Bioinformatics 2003 (http://www.gcb04.de/), GCB'03, October 12-14, 2003, Neuherberg-Garching. [70]

International Conference on Intelligent Systems in Molecular Biology 1999, ISMB'99, Heidelberg, August 8-12, 1999. [61]

2.7.3.1 International integration and co-operation

The unit participates in the organisation and program committees of the major national and international bioinformatics conferences (ISMB International Conference on Intelligent Systems in Molecular Biology; RECOMB International Conference on Computational Biology; GCB German Conference on Computational Biology; ECCB European Conference on Computational Biology) and presents papers at these highly competitive conferences. The unit performs several DFG, BMBF, and industry funded projects and co-operates with several other universities (Bonn, Cologne, Erlangen, Frankfurt, Hamburg, Mainz, Münster, Rummelsberg, Saarbrücken), research institutes (caesar, Bonn) and research centres (Fraunhofer society, institute SCAI, Sankt Augustin; DKFZ, Heidelberg; GBF, Braunschweig; and GSF, Neuherberg), Max-Planck-Institutes (MPI Informatics, Saarbrücken; MPI Biochemistry, Martinsried), large companies (Aventis, Frankfurt; Boehringer Ingelheim; Bayer Pharma, Wuppertal), medium (GPC AG, Martinsried; Medigene AG, Martinsried; Qiagen GmbH, Hilden; Bruker Daltronic, Bremen) as well as small start-up companies (BioTeZ GmbH, Berlin-Buch; Invitek, GmbH, Berlin; Nascacell AG, Tutzing, BioSolveIT GmbH, Sankt Augustin). Results of research projects are utilised and commercialized according to the BMBF rules via a bioinformatics start-up company BioSolveIT GmbH. Professor Zimmer co-founded BioSolveIT GmbH, Sankt Augustin, as a spin-off of the GMD/FhG in 2001. Currently, BioSolveIT has created 15 jobs, mostly for bioinformatics researchers at the postdoc level. In 2002, the unit has raised funds of about 1200 TEUR for employment and further qualification of ten scientists and ten students and for equipment (120 TEUR for a server/cluster computer). In addition, the Bioinformatics Initiative Munich is funded with about 3500 TEUR by the DFG.

Publications: [1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 15, 16, 17, 18, 19, 20, 21, 22, 25, 26, 28, 32, 33, 34, 35, 37, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 55, 57, 58, 59, 60, 61, 62, 63, 64, 67, 69, 70, 71, 73, 75, 76, 77, 78, 79, 80, 81, 82, 83, 85, 86, 88, 89, 91, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107]

Poster presentations: [6, 27, 36, 56, 68]

Dissertation Theses: [31, 38, 65, 84, 87, 92]

Bachelor and Master Theses: [13, 14, 23, 24, 26, 29, 30, 54, 66, 72, 74, 90]

University lecture notes: [41, 43]

2.7.4 Literature:

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3 Institute for Statistics

The research report for the institute for statistics is organized as follows:

- Research Profile [see page 168]
- Research Strategies [see page 169]
- Research Program and Activities [see page 170]
- Cooperations and Workshops [see page 188]
- References of Publications in the Department [see page 192]

3.1 Research Profile

- Core Competence: Development and application of statistical methods in economic, social and life sciences.
- Research at high international level based on interaction between substantive areas of applications and methodological innovations, and in cooperation with partners inside and outside the university.
- Providing subject competence for research partners from other disciplines within the university and from research institutions.
- Communication of research results through research monographs, publications in highly ranked international journals, organization of and participation in international workshops and conferences, editorial work as service to the scientific community.
- Knowledge transfer to the society through the Statistical Consulting Unit.
- Promotion of young scientists through incorporation in interdisciplinary projects.
- Establishing Munich as an international centre of statistics.

3.2 Research Strategies

3.2.1 Cooperation

- Within the Department:
  Formation of research clusters [see page 170] , Regular internal research seminars, Discussion paper series.
- Cross-departmental research and projects with academic collaborators [see page 188]
- Cooperation with partners in business, industry, and public or private institutions [see page 188])
- The Statistical Consulting Unit supports scientists of the LMU when applying statistical methods. This leads to an improvement of scientific work at the LMU and is a valuable input for new relevant methodological research questions in statistics. Many interdisciplinary projects at LMU were initiated by the Statistical Consulting Unit.
  Furthermore the Statistical Consulting Unit offers scientific assistance for industry, financial sector, research institutes and public authorities. Many projects of different size have been conducted leading to a considerable funding for the department of statistics. Credit scoring, determining effects of air pollution, costs of telecommunication, geophysical research, risk analysis for high speed trains were issues of major projects

3.2.2 Organization of Workshops and Meetings

Various workshops [see page 188] ranging from Semi- and nonparametric Modelling to Statistics in Genetics have been organized.

3.2.3 National and International Visitors

A large number of researchers have visited the department [see page 190] , various seminars have been given and research projects initiated.

3.2.4 Funding

Sum total third-party funds 1998- 2003

Sonderforschungsbereich 386 "Statistical Analysis of Discrete Structures"	**€**	**3.765.440,00**
Statistical Consulting Unit (1998-2002)	**€**	**546.808,51**
DFG-"Emmy-Noether" Fellowship 2000 - 2001	**€**	**70.000,00**
DFG-"Emmy-Noether" Research Group (2002-2003)	**€**	**380.000,00**
VW-Project (total volume DM 1.77 Mio.) in Munich since 2003	**€**	**597.515,00**

3.3 Research program and activities

Methodological research at the department is usually motivated and stimulated through demand and challenge in diverse fields of applications and empirical research. Vice versa, applied research in life, economic and social sciences is often based on our own development of adequate statistical methods or on related work of colleagues in our scientific community.

This interplay between methods and applications is reflected in the structure of research activities, and the following topics are of prime applied or methodological interest.

Statistical Modelling [see page 170]
Computational Statistics [see page 175]
Econometrics [see page 178]
Biostatistics [see page 181]
Statistics in business, economics and social sciences [see page 184]
Methodological Foundations of Statistics [see page 186]

These research clusters enhance the formation of groups of scientists cooperating within the department. Additionally, this structure stimulates joint scientific work and research seminars, and it aims at transcending traditional organizational borders.

The following sections provide an overview on research activities in these clusters. The clusters are partially overlapping, so some research results appear in more than one topic.

3.3.1 Statistical Modelling

Classical statistical models are generally useful in situations where data are approximately Gaussian and can be explained by some linear structure. Although easy to interpret and theoretically well understood, underlying assumptions are often too restrictive in situations where data are clearly non-Gaussian or have nonlinear structure. Driven by the demands in biological, economic and social sciences, and grown around generalized linear models, statistical modelling emerges as a broad and flexible extension of model-based statistical inference in more complex data situations, in particular with discrete and correlated data. Inference is mostly likelihood-based, including modern Bayesian approaches.

We roughly distinguish three major, overlapping subclusters: Semi- and nonparametric Regression (Likelihood-based Semiparametric Regression [see page 170] and Bayesian Semiparametric Regression [see page 171]), Deficient Data (Missing data [see page 172] and Measurement error models [see page 173]), Time-dependent and Spatial Data (Time-dependent and Spatial data [see page 174]).

3.3.1.1 Likelihood-based Semiparametric Regression

Principal investigators: Gerhard Tutz, Göran Kauermann

Semiparametrically structured regression models are defined as a class of models for which the predictors may contain parametric parts, additive parts with an unspecified functional form of covariates as well as interactions between variables which are described as varying coefficients. The approaches are extremely flexible in capturing the way in which the predictor influences the dependent variable. Research focuses on approaches which are

embedded into the framework of semiparametric generalized models, allowing for response variables which are given as count data or binary variables, or metrically scaled variables of various distributional form. Development of methods includes localizing approaches as well as penalized maximum likelihood methods.

Contributers:

Jochen Einbeck, Göran Kauermann, Helmut Küchenhoff, Torsten Scholz, Gerhard Tutz

Publications:

Dreesman and Tutz (2001), Edlich, Kauermann and Tutz (1998), Einbeck (2001), Einbeck (2003), Einbeck, de André and Singer (2002), Einbeck and Kauermann (2003), Galindo, Kauermann, Liang and Carroll (2000), Kauermann (2000), Kauermann (2002), Kauermann and Berger (2003), Kauermann and Carroll (2000), Kauermann and Opsomer (2001), Kauermann and Tutz (1999), Kauermann and Tutz (2000), Kauermann and Küchenhoff (2003), Kauermann and Tutz (2003), Simonoff and Tutz (1999), Tutz (2000), Tutz (2002a), Tutz (2002b), Tutz (2003a), Tutz (2003b), Tutz, Edlich and Bäumer (1999), Tutz and Kauermann (2003), Tutz and Scholz (2003a), Tutz and Scholz (2003b).

Funding:

SFB 386, Projekt C4 *Local adaptive statistical methods*

3.3.1.2 Bayesian Semiparametric Regression

Principal Investigators: Ludwig Fahrmeir, Stefan Lang

Bayesian approaches for non- and semiparametric regression models have recently gained much interest. They offer some advantages, in particular: choice of smoothing or tuning parameters are an integral part of the model, and extensions to more complex situations, such as longitudinal or spatial data, are conceptually easy. We distinguish between smoothness prior approaches as a stochastic generalization of penalized likelihood methods and adaptive basis function approaches. We have worked in both directions, but our current focus is on smoothness prior approaches. Inference is usually fully Bayesian using Markov chain Monte Carlo (MCMC) simulation. As an alternative, we developed empirical Bayes inference based on mixed model technology. To make the methods accessible for nonspecialists and to facilitate cooperation with applied researchers, we developed public-domain software, in particular BayesX, see Computational Statistics [see page 175] .

Contributors:

Clemes Biller, Andreas Brezger, Ludwig Fahrmeir, Alexander Jerak, Thomas Kneib, Stefan Lang.

Publications:

Biller (2000a, b); Fahrmeir (2001); Brezger (2003); Brezger and Lang (2003); Fahrmeir (1999); Fahrmeir and Lang (2001a, b); Fahrmeir and Tutz (2001), Fahrmeir and Mayer (2001), Jerak and Lang (2003); Klinger et al (2000); Klinger (2001); Lang and Brezger (2003); Lang, Adebayo and Fahrmeir (2002); Lang, Fronk and Fahrmeir (2002); Lang (2003).

Cooperation:

Our academic collaborators are Michel Denuit (Louvain), Stephan Klasen (LMU, VWL, and University of Göttingen), Dietmar Harhoff (LMU, BWL), Winfried. Steiner (University of Regensburg, Marketing), Kurt Ulm (TUM, IMSE).

Partners in the banking and insurance sector and in other institutions are Allianz Group (Munich), HypoVereinsbank (Munich), SCHUFA (Bonn).

Funding:

SFB 386, Project C1 “Semi- and nonparametric methods”, since 1995, Humboldt Foundation (Murray Smith).

3.3.1.3 Missing data

Principal investigators: Helge Toutenburg, Christian Heumann

In practical statistics investigators often are confronted with the problem of incomplete data sets. Therefore, statistics as a field of research has to develop empirical-analytical tools to deal with this problem. In the centre of research we consider the estimation and the prediction in models of regression type ander the complication of incomplete data. This concerns missing data problems for longitudinal- and cluster data as well as linear regression models with incomplete discrete and continuous covariates. The methods partially were implemented in the software tool MAREG & WinMAREG. Further research topics are semiparametric models with missing data, selection models with flexible modelling of the drop-out rate and generalized linear models with random effects and missing MNAR response. In non- and semiparametric regression model methods known from linear regression and the Nearest Neighbor Imputation were investigated. Marginal regression models, conditional models and random effects models are a possible adaption of Generalized Linear Models to dependent response and were also handled.

Contributors:

C. Kastner, S. Storck, T. Nittner, S. Scheid, N. Lieske, A. Dörfler, A. O. Adejumo (DAAD)

Publications:

Fahrmeir, Gieger and Heumann (1999), Fieger (2001), Heumann (1998), Kastner (2001), Nittner (2003), Rao, Srivastava and Toutenburg. (1998), Rao and Toutenburg (1998), Rao and Toutenburg (1999), Rao and Toutenburg (2001), Shalabh and Toutenburg (2003), Toutenburg (2002), Toutenburg (2002), Toutenburg, Fieger and Heumann (2000), Toutenburg, Fieger and Schaffrin (2002), Toutenburg, Fieger and Srivastava (1999) Toutenburg, Heumann, Nittner and Scheid (2002), Toutenburg and Shalabh (2000), Toutenburg and Shalabh (2001), Toutenburg and Shalabh (2002), Toutenburg and Shalabh (2003), Toutenburg and Srivastava (1998), Toutenburg and Trenkler (1998), Toutenburg and Nittner (2002), Toutenburg and Srivastava (2001), Toutenburg and Srivastava (2002), Toutenburg, Srivastava, Schaffrin and Heumann (2003), Ziegler, Blettner, Kastner and Chang-Claude (1998), Ziegler, Hebebrand, Kastner and Müller-Myhsok (1999), Ziegler, Kastner and Blettner (1998).

Cooperations:

Research cooperation depends on projects currently having problems with missing data. In the past these were, for example, the projects B6, B7, C1 and C4 of SFB 386.

Funding:

SFB 386 (C3 "Missing Data", 1995-2003), DAAD

3.3.1.4 Measurement error models

Principal investigators: Thomas Augustin, Helmut Küchenhoff, Hans Schneeweiß

A widespread problem in applying regression analysis is the presence of measurement error. Often the variables of interest cannot be observed directly or measured correctly, and one has to be satisfied with surrogates (often also named indicators or proxies). If one ignores the difference between the ideal variables in the model and their observable counterparts, and just plugs in the surrogates instead of the variables (‘naive estimation’), then all the estimators must be suspected to be severely biased. So the development of adjusted estimators is indispensable to avoid deceptive conclusions. These methods have received increasing attention especially in epidemiology and econometrics.

One focus of our research is survival analysis, where we, in particular, derived an exact corrected score function for the Cox model and a general unifying approach to deal with measurement error in parametric accelerated failure time models. Further research was concerned with the comparison of different approaches with regard to efficiency, the behavior of structural estimators under misspecification, and the search for robust (outlier resistant and Ridge type) estimators. We also work on nonstandard measurement error problems in linear and nonlinear models, like rounding, heaping, complex error models, the superposition of Berkson and classical error, and deliberately contaminated data to guarantee anonymity.

We have applied the methods in nutritional epidemiology (influence of nutrition habits on cardiovascular disease), several radiation studies, micro-econometrics and sociology (unemployment duration data from the German Socio-Economic Panel) and dental medicine

Contributors:

A. Kukush, I. Langner, D. Rummel, M. Thamerus, R. Schwarz, G. Schuster, R. Wolf, T. Nittner.

Publications:

Augustin (2000); Augustin (2002c); Augustin (2002d); Augustin (2003a); Augustin, Döring and Rummel (2003); Augustin and Wolff (2003); Augustin and Schwarz (2002); Bender, Augustin and Blettner (2003); Cheng and Schneeweiss (1998); Cheng and Schneeweiß (2002); Cheng, Schneeweiß and Thamerus (2000); Heid, Gerken, Wellmann, Küchenhoff, Kreienbrock and Wichmann (2002); Heid, Schaffrath, Kreienbrock, Küchenhoff and Wichmann (2003); Küchenhoff, Bender, Langner and Lenz-Tönjes (2003); Kukush and Maschke (2003); Kukush, Schneeweiß and Wolf (2003); Kukush, Schneeweiß and Wolf (2001a); Kukush, Schneeweiss and Wolf, R. (2001b); Kukush, Schneeweiss and Wolf (2002); Schneeweiß (2003); Schneeweiß and Cheng (2003); Schneeweiß, Cheng and Wolf (2002); Schneeweiß and Nittner (2001); Shklyar and Schneeweiß (2002); Thamerus (1998); Thamerus (2003); Wolff and Augustin (2003);

Collaboration:

Ahmad Amar, John Komlos, Marco Sander (Institute of Economic History, University of Munich), A. Döring and H.-E. Wichmann, I. Heid, GSF–National Research Center for Environment and Health, Neuherberg), M. Blettner and R. Bender, School of Public Health, University of Bielefeld), Institut für Angewandte Wirtschaftsforschung, Tübingen, A. Kukush (Kiev), E. Lesaffre (Kath. University of Leuven), Chi-Lun Cheng (Academia Sinica, Taipei), Raymond Carroll (Texas A&M), Ori Davidov (Haifa, Israel).

Funding:

SFB 386, Project C2: "Mess- and Klassifikationsfehler mit diskreten Daten". Health Effects Institute (USA).

3.3.1.5 Time-dependent and Spatial data

Principal investigators: Ludwig Fahrmeir, Leonhard Held, Stefan Lang

In life and social sciences as well as in business and industry, the availability of data that carry temporal or spatial information is nearly exploding and creates an important and challenging topic of current international research where the Department contributes. Our methodological research is mainly motivated and driven by biostatistical [see page 181] and economic [see page 184] applications, in cooperation with partners from various fields. The focus is on models and methods for longitudinal data, in particular with discrete responses, for survival and event history data, and for spatial or spatio-temporal data. The complexity of realistic models for temporal and spatial data necessitates computer-intensive data analytic methods, thus strengthening the link to Computational Statistics [see page 175] .

Approaches with an emphasis on economic times series and longitudinal data, in particular for data from financial markets, are contained in Econometrics [see page 178] .

Contributors:

Clemens Biller, Ludwig Fahrmeir, Leonhard Held, Thomas Kneib, Stefan Lang, Andrea Hennerfeind, Leyre Osuna, Günter Raßer, Volker Schmid, Gerhard Tutz.

Publications:

Biller (2000c); Biller (2001); Dreesman and Tutz (2001); Fahrmeir, Gieger and Heumann (1999); Fahrmeir and Künstler (1999); Fahrmeir and Knorr-Held (2000); Fahrmeir and Hennerfeind (2003); Fahrmeir, Gössl and Hennerfeind (2002, 2003); Fahrmeir, Kneib and Lang (2003); Gehrmann et al. (2003); Gieger (1999); Hennerfeind, Brezger and Fahrmeir (2003); Kauermann and Tutz (2001); Knorr-Held (2000); Knorr-Held and Besag (1998); Knorr-Held and Raßer (2000); Lang and Brezger (2003); Schmid and Heald (2003); Tutz (2002); Tutz (2003b); Tutz and Binder (2002); Yassouridis et al. (1999).

Cooperations:

Dorothee Auer (MPI für Psychiatrie), Nicole Augustin (University of Glasgow), German Cancer Research Center (DKFZ, Heidelberg), Stephan Klasen (VWL, LMU und Universität Göttingen), Monica Musio (FDM, Freiburg), Albrecht Neiss (IMSE, TUM and Sylvia Lawry Center for Multiple Research); Michael Smith (University of Sydney, Australia); Kurt Ulm (IMSE, TUM).

Funding:

SFB 386, Project A5 „Spatial Statistics“ since 1998; Humboldt Foundation (Michael Smith); Graduiertenkolleg Angewandte Algorithmische Mathematik (TUM).

3.3.2 Computational Statistics

Computational statistics is a statistical science at the interplay between computer science and data analysis. The topic includes various state-of-the-art methods for statistical inference such as resampling methods (e.g. bootstrap and jackknife), Monte Carlo and Markov chain Monte Carlo (MCMC) methods, non- and semiparametric regression as well as methods for prognosis, classification and data mining.

3.3.2.1 Markov Chain Monte Carlo (MCMC)

Principal investigators: Leonhard Held, Stefan Lang

MCMC methodology provides enormous scope for realistic statistical modelling. Research at the department has focused on designing efficient MCMC algorithms for latent parameter in complex hierarchical models. In particular, methods for estimating latent Gaussian Markov random fields (GMRFs) and Bayesian P-Spline models have been developed, with strong emphasis on so-called block updating algorithms. Such algorithms have considerably improved convergence and mixing properties. Furthermore, methods based on auxilliary variables have been investigated, which allow for block-updating via Gibbs sampling in binary and multicategorical regression problems, in contrast to Metropolis-Hastings steps based on multivariate Taylor expansions. Finally, specific implementations of Bayesian partition models via reversible jump MCMC have been developed. The algorithms are basic building blocks for fully Bayesian inference in complex semiparametric models, see 3.1 “Statistical Modelling”.

Contributors:

Andreas Brezger, Ludwig Fahrmeir, Leonhard Held, Andrea Hennerfeind, Alexander Jerak, Stefan Lang, Leyre Osuna, Günter Raßer, Volker Schmid

Publications:

Brezger and Lang (2003); Fahrmeir and Lang (2001a); Fahrmeir and Lang (2001b); Fahrmeir and Hennerfeind (2003); Fahrmeir and Osuna (2003); Guidici, Knorr-Held and Rasser (2000); Held (2004); Hennerfeind, Brezger and Fahrmeir (2003); Holmes and Held (2003); Jerak and Lang (2002); Jerak and Lang (2003); Knorr-Held (1999); Knorr-Held and Raßer (2000); Knorr-Held and Rue (2002); Lang and Brezger (2003); Lang, Fronk and Fahrmeir (2002); Lang, Adebayo and Fahrmeir (2002); Lang, Adebayo, Fahrmeir and Steiner (2003); Schmid and Held (2003).

Cooperations:

Chris Holmes (Imperial College London), Havard Rue (Norwegian University of Science and Technology, Trondheim).

Funding:

SFB, project A5 “Spatial Statistics” and C1 “Non- and semiparametric Methods”, since 1995.

3.3.2.2 Statistical Computing and Software

Principal investigators: Christian Heumann, Leo Knüsel, Stefan Lang

Scientific statistical computing requires reliable statistical software. We test standard statistical software packages and point out possible errors so that these errors can be eliminated in future versions of the software. Great efforts have been taken to provide public domain software for the new statistical methodology developed at the department. The following statistical packages have been developed (among others):

Bamp (www.stat.uni-muenchen.de/~schmidt/bamp/ (http://www.stat.uni-muenchen.de/~schmidt/bamp/)): A program for Bayesian Age-Period-Cohort-Modelling and Prediction.

BayesX (www.stat.uni-muenchen.de/~lang/bayesx/bayesx.html (http://www.stat.uni-muenchen.de/~lang/bayesx/bayesx.html)): Software for Bayesian Inference. BayesX is able to estimate very complex semiparametric regression models with sutructured additive predictors in a Bayesian framework.

BDCD (www.stat.uni-muenchen.de/~rasser/bdcd/ (http://www.stat.uni-muenchen.de/~rasser/bdcd/)): A program for Bayesian Detection of Clusters and Discontinuities in Disease Maps. This command-line based program allows for the estimation of unknown relative risk parameters in a typical disease mapping setting.

BVCM (www.stat.uni-muenchen.de/sfb386/software/bvcm.html (http://www.stat.uni-muenchen.de/sfb386/software/bvcm.html)): A program for Bayesian Varying-Coefficient Models. The software estimates varying coefficient models in a Bayesian framework.

ELV (www.stat.uni-muenchen.de/~knuesel (http://www.stat.uni-muenchen.de/~knuesel)): Computation of elementary statistical distributions.

GENcon/GENbin: Programs for solving optimization problems characterized by real respectively binary values. Both software tools base on the concept of genetic algorithms and run on MATLAB6.

GraphFitI (www.stat.uni-muenchen.de/~blauth/GraphFitI/graphFitI.html (http://www.stat.uni-muenchen.de/~blauth/GraphFitI/graphFitI.html)): A program for model selection in graphical chain models (Graphical models Fitting Interactions). It is designed to fit a graphical model to a multivariate data set; it applies a data-driven selection strategy introduced by Cox and Wermuth.

Mareg/WinMareg (www.stat.uni-muenchen.de/~andreas/mareg/winmareg.html (http://www.stat.uni-muenchen.de/~andreas/mareg/winmareg.html)): A Program for computation of semiparametric (GEE1, GEE2) and likelihood based marginal models for longitudinal and clustered categorical data with treatment of missing values.

S-Plus Code for multicategorical penalized spline regression. Based on the P-Splines approach the software allows for nonparametric extensions of common models for nominal and ordinal responses.

For further software projects see the section about Statistical Genetics and Bioinformatics [see page 182] .

Contributors:

Christiane Belitz, Angelika Blauth, Clemens Biller, Andreas Brezger, Angelika Caputo, Vanessa Didelez, Eva-Maria Fronk, Leonhard Held, Andrea Hennerfeind, Manuela Hummel, Alexander Jerak, Stefanie Kessner, Thomas Kneib, Leo Knüsel, Petra Kragler, Rüdiger Krause, Stefan Lang, Leyre Osuna, Iris Pigeot, Günter Raßer, Evi Rainer, Volker Schmid, Torsten Scholz, Kurt Watzka.

Publications:

Biller (2000a, 2000b, 2000c); Blauth (2002); Blauth, Pigeot and Bry (2000); Brezger, Kneib and Lang (2003a, 2003b); Fahrmeir, Gieger and Heumann (1999); Fahrmeir, Kneib and Lang (2003); Fieger, Kastner and Heumann (1998); Heumann (1998, 2000, 2003); Heumann, Fieger and Kastner (1998); Kastner, Fieger and Heumann (1999); Knorr-Held and Rainer (2001); Knorr-Held and Raßer (2000); Knüsel (2001, 2002, 2003a, 20003b); Krause and Tutz (2003a); Toutenburg, Fieger and Heumann (1998, 1999); Toutenburg et al. (2002, 2003); Trevisani et al. (1999); Tutz and Scholz (2003a).

3.3.2.3 Multivariate Methods and Statistical Data Mining

Principal investigator: Gerhard Tutz

Multivariate statistical analysis is concerned with data that consist of sets of measurements on a number of individuals or objects. The basis is the analysis of dependence between variables, between sets of variables and between variables and sets of variables. The investigation of the structure of variables is used in prognosis and classification and for the detection of similarity of objects. Methods are often based on computer intensive methods as boosting or bootstrapping, genetic algorithms and tree-based methods. In high dimensional statistical analysis problems of dimension reduction prevail. Strongly related to multivariate methods is statistical data mining which is the process of selecting, exploring, modifying and modelling large sets of data by statistical methods to uncover previous unknown patterns. Bump hunting has been explored as a new tool of statistical data mining for analyzing risks in finance and survival analyis.

Contributors:

Anne-Laure Boulesteix, Jochen Einbeck, Rüdiger Krause, Ludwig Fahrmeir, Klaus Hechenbichler

Publications:

Becker and Fahrmeir (2000, 2001), Boulesteix and Tutz (2003), Einbeck (2003), Einbeck and Kauermann (2003), Einbeck, Tutz and Evers (2003), Friedl and Kauermann (1999), Galindo, Kauermann, Liang and Carroll (2000), Kauermann and Opsomer (2001), Krause and Tutz (2003a,b), Spieß and Tutz (2003), Tutz and Binder (2003), Tutz and Evers (2003), Tutz and Hechenbichler (2003).

Cooperations:

Deutsches Institut für Wirtschaftsforschung (Berlin).

Funding:

SFB 386, Projekt C4 *Local adaptive statistical methods*

3.3.2.4 Resampling Methods and Graphical Modelling

Principal investigator: Iris Pigeot-Kübler

Graphical models are a useful tool for modelling complex high-dimensional association. The group has developed theoretical and computational tools in order to apply graphical models in a wide area of applications. Furthermore, extensive research has been done in applying resampling methods in the area of bioaquivalence and non-inferiority trials.

Contributors:

Angelika Blauth, Angelika Caputo, Vanessa Didelez, Eva-Maria Fronk, Astrid Heinicke, Iris Pigeot-Kübler, Kurt Watzka, Astrid Zierer

Publications:

Blauth, Pigeot and Bry (2000); Caputo, Foraita, Klasen and Pigeot (2003a); Caputo, Heinicke and Pigeot (1999); Didelez (2002, 2003); Didelez and Pigeot (1998); Didelez, Pigeot, Dean and Wister (2002); Fried and Didelez (2003); Lang, Fronk and Fahrmeir (2001); Pigeot, Heinicke, Caputo and Brüderl (2000); Shao, Kübler and Pigeot (2000).

Funding:

SFB 386, Project B5

3.3.3 Econometrics

Econometrics combines economic theory with techniques from statistics and mathematics to model economic and financial systems. Econometric models help to better understand the economic processes we observe and, thus, to improve the design of economic systems. Specifically, econometric models play an important role in testing economic theories, in predicting future economic developments and in supporting economic policy making. The department’s research activities focus particularly on econometric methods, financial econometrics, time series analysis, empirical macroeconomics, and empirical industrial economics.

3.3.3.1 Econometric Methods

Principal investigators: Stefan Mittnik, Hans Schneeweiß

The department’s research in the area of econometric methods covers a range of issues pertaining to estimation, testing and economic decision making. Among others, it includes the analysis of regression models in the presence of heavy-tailed disturbances, testing for the presence of structural breaks, and the detection of outliers.

Contributor:

Erich-Otto Maschke

Publications:

Schneeweiß, H., Maschke, E.-O., Pfannes, M. (2001); Klebanov et al. (2000); Mittnik, S., Rachev, S.T. (2000); Mittnik, S., Paulauskas, V., Rachev, S.T. (2001); Mittnik, S., Rachev, S.T., Samorodnitsky, G. (2001); Klein, I., Mittnik, S. (2002); Mittnik, S., Rachev, S.T., Samorodnitsky, G. (2000); Mittnik, S., Rachev, S.T. (2001).

3.3.3.2 Financial Econometrics

Principal investigator: Stefan Mittnik

Compared to other economic data, financial data often behave very differently. Specifically, they can be characterized by heavy tails (i.e., extreme price movements are more likely than the normal distribution implies) and, although practically uncorrelated over time, can exhibit strong temporal depencencies in higher moments, such as found in volatility. These properties prevent the use of most “standard” techniques developed in statistics and econometrics for a wide range of questions in empirical finance. The department’s research in this area is concerned with both methodological developments as well as practical applications, such as the prediction of financial risk, the examination of market efficiency, portfolio optimization, and modeling energy markets.

Contributors:

Toker Doganoglu, Markus Haas, Christoph Hartz, Christian Pigorsch, Corinna Prange

Publications:

Claessen, H., Mittnik, S. (2002); Doganoglu, T. Mittnik, S. (2003); Haas, M., Mittnik, S., Paolella, M.S. (2002); Haas, M., Mittnik, S., Paolella, M.S. (2003); Hartz, C., Mittnik, S., Paolella, M. (2003a); Hartz, C., Mittnik, S., Paolella, M. (2003b); Küster, K., Mittnik, S., Paolella, M. (2003); Mittnik, S., Paolella, M.S. (2000); Mittnik, S., Paolella, M.S., Rachev, S.T. (2000); Mittnik, S., Rachev, S.T. (2000); Mittnik, S., Rieken, S. (2000); Mittnik, S., Rieken, S. (2000); Mittnik, S, Rachev, S.T., Samorodnitsky, G. (2001); Mittnik, S., Paolella, M.S., Rachev, S.T. (2002); Mittnik, S, Rachev, S., Schwartz, E. (2002); Mittnik, S., Paolella, M.S. (2003); Hübler, O., Mittnik, S., Schmid, W. (2002); Mittnik, S. (2001); Mittnik, S., Rachev, S.T. (2001); Mittnik, S., Rachev, S.T. (2002); Pigorsch, C. (2003); Prange, C. (2003a); Prange, C. (2003b)

Cooperations:

Svetlozar Rachev (University of Karlsruhe and University of California – Santa Barbara), Genady Samorodnitsky (Cornell University), Marc Paolella (University of Zurich), Francis X. Diebold (University of Pennsylvania), Eduardo Schwartz (University of California – Los Angeles).

Institutional Cooperations:

Center for Financial Studies, Frankfurt; Institut für Quantitative Finanzanalyse GmbH, Kiel; HSH Nordbank, Hamburg and Kiel.

3.3.3.3 Time Series Analysis

Principal investigator: Stefan Mittnik

The research in time series analysis addresses both, theoretical and applied issues. In addition to economic and financial applications, there are contributions in the area of medical psychology.

Contributors:

Markus Haas, Christoph Hartz

Publications:

Haas, M., Mittnik, S., Paolella, M.S. (2002); Haas, M., Mittnik, S., Paolella, M.S. (2003); Hartz, C., Mittnik, S., Paolella, M. (2003a); Mittnik, S., Paolella, M.S., Rachev, S.T. (2003); Schubert Ch. et al. (2001); Mittnik, S., Rachev, S.T., Samorodnitsky, G. (2000); Schubert, Ch. et al. (2003).

Cooperations:

Christian Schubert (University Hospital, Innsbruck), Marc Paolella (University of Zurich), Svetlozar Rachev (University of Karlsruhe and University of California – Santa Barbara), Peter Zadrozny (Bureau of Labor Statistics, Washington, D.C.).

3.3.3.4 Empirical Macroeconomics

Principal investigator: Stefan Mittnik

The research in empirical macroeconomics investigates the interaction of the financial sector and the real sector of an economy. A second field of investigation concerns questions in public economics. Here, we analyze the effect public spending, specifically public consumption versus public investment has an long term economic growth.

Publications:

Chiarella, C. et al. (2002); Mittnik, S., Neumann, T. (2001); Mittnik, S., Neumann, T. (2003).

Cooperations:

Thorsten Neumann (Deka Bank, Frankfurt), Willi Semmler (University of Bielefeld and New School, New York), Peter Zadrozny (Bureau of Labor Statistics, Washington, D.C.).

Institutional Cooperation:

ifo Institute for Economic Research, Munich.

3.3.3.5 Empirical Industrial Economics

Principal investigator: Toker Doganoglu

In the last two decades, Industrial Economics have been going through an empirical revolution. Researchers have applied econometric techniques beyond hypothesis testing, and as a toolbox for measurement of important industry determinants. By means of structural

models, important unobservables such as demand elasticities and marginal costs can be measured. Furthermore, newly developed demand estimation techniques allow measurement of impact of policies on welfare and costs, thus econometric analysis has become a necessary step in antitrust and merger analysis. The group employs such techniques to analyze network industries, most notably telecommunications. The research is concentrated on estimating demand in a competitive telecommunications industry, using these to measure welfare impact of liberalization, and on measuring competitiveness of industries across Europe. Other research areas are internet auctions, network interconnection, research and development with network effects, and open source software development.

Contributors

Daniel Cerquera, Sascha Frohwerk, Lukasz Grzybowski, Kerstin Lange, Martin Reichuber, Katharina Sailer

Publications:

Doganoglu, T. (2002); Doganoglu, T. (2003); Sailer, K. (2001); Doganoglu, T., Sailer, K. (2003); Klodt, H. (2003); Sailer, K. (2001), Doganoglu, T. (2003a); Doganoglu, T.(2003b); Doganoglu, T., Wright, J. (2003); Doganoglu, T., Grzybowski, L. (2003); Grzybowski, L. (2003); Lange, K. (2002); Lange, K. (2003); Frohwerk, S. (2003).

Cooperations:

Institute for World Economics, Kiel

Funding:

Volkswagen Foundation.

3.3.4 Biostatistics

Biostatistics creates and applies methods for quantitative research in the health sciences. Common applications include clinical medicine, epidemiological studies, genetics, environmental health, ecology, forestry, and general biology. At the Department of Statistics at Munich University particular emphasis is placed on research related to epidemiology, genetics, and neuro science.

Research is often done in close collaboration with various national and international partners.

3.3.4.1 Statistical Methods in Epidemiology

Principal investigator: Leonhard Held

The group develops methodology for spatial and spatio-temporal, longitudinal, and survival data on chronic and infectious diseases. Recent work has focussed on the spatial and temporal analysis of cancer incidence and mortality. Furthermore, problems in infectious disease epidemiology of animals and humans are being considered. Papers on these issues in journals like "Biometrics", "Biostatistics", "Statistics in Medicine" and "Applied Statistics" have led to international recognition of the group.

Contributors:

Leonhard Held, Michael Höhle, Mathias Hofmann, Argwings Otieno Ranyimbo, Volker Schmid.

Publications:

Carvalho and Knorr-Held (2003); Crook, Knorr-Held and Hemingway (2003); Diggle, Knorr-Held, Rowlingson, Su, Hawtin and Bryant (2003); Guidici, Knorr-Held and Raßer (2000); Hansell, Knorr-Held and Schmid (2002); Hansell (2003), Held, Natario, Fenton, Rue and Becker (2003);Höhle (2002); Höhle, Jørgensen and O'Neill (2003); Knorr-Held (2000, 2003); Knorr-Held and Becker (2000); Knorr-Held and Besag (1998); Knorr-Held and Best (2001); Knorr-Held and Rasser (2000); Knorr-Held, Raßer and Becker (2002); Knorr-Held and Rainer (2001); Knorr-Held and Richardson (2003); Natario and Knorr-Held (2003); Schmid and Held (2003); Staubach, Schmid, Knorr-Held and Ziller (2002).

Cooperations:

Our partners at research institutes and universities are Nikolaus Becker (German Cancer Research Center (DKFZ), Heidelberg), Robert-Koch-Institut (RKI), Berlin, Christoph Staubach (Department of Epidemiology at the Federal Research), Centre for Virus Diseases of Animals, Wusterhausen), Peter Diggle (Medical Statistics Group at Lancaster University), Nicky Best, Angela Crook, Anna Hansell, and Sylvia Richardson (Department of Epidemiology and Public Health at Imperial College London), Philip O'Neill (Nottingham University, Statistics Division), Marilia Sa Carvalho (National School of Public Health/FIOCRUZ, Rio de Janerio, Brasilien), Isabel Natario (University of Lisbon)

Funding:

SFB386, Project A5 "Spatial Statistics" (since 1995), B9 "Statistical Methods for Surveillance of Infectuous Diseases" (since 2003), DAAD (Argwings Otieno Ranyimbo).

3.3.4.2 Statistical Genetics and Bioinformatics

Principal investigator: Korbinian Strimmer
Contributors:

Anne-Laure Boulesteix, Gangolf Jobb, Rainer Opgen-Rhein, Juliane Schäfer, Korbinian Strimmer, Gerhard Tutz, Sofia Wichert.

Publications:

Paradis et al. (2003); Boulesteix et al. (2003); Wichert et al. (2003); Strimmer et al. (2003); Strimmer (2003); Schmidt et al. (2002); Strimmer and Rambaut (2002); Strimmer and Pybus (2001); Drummond and Strimmer (2001); Strimmer et al. (2001); Salemi et al. (2001); Strimmer and Moulton (2000).

Software:

The group actively develops a number of software package for the analysis of genetic data, that are freely available for download:

APE: R-package for statistical analyses in phylogenetics and evolution (http://cran.r-project.org/src/contrib/PACKAGES.html#ape (http://cran.r-project.org/src/contrib/PACKAGES.html#ape)).

GeneTS: R package for the analysis of microarray time series data (http://www.stat.uni-muenchen.de/~strimmer/genets/ (http://www.stat.uni-muenchen.de/~strimmer/genets/)).

TREE-PUZZLE: Program to infer phylogenetic trees from DNA sequences using a maximum-likelihood approach (http://www.tree-puzzle.de (http://www.tree-puzzle.de/)).

PAL: Java library for algorithms and methods used in molecular evolution, statistical genetics, and sequence analysis (http://www.cebl.auckland.ac.nz/pal-project/ (http://www.cebl.auckland.ac.nz/pal-project/)).

TREEFINDER: Java/C program for molecular phylogenetics (http://www.treefinder.de (http://www.treefinder.de/)).

The main interest of this group are statistical aspects of bioinformatics and computational biology. Current research focuses on the development of methods for analysing gene expression data and on probabilistic models for DNA sequence analysis.

Cooperations:

Local collaboration with experimental and theoretical groups, e.g. at the Center for Nanoscience CeNS/LMU, via the "Munich Systems Biology Forum" (http://www.sysbio-muenchen.de). International cooperation with the Bioinformatics Center (Birc) at the University of Aarhus, and the Biomedical Center of the University of Uppsala.

Funding:

DFG (Emmy Noether), SFB 386

3.3.4.3 Statistical Methods in Human Brain Research

Principal investigators: Ludwig Fahrmeir in cooperation with Dorothee Auer (MPI for psychiatry)

An important area of substantive research in neuroscience is functional neuroanatomy of the human brain. Brain mapping aims at detecting areas of functional activities, for example the visual cortex, based on functional magnetic resonance imaging (fMRI) data. Compared to conventional methods of “statistical parametric mapping” (SPM), we develop and apply modern Bayesian techniques for modelling and analysing these massive spatio-temporal fMRI data. More recently, functional connectivity, that is detection and tracking of fiber bundles connecting functional areas, based on diffusion tensor imaging (DTI) data, has gained much interest. Because of the structure of fMRI and DTI data, statistical methods in human brain research are strongly related to the research cluster.

Contributors:

Dorothee Auer, Ludwig Fahrmeir, Christoff Gössl, Susanne Heim

Publications:

Auer et al. (2001); Fahrmeir and Gössl (2002); Gössl, Auer and Fahrmeir (2000); Gössl and Fahrmeir (2001); Gössl, Auer and Fahrmeir (2001); Gössl, Fahrmeir and Auer (2001); Fahrmeir, Gössl and Hennerfeind (2002); Gössl (2002); Gössl et al. (2002); Smith et al. (2003); Fahrmeir, Gössl and Hennerfeind (2003).

Cooperations:

Klaus Hahn, Gerhard Winkler (GSF), Mike Smith (University of Sydney, Australia)

Funding:

SFB 386, Project A5 “Spatial Statistics”, since 1998.

3.3.5 Statistics in business, economics and social sciences

This research cluster comprises primarily applied research and empirical analyses, with an emphasis on tackling and solving substantive problems in business, economics and social science. Topics cover a broad field of applications, ranging from marketing research, industrial economics, risk management for banks and insurance companies, socio-economic development, labour market analyses, official statistics and demography to empirical sociology and psychology. Financial econometrics is subsumed in the cluster Econometrics [see page 178] .

Research is often carried out in joint work with partners from universities and research institutions, or in cooperation with partners in business and industry. Research questions also emerge from consulting cases handled by the Statistical Consulting Unit. The focus is on solving substantive research questions with state-of-the-art methods developed within the department or in related work.

3.3.5.1 Business and Economics Statistics

Principal investigators: Ludwig Fahrmeir, Stefan Lang

Empirical research and practical problems in business and economics confront scientists and practitioner with increasingly large and complex data sets, requiring modern statistical tools for adequate data analysis. Consulting cases and cooperation’s with partners inside and outside of the university initiate much of our methodological research, and – as an ultimate goal – result in interdisciplinary work and publications. Areas of current major interest are: risk analyses in the credit and actuarial sector, marketing research, labour market analyses, and public health as well as socio- economic problems in developing countries.

Contributors:

Samson Adebayo, Ludwig Fahrmeir, Alexander Jerak, Ngianga-Bakwin Kandala, Stefan Lang, Helmut Küchenhoff, Gerhard Tutz, Renata Eva Zambrzycka.

Publications:

Adebayo (2003, 2003a, b); Adebayo and Fahrmeir (2003), Bender, Fahrmeir and Lang (2002); Bender, Kohlmann and Lang (2003); Berger, Fahrmeir and Klasen (2002); Denuit and Lang (2003); Fahrmeir and Lang (2003a, b); Fahrmeir, Lang and Spies (2003); Fahrmeir, Lang, Wolff and Bender (2003); Frank (2000); Fahrmeir, Henking and Hülst (2003); Jerak and Wagner (2003); Kandala, Lang and Klasen (2002); Kandala et al. (2001); Kandala (2002), Kauermann and Tutz (2001), Lang et al. (2002), Lang and Sunder (2003), Payer and Küchenhoff (2003), Tutz (1998), Uehlein and Küchenhoff (2003).

Cooperations:

Our academic collaborators are Stephan Klasen (VWL, LMU and University of Göttingen, Dietmar Harhoff (BWL, LMU), Winfried Steiner (University of Regensburg), Michel Denuit (Université Louvain).

Partners in the banking and insurance sector and in other institutions are Stefan Bender (IAB, Nürnberg), Allianz (Munich), Hypo-Vereinsbank (Munich), Deutsche Bank (Frankfurt), Deutsche Telekom (Bonn), Deutsche Bahn (Munich), LV von 1871 (Munich), Oberfinanzdirektion (Hannover), SCHUFA (Bonn), System Analysis Dept. Riso National Laboratory (Roskilde/Denmark).

Funding:

SFB 386, Projects A5 “Spatial Statistics” and C1 “Non- and semiparametric Methods”, since 1998; DAAD; BMBF (starting in 2004); Klapproth-Stiftung.

3.3.5.2 Statistics in social and psychological fields

Principal investigator: Bernhard Rüger

There is an intensive participation of our department of statistics in empirical research on fields of social and psychological problems. Bernhard Rüger is a member and consultant of different research groups on this field: DPV (German psychoanalytical association), Sigmund Freud Institut Frankfurt and the group “children of world war II in Europe coming to age”: Within these cooperations new methods result in sampling design, hypotheses testing and cohorts analysing.

Publications:

Rüger (1998a); Kleindienst, Greil, Rüger and Möller (1999); Leuzinger-Bohleber, Stuhr, Rüger and Beutel (2000); Leuzinger-Bohleber, Stuhr, Beutel, Rüger and Kächele (2001); Leuzinger-Bohleber, Stuhr, Rüger and Beutel (2001a, b); Rüger (2001); Leuzinger-Bohleber, Stuhr, Rüger and Beutel (2002); Rüger (2002a); Augustin and Wolff (2003); Wolff and Augustin (2003).

Contributor:

Thomas Augustin

Cooperations:

Marianne Leuzinger-Bohleber (SFI, Frankfurt), Hartmut Radebold (University Kassel), Elmar Brähler (University Leipzig), Gereon Heuft (University Münster), Andreas Kruse (DZFA, Heidelberg), Sozialwissenschaftliches Institut, SIM-ISW (Munich).

3.3.6 Methodological Foundations of Statistics

In order to derive results of relevance and reliable conclusions, statistics and probability indispensably requires rigorous and steady reflection on its methodological foundations. Two subclusters of vivid research at the department can be distinguished: Foundations of Statistical Inference, and Interval Probability .

3.3.6.1 Foundations of Statistical Inference

Principal investigators: Bernhard Rüger, Christina Schneider

“Foundations of Statistical Inference” or “Foundations of Probability” usually have a twofold connotation: One connotation points to the task of elucidating, enhancing and formulating the mathematical background of the methods in question. The other points to what may be called the conceptual background and paradigms prevalent in various interpretations of probability. Foundational questions of the second sort arise at the borderline of Statistics, Probability Theory, Philosophy, and Philosophy of Science. There are several – partially conflicting – paradigms how to learn from a sample about the population, i.e. how to make statistical inference. Currently, research in that field is centered around testing statistical hypotheses, statistical estimation theory and modelling genuinely indeterministic frames. Developments in Philosophy of Science contribute to the understanding of probability and inference.

Contributors:

Thomas Augustin, Kurt Weichselberger

Publications:

Augustin (1998); Augustin (1999a); Augustin (1999b); Augustin (2002a); Pöhlmann and Augustin (2001); Rüger (1998); Rüger (1999); Rüger (2002); Wassmer and Rüger (1998); Weichselberger und Augustin (1998a)

3.3.6.2 Interval probability

Principal investigators: Thomas Augustin, Kurt Weichselberger

The research group has been devoted to the development of the theory of interval-probability since more than ten years. This theory constitutes a consistent reaction to the methodological debate of the last decades concerning the appropriate description of uncertainty in those situations where the traditional “classical” theory of probability proves to be not suitable - especially because it is not possible to characterize the events by precise numbers distinguishing the respective component of probability. The theory of interval-probability represents a comprehensive generalization of the classical theory, as determined by Kolmogorov’s axioms, conceived to be interpretation-independent. It constitutes a system of axioms and definitions producing statements of the same fundamental rigour as the classical theory – but with a much wider area of application. Therefore it promises to be advantageous in all discipline employing descriptions of uncertainty, especially in economics – e.g. risk analysis and insurance – , in social sciences, in medicine and other empirical fields. Beyond foundations of the theory of interval-probability, its application to statistical inference, to decision theory and to robust statistics may be emphasized as prominent subjects of engagement for the research group.

Contributors:

Anton Wallner, Bernhard Rüger

Publications:

Augustin (1998); Augustin (1999a); Augustin (1999b); Augustin (1999d); Augustin (2001); Augustin (2002a); Augustin (2002b); Augustin (2003b); Augustin (2003c); Augustin (2003d); Augustin and Coolen (2003); Augustin and Pöhlmann (2003); Rüger (2002), Utkin and Augustin (2003a); Utkin and Augustin (2003b); Wallner (2002); Wallner (2003a); Wallner (2003b); Weichselberger (2000); Weichselberger (2001); Weichselberger (2002); Weichselberger and Augustin (1998b); Weichselberger and Augustin (2003).

Cooperations:

Our academic collaborators are Frank Coolen, Dept. of Mathematical Sciences, University of Durham (England); Gert de Cooman, SYSTeMS Research Group, Ghent University (Belgium); Renato Pelassoni and Paolo Vicig, Dept. of Applied Mathematics, Faculty of Economics, University of Trieste (Italy); Lev Utkin, Depts. of Computer Sciences and Mathematical Modeling in Economics, St. Petersburg Forest Technical State Academy (Russia).

Partners in the banking and insurance sector and in other institutions are Martin Gümbel, izb-software (computing center of the Sparkassen bank), Munich; Igor Kozine, System Analysis Dept. Riso National Laboratory, Roskilde (Denmark); Sigrid Pöhlmann, LV von 1871 (insurance company), Munich.

Funding:

From July 1999 to June 2000: Anton Wallner as reseach assistant by DFG.

In 2001 the publication of the first volume of the book *Elementare Grundbegriffe einer allgemeineren Wahrscheinlichkeitstheorie* was supported by DFG.

Workshop *Recent Developments in the Theory and Application of Interval-Probability*, Munich, May 1st, 2002, partially sponsored by the DFG and from the NATO and London Mathematical society travel grants.

3.4 Cooperations and Workshops

3.4.1 Cross-departmental research and projects with academic collaborators

Academia Sinica, Taipei; Bioinformations Center, University of Aarhus; Biomedical Center, University of Uppsala; BWL, University of Munich; Bureau of Labour Statistics, Washington D.C.; Center of Nanoscience, University of Munich; Center of Virus Diseases of Animals, Wusterhausen; Cornell University; Davidov Ori, Haifa/Israel; Denuit Michel, Louvain; Department of Applied Mathematics, University of Trieste/Italy; Department of Computer Sciences and Mathematical Modelling in Economics, St. Petersburg Forest Technical State Academy/Russia;Department of Mathematical Science, University of Durham; Deutsches Institut für Wirtschaftsforschung, Berlin; German Cancer Research Center, Heidelberg; DZFA, Heidelberg; GSF-National Research Center for Environment and Health/Neuherberg; Imperial College, London; IMSE/TU Munich; Institut für Angewandte Wirtschaftsforschung, Tübingen; Institute of Economic History, University of Munich; Institute for World Economics, Kiel; Katholic University of Leuven; Kukush A., Kiev; Marketing, University of Regensburg; Max-Planck-Institute for psychatry, Munich; Medical Statistics Group, University of Lancaster; National School of Public Health, Rio de Janeiro/Brasilia; New School, New York; Norvegian University of Science and Technology, Trondheim; Nottingham University; Robert-Koch-Institute, Berlin; School of Public Health, Siegmund Freud Institute, Frankfurt; Sylvia Lawry Center for Multiple Research, Munich; Systems Research Group, Ghent University/Belgium; Texas A & M.; University of Bielefeld; University of Santa Barbara/California; University of Glasgow; University Hospital, Innsbruck; University of Kassel; University of Karlsruhe; University of Leipzig; University of Los Angeles/California; University of Lisbon; University of Munster; University of Pennsylvania; Universidade de Sao Paulo; University of Sidney/Australia; University of Zurich; VWL/University of Munich and University of Göttingen.

3.4.2 Cooperations with partners in business, industry and public or private institutions

Allianz Group (Munich), Center of Financial Studies (Frankfurt), Deka Bank (Frankfurt), Deutsche Bank (Frankfurt), Deutsche Telekom (Bonn), Deutsche Bahn (Munich), HSH Nordbank (Hamburg/Kiel), HypoVereinsbank (Munich), IAB (Nürnberg), ifo Institute for Economic Research (Munich), Institut für Quantitative Finanzanalyse GmbH (Kiel), izb-Software (Munich), Oberfinanzdirektion (Hannover); SCHUFA (Bonn).

3.4.3 Workshops and Meetings

Workshop „Models and Methods for Spatial and Spatio-Temporal Data“, 19. - 20. Oktober 1998

Marit Holden (Oslo); Mark Berliner (Columbus/Ohio); Nicola Best (London); Rainer Dahlhaus (Heidelberg); Arnoldo Frigessi (Oslo); Katja Ickstadt (North Carolina); Hans Künsch (Zürich); Diana Miglioretti (Maryland); Antonio Pievatolo (Mailand); Jörg Polzehl (Berlin); Vladimir Spokoiny (Berlin).

Workshop "Semi- and Nonparametric Modelling: Theory and Practice", 11. –12. Oktober 1999

Adrian Bowman (Glasgow); Leo Breiman (Berkeley); Raymond Carroll (Texas A&M); Holger Dette (Bochum); Wolfgang Härdle (Berlin); Robert Kohn (Sydney); Burkhard Seifert (Zürich); Sara van Geer (Leiden); Lue Ping Zhao (Seattle).

Workshop "Data Analysis with Graphical Models", 13. – 15. März 2000

Rainer Dahlhaus (Heidelberg); David Edwards (Kopenhagen); Ursula Gather (Dortmund); Zhi Geng (Peking); Paolo Giudici (Pavia); Niels Keiding (Kopenhagen); Masahiro Kuroda Kurasiki (Science and Art Tokio); Steffen Lauritzen (Aalborg); Thomas Richardson (Warwick); Nanny Wermuth (Mannheim).

Workshop "Statistics with Deficient Data", 13. –15. Juli 2000

Paul Biemer (North Carolina); Raymond A. Carroll (Texas A&M); Montezuma Dumangane (Bristol); Jouni Kuha (Penn State); Bani K. Malik (Texas A&M); Geert Molenberghs (Limburg); Joseph Schafer (Penn State); Burkhard Schaffrin (Columbus/Ohio); Chris Skinner (Southhampton); Silvelyn Zwanzig (Hamburg).

Euroworkshop „Statistical Modelling - Mixed Models“, 2. - 5. November 2000

Murray Aitkin (Newcastle); Dankmar Böhning, (Berlin); Jim Booth (Gainesville, Florida); David Clayton (Cambridge); Geert Molenberghs (Limburg) ; Geert Verbeke (Leuven)

Workshop „Recent Developments and Applications in the Statistical Analysis of Discrete Structures“, 11.-13. Oktober 2001

Paul Albert (Maryland), Per Kragh Andersen (Kopenhagen), Wiji Arampulam (Warwick), John Bailer (Miami), Luc Bauwens (Louvain), Peter Brockwell (Colorado), Phil Dawid (London), Vanessa Didelez (London), Jürgen Franke (Kaiserslautern), Sylvia Frühwirth-Schnatter (Wien), J.C. van Houwelingen (Leiden), Tony Morton-Jones (Manchester), John Petkau (Vancouver), Mike Smith (Sydney), Werner Vach (Odense), Jian-Feng Yao (Rennes).

Euroworkshop „Statistical Modelling - Nonparametric Models", 1.-4. November 2001

Adrian Bowman (Glasgow); Theo Gasser (Zürich); Peter Green (Bristol); Jim Ramsay (Canada); Matt Wand (Boston).

Workshop “Recent Developments in the Theory and Application of Internet Probability, May 1^{s} ,2002

F. Coolen (Durham), G. de Cooman (Ghent), F. Kozine (Roshilde, DK), H. Rieder (Bayreuth), M. Zaffalon (Lugano.

Workshop " Statistics in Genetics", 14.-16. August 2002

David Balding (London); Carsten Wiuf (Boston); Gesine Reinert (Oxford); Paul Eilers (Leiden); Arndt von Haeseler (Düsseldorf); Nuala Sheehan (Leicester); Chris Holmes (London); Michael Newton (Madison); Terry Speed (Berkeley).

Euroworkshop „Statistical Modelling - Model Building and Evaluation“, 31. Oktober - 2. November 2002

Anthony Davison (Swiss Federal Institute of Technology); Arnoldo Frigessi (Norwegian Computing Center); Jeffrey Hart (Texas A&M); Brian Ripley (Oxford); Antony Unwin (Augsburg).

Workshop " Stochastic volatility and risk management - temporal and spatial dependence ", 4.-6. Dezember 2002

Ole Barndorff-Nielsen (Aarhus); Peter Brockwell (Colorado); Petros Dellaportas (Athen); Joachim Grammig (St. Gallen); Friedrich Hubalek (Vienna); Jan Kallsen (Freiburg); Christoph Kühn (München); Stefan Mittnik (Kiel / München); Winfried Pohlmeier (Konstanz); Martin Schlather (Bayreuth); Neil Shephard (Oxford); Niklas Wagner (München).

Workshop " Statistical Modelling of Discrete Structures in Economics: Methods and Applications ", 30. Juni - 2. Juli 2003

Yasuo Amemiya (New York); Badi Baltagi (Texas); Steve Bond (Oxford); Peter Bühlmann (Zürich); Bernd Fitzenberger (Mannheim); Harald Hruschka (Regensburg); Hans-Joachim Lenz (Berlin); Costas Meghir (London); Germano Mwabu (Nairobi); Regina Riphahn (Basel); Gerd Ronning (Tübingen); Christoph Schmidt (Essen); Paul Schultz (Yale); Wilfried Seidel (Hamburg); Tom Wansbeek (Groningen); Rainer Winkelmann (Zürich).

3.4.4 National and International Visitors

1998

Aalen, O. (Oslo); Albert, P. (Maryland); Beibel, M. (Freiburg); Cheng, C. (Taipeh); Davies, L. (Essen); Edwards, D. (Kopenhagen); Fokianos, K. (Columbus/Ohio); Gemperli, A. (Bern); Heuer, C. (Heidelberg); Hruschka, H. (Regensburg); Lang, J. (Iowa); Nikitin, Y. (St. Petersburg); Rieder, H. (Bayreuth); Rödel, E. (Berlin); Santner, T. (Columbus/Ohio); Schaffrin, B. (Columbus/Ohio); Sheehan, N. (Loughborough); Smith, M. (Sydney); Spokoiny, V. (Berlin); Stasinopoulos, D. (London); Timmer, J. (Freiburg); Wellner, J. (Washington); Wolters, J. (Berlin); Ziegler, A. (Marburg).

1999

Berliner, M. (Columbus/Ohio); Briegel, T. und Tresp, V. (München); Fokianos, K. (Nikosia); Gamerman, D. (Rio de Janeiro); Gasmi, S. (Magdeburg); Gelfand, A. (Connecticut); Giudici, P. (Pavia); Hart, J. (Texas A&M); Hübner, U. und Herrmann, P. (Mannheim); Hujer, R. (Frankfurt); Keiding, N. (Kopenhagen); Kohn, R. (Sydney); Kukush, O. (Kiew); Mittag, H.-J. (Hagen); Müller, H.-G. (Berkeley); Pohlmeier, W. (Konstanz); Prigarin, S. (Novosibirsk); Rammelt, P. (Berlin); Richardson, S. (Villejuif, Frankreich); Santner, T.J. (Columbus/Ohio); Shalabh, (Chandigarh/Indien); Shao, J. (Wisconsin); Srivastava, V. (Lucknow/Indien); Stemann, D. (Hagen); Viertl, R. (Wien); Wermuth, N. (Mannheim); Zwanzig, S. (Hamburg).

2000

Booth, J. (Gainsville, Florida); Cressie, N. (Columbus/Ohio); Friedl, H. (Graz); Frühwirth-S. S. (Wien); Hobart, J. (Florida, Gainsville); Marx, B. (Baton Rouge); Müller, P. (North Carolina); Opsomer, J. (Iowa); Rue, H. (Trondheim); Schaffrin, B. (Columbus/Ohio); Shalabh,

(Chandigarh/Indien); Wilrich, T. (Berlin).

2001

Bartels, R. (Sydney); Becker, C. (Dortmund); Brännäs, K. (Umea); Coolen, F. (Durham); Dannegger, F. (München); di Serio, C. (San Raffaele, Italien); Gelfand, A. (Connecticut/USA); Gerhard, F. Nuffield College, (Oxford); Göttlein, A. (München); Heikkinen, J. (Helsinki); Kauermann, G. (Glasgow); Knorr-Held, L. (London); Kukush, A. (Kiew); Smith, Michael, (Sydney); Smith, Murray, (Sydney); Odejar, M.A. (Los Banos, Philippines); Ranta, J. (Helsinki); Schaffrin, B. (Columbus/Ohio); Shafer, G. (Newark); Shklyar, S. (Kiew).

2002

Adebayo, S. (Ilorin, Nigeria); Augustin, N. (Freiburg); Musio, M. (Freiburg); Berger, U. (Glasgow); Coolen F. (Durham), Chung, C.F. (Taipeh); de Cooman, G. (Ghent); Fokianos, K. (Nikosia); Friedl, H. (Graz); Gamerman, D. (Rio de Janeiro); Gieger, C. (Heidelberg); Grammig, J. (St. Gallen); Hafner R. (München); Hart, J. (Texas A&M); Hipp, C. (Karlsruhe); Knorr-Held, L. (Lancaster); Kukush, A. (Kiew); van der Linde, A. (Bremen); Mira, A. (Varese/Italien); Muliere, P. (Mailand); Odejar, A. (Los Banos, Philippines); Schaffrin, B. (Columbus/Ohio); Shalabh, (Chandigarh/Indien); Smith, Mike, (Sydney); Utkin, L.V. (St. Petersburg), Zaffalon, M. (Lugano).

2003

Alonso, A. (Limburg); Belenkiy, S. (Rußland); Bender, R. (Bielefeld); Carroll, R. (Texas A&M); Cheng, C. (Taipeh); Coolen, F. (Durham); Davidov, O. (Haifa, Israel); Höhle, M. (Aalborg); Kauermann, G. (Bielefeld); Lenz-Tönjes, R. (Bielefeld); Mackerras, D. (Alice Springs, Australia); Mansmann, U. (Heidelberg); Marx, B. (Baton Rouge); Molenberghs, G. (Limburg); O'Neill, P. (Nottingham); Santner, T. (Columbus/Ohio); Seeber, G. (Innsbruck); Shalabh, (Chandigarh/Indien); Wood, S. (Glasgow); Vardeman, S. (Iowa State); Vontheim, R. (Tübingen); Zucchini, W. (Göttingen).

3.5 References of Publications in the Department

3.5.1 Books and Refereed Articles

Adebayo, S. (2003). *Semiparametric Bayesian Regression for Multivariate Responses*. Hieronymus, München.

Adebayo, S. (2003a). Bayesian Geoadditive Modelling of Breastfeeding Initiation in Nigeria. To appear in: *Journal of Applied Econometrics.*

Adebayo, S. (2003b). Modelling Childhood Malnutrition in Zambia: an Adaptive Bayesian Splines Approach. To appear in: *Statistical Methods and Applications, Journal of the Italian Statistical Society.*

Auer, D.P., Pütz, B., Gössl, C., Elbel, G-K., Gasser, Th., Dichgans M. (2000): Differential lesion pattern in CADASIL and spontaneous subcortical arteriosclerotic encephalopathy: a MRI study using statistical parametric group comparison. To appear in: *Radiology.*

Augustin, T. (1998): *Optimale Tests bei Intervallwahrscheinlichkeit.* Vandenhoeck und Ruprecht, Göttingen.

Augustin, T. (1999a): Globally least favorable pairs and Neyman-Pearson testing under interval probability. In: G. de Cooman, F.G. Cozman, S. Moral and P. Walley (eds.): *ISIPTA'99: Proceedings of the First International Symposium on Imprecise Probabilities and their Applications.* Gent, 15-24.

Augustin, T. (1999b): On data-based checking of hypotheses in the presence of uncertain knowledge. In: W. Gaul and H. Locarek-Junge, H. (eds.): *Classification in the Information Age.* Springer. Heidelberg, 127-135.

Augustin, T. (2001). On decision making under ambiguous prior and sampling information. In: G. de Cooman, T. Fine, S. Moral, T. Seidenfeld (eds.): *ISIPTA 01: Proceedings of the Second International Symposium on Imprecise Probabilities and their Applications*. Cornell University, Ithaca (N.Y.), Shaker, Maastricht, 9-16.

Augustin, T. (2002a). Neyman-Pearson testing under interval probability by globally least favorable pairs - Reviewing Huber-Strassen theory and extending it to general interval probability. *Journal of Statistical Planning and Inference* 105, 149-173.

Augustin, T. (2002b): Expected utility within a generalized concept of probability – A comprehensive framework for decision making under ambiguity. *Statistical Papers* 43, 5-22.

Augustin, T. (2002c): Some basic results on the extension of quasi-likelihood based measurement error correction to multivariate and flexible structural models. In: W. Gaul and G. Ritter (eds.): *Classification, Automation, and New Media.* Springer, Heidelberg, 29-36.

Augustin, T. (2003a). An exact corrected log-likelihood function for Cox's proportional hazards model. To appear in: *Scandinavian Journal of Statistics*.

Augustin, T. (2003b). On the suboptimality of robust Bayesian procedures from the decision theoretic point of view. To appear in: J.M. Bernard, T. Seidenfeld, M. Zaffalon (Hg.): *ISIPTA 03: Proceedings of the Third International Symposium on Imprecise Probabilities and their Applications*, Lugano. Carleton Scientific, Waterloo, 31-45.

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