Introduction

Highlights


A total of 44 journal papers, 1 book, 1 edited book, 9 chapters in books, and 36 refereed contributions to conference proceedings and 15 other professional publications were published. Especially productive were the Systems and Control group (prof. Curtain, dr. Trentelman, prof. Willems) with 9 journal papers and 10 contributions to conference proceedings and the Probability and Statistics group (prof. Dehling, dr. Mikosch, prof. Schaafsma) with 9 journal papers. The book “Modelling Extremal Events for Insurance and Finance” co-authored by dr. Mikosch received the 1999 best publication award (Honorable Mention) of the Applied Probability Section of INFORMS (Institute for Operations Research and the Management Sciences).

In 1999 members of the institute were successful in attracting external funds. Seven PhD positions were granted by the Dutch Organisation for Scientific Research (NWO) and other organisations to: prof. Broer and dr. Vegter, dr. Mikosch, prof. Renardel de Lavalette, prof. van der Put and dr. Top, dr. Roerdink, and prof. Veldman. The governing body of the University rewarded the Systems and Control group of prof. Willems for their excellent research with an additional PhD position. Prof. Renardel de Lavalette and Dr. Top got grants for a postdoc position and dr. H.P. Bruin from the California Institute of Technology was awarded a 3-year fellowship by the KNAW which he will spend with prof. Broer.

Several summer schools were organised as well as a number of conferences:

- Top and Van der Put organized a Spring school on “Aspects of differential equations”
- Trentelman organised the workshop “The Mathematics of Systems and Control: from Intelligent Control to Behavior Systems,” held in Groningen, on the occasion of the 60th birthday of prof. Willems.
- Mikosch was co-organizer of a course on “Financial Derivatives and Port-
folio Theory“ and of two workshops, one on “Non-Linear Modelling in Finance“ and one on “Financial Risks“

– Renardel was co-organizer of the “Symposium on Constrictivism in Mathematics and Computing“


The American Mathematical Society Meeting Las Vegas had a special session that was officially motivated by three papers published in the past, one of which was work of prof. Thomas.

Members of the institute served as editors-in-chief, associated editors or members of the editorial boards of 22 international journals and book series.

PhD students presented their work on 24 international conferences. The PhD student Van Veelen received a Best Presentation Award during the International Joint Conference on Neural Networks (Washington, D.C.).

Members of the institute gave 19 invited lectures on international conferences and at foreign universities.

The institute was visited by 60 foreign scientists. Professor Hector Sussmann from the Rutgers University, New Jersey had the Johan Bernoulli endowed chair at the institute in the period May - July 1999.

**Personnel mutations and policy changes**

In 1999 Dr. J.T. Udding (associate professor in computing science) left the institute to pursue a further professional carrier in industry. Dr. Michael H.F. Wilkinson joined the Institute as an assistant professor in computing science. Professor Floris Takens chose for an early retirement, effected on December 1, 1999.

Late in 1998 the Governing body of the University and the board of the Faculty of Mathematics and Natural Sciences commissioned an advisory committee, consisting of prof.dr. J.H. van Lint (chairman), prof.dr. P.C. Baayen and prof.dr. H.J.C. Berendsen, to prepare a report on the research institute IWI and the teaching institute OWI. One of the recommendations made concerned selective criteria for participation in the research institute. Following these criteria, the institute set up
a model for the selective assignment of research time to the faculty members. In brief, this model includes the following aspects:

- Supervision of PhD students: 0.1 fte (full time equivalent) are assigned per student per year (for a maximum of four years). This component has a maximum of 0.4 fte.

- Scientific production: a maximum of 0.4 fte can be assigned, under the condition that at least two journal papers or one journal paper and two conference proceedings papers are published. (The number of faculty member co-authors and pages are taken into account.) Books are treated per case.

- Special aspects, such as high citation score, important international functions (e.g. editor-in-chief of a high standard journal): a maximum of 0.2 fte.

- Sponsored research: a maximum of 0.1 fte can be assigned under the condition that the corresponding grant is not taken into account elsewhere. (For instance, an externally financed postdoc position is rewarded by 0.05 fte.)

- Miscellaneous, e.g. compensation for previous administrative work.

The maximum assignment of research time which can be made to a faculty member with a full time appointment is 0.7 fte. The advisory committee recommended to admit to the new selective research institute only faculty members whose actual participation in research is at least 0.4 fte. The scientific board of the institute and the director made a proposal for such an assignment of research time per person, varying from 0.4 to 0.7 fte, and selective admission to the institute to the Faculty board. This assignment and selective admission has been approved by the Faculty Board and will take effect starting in September 2000.

Another aspect which was given special attention in 1999 was the quality of research. The institute adopted the policy that each member of the institute is expected to publish (at least) one paper in a high standard international journal a year on average. The director recommended to use the position of journals in the Journal Citation Reports of ISI (Institute of Scientific Information) as a merit of standard.

The institute adopted a policy of matching external grants and giving personal rewards aimed at stimulating the effort of researchers to attract external funds.

Prof.dr. N. Petkov
Scientific Director

Prof.dr. W.C. Nieuwpoort
Chairman of the Advisory Counsel
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Research Institute for Mathematics and Computing Science (IWI)

Scientific director: Prof.dr.sc.tech. N. Petkov

Advisory council:
Prof.dr. W.C. Nieuwpoort – chairman
   (Emeritus, Professor of Theoretical Chemistry, RUG)
Prof.dr. F. Takens – vice chairman
   (Professor of Mathematics, RUG (till December 1, 1999))
Prof.dr. G.R. Renardel de Lavalette
   (Professor of Computing Science, RUG)
Prof.dr. H.A. van der Vorst
   (Professor of Mathematics, University of Utrecht)

Scientific policy collaborator: Dr. R. Smedinga

Secretary: E.J. Adema–Houben

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Scientific programmes and senior researchers

Mathematics

Programme 1 : Algebra and Geometry
Prof.dr. M. van der Put
Dr. J. Top

Programme 2 : Analysis
Prof.dr.ir. A. Dijksma
Prof.dr.ir. H.S.V. de Snoo
Prof.dr. E.G.F. Thomas

Programme 3 : Dynamical Systems
Prof.dr. H.W. Broer
Prof.dr. F. Takens (till December 1, 1999)

Programme 4 : Systems and Control
Prof.dr. R.F. Curtain
Dr. H.L. Trentelman
Prof.dr.ir. J.C. Willems

Programme 5 : Probability and Mathematical Statistics
Prof.dr. H.G. Dehling
Dr. T. Mikosch
Prof.dr. W. Schaafsma

Programme 6 : Computational Mechanics and Numerical Mathematics
Dr. E.F.F. Botta
Prof.dr.ir. H.W. Hoogstraten
Prof.dr. A.E.P. Veldman
Dr.ir. R.W.C.P. Verstappen
Dr.ir. F.W. Wubs

Programme 7 : Teaching and History of Mathematics
Dr. J.A. van Maanen
Dr. A. van Streun
Computing Science

Programme 8 : Fundamental Computing Science
Prof.dr. W.H. Hesselink
Prof.dr. G.R. Renardel de Lavalette
Dr. R. Smedinga
Dr. J. Terlouw

Programme 9 : High Performance Computing and Imaging
Dr. H. Bekker
Prof.dr.sc.tech. N. Petkov
Dr. J.B.T.M. Roerdink
Dr. G. Vegter
Dr. M.H.F. Wilkinson (since July 1, 1999)

Programme 10 : Systems Technology
Prof.dr.ir. L.J.M. Nieuwenhuis (extra-ordinarius) (till April 1, 1999)
Dr.ir. J.A.G. Nijhuis
Prof.dr.ir. L. Spaanenburg
**Research Schools**

Researchers of the IWI participate in the following research schools:

1. **Mathematical Research Institute (MRI)**
   - Coordinating institution: Universiteit van Nijmegen
   - Director: Prof.dr. J.H.M. Steenbrink
   - Participating IWI programmes: 1, 2, 3, 5, and 7

2. **Dutch Institute of Systems and Control (DISC)**
   - Coordinating institution: University of Twente
   - Director: Prof.dr.ir. H. Kwakernaak
   - Participating IWI programme: 4

3. **The J.M. Burgers Centre for Fluid Dynamics**
   - Coordinating institution: Delft University of Technology
   - Director: Prof.dr.ir. G. Ooms
   - Participating IWI programme: 6

4. **Dutch Graduate School in Logic (LOGICA)**
   - Coordinating institution: University of Amsterdam
   - Director: Prof.dr. D.J.N. van Eijck
   - Participating IWI programme: 8

5. **Institute for Programming Research and Algorithmics (IPA)**
   - Coordinating institution: University of Eindhoven
   - Director: Prof.dr. J.C.M. Baeten
   - Participating IWI programmes: 8 and 10

6. **Advanced School for Computing and Imaging (ASCI)**
   - Coordinating institution: Delft University of Technology
   - Director: Prof.dr. A.S. Tanenbaum (Free Univ. Amsterdam)
   - Participating IWI programme: 9
7. School of Behavioral and Cognitive Neurosciences (BCN)
   Coordinating institution: University of Groningen
   Director: Prof. Dr. F. Zwarts
   Participating IWI programme: 9
Doctoral Dissertations 1999


1 Programme 1: Algebra and Geometry

1.1 Programme members

Prof.dr. M. van der Put
Dr. J. Top

1.2 Promovendi, postdocs and long-time visitors

Dr. R. Auer (postdoc, NWO, “groot project getaltheorie”)
Drs. M. Berkenbosch (Ph.D. student, IWI, supervisors: van der Put, Top)
Drs. G.-J. van der Heiden (Ph.D. student, NWO, supervisors: Top, van der Put)
Drs. W.R. Oudshoorn (Ph.D. student, IWI, supervisors: Van der Put, Top) (till 1-6-1999)
Drs. J. Scholten (Ph.D. student, IWI, supervisors: Top, Van der Put) (till 31-1-1999)
Drs. R. Vidunas (Ph.D. student, IWI, supervisor: Van der Put, jointly with Vegter of programme 9)

Long-time visitors

Dr. H. Voskuil since 1-6-1999

Promotions (Ph.D. defenses)


1.3 Research Program

The main subjects of research are:

1. Number theory, especially elliptic curves. Arithmetic properties of elliptic curves over a number field or a function field, like the rank of the Mordell-Weil group, the conductor, associated Galois representations, are the subjects of study. Also, work is done on applications to Diophantine equations and arithmetic algebraic geometry.
2. **Langlands theory.** Calculations on representations are made, using advanced machinery from algebraic geometry.

3. **Rigid analytic geometry.** In this type of geometry, one works over non-archimedean valued base fields. The geometry has natural links with algebraic geometry and with complex analytic geometry. Symmetric spaces over local fields, which are special cases of rigid spaces, play an important role in number theory and the Langlands conjectures over function fields.

4. **Drinfeld modules.** This concerns a theory in positive characteristic which has similarities with the theory of elliptic curves and abelian varieties.

5. **Differential equations and Difference equations.** The differential (or difference) equations that are studied are ordinary linear (complex) differential equations. For linear and non-linear differential equations, the theory of Lie-symmetries is also studied. The methods are very often algebraic. The analytic part of the research concerns “multisummation” and other types of liftings of formal solutions to actual solutions as functions on suitable sectors.

6. **Computeralgebra and Number theory.** One of the activities concerns the construction of algorithms for finding symbolic solutions of ordinary linear differential and difference equations. There is also interest in real-algebraic geometry, splines, robotica, Gröbner theory, LLL-algorithm, the number field sieve and the like.

Overview of scientific results:

ad (1).
Some goals of the research in this area include the study of constructions and also limitations of methods that yield elliptic curves of high rank, and the construction of Galois representations associated with families of elliptic curves. Various papers on methods for calculating ranks and papers which use geometry of surfaces in the present context have been written and/or are still the topic of joint research. For example, Top worked on constructions of K3 surfaces with maximal rank. This resulted in the Master’s thesis of Matthijs Meijer (October 1999) and in a joint paper on this and similar problems with Meijer and Chahal (Provo, Utah). The paper was recently submitted to Comm. Math. St. Pauli (Japan). Also, a joint paper with Kuwata (Caen) relating certain surfaces to Diophantine equations was accepted for publication in Indagat. Math., where it is expected to appear in 2000. Finally, Top was a “professeur invité” at the Institut Henri Poincaré in Paris in
February, where he gave a course on relations between elliptic curves and the \textit{abc}\nconjecture. There are plans to publish this work together with other courses in Paris by Moonen and by Oort (Utrecht) in the Springer LNM series.

\textit{ad (2).}

Top has continued joint work with Van Geemen on automorphic representations of $GL(3)$. Based on suggestions of Avner Ash and of Kevin Buzzard, a phenomenon discovered in our earlier work could be explained. This will appear in July 2000 in the ANTS-proceedings, which are published in the Springer Lecture Notes in Computer Science series. Scholten succeeded in establishing results for $GL(4)$ which are analogous to what Top and van Geemen did for $GL(3)$. This is now a chapter in his PhD thesis.

\textit{ad (3).}

The work on rigid analytic geometry and its relations with (arithmetic) algebraic geometry has been a major research subject of van der Put over a long period. In 1999 the project of writing a “revised and expanded second edition” of the book “J. Fresnel, M. van der Put - \textit{Géométrie rigide et applications} - Progress in Math. 18, 1981, has started. Special emphasis will be given to the recent works of M. Raynaud and D. Harbater on fundamental groups in positive characteristic.

\textit{ad (4).}

The subject “Drinfeld modules” has not obtained much attention by M. van der Put and J. Top in 1999. However, it is the main topic for the research of G.-J. van der Heiden and some informal discussions on the topic have taken place. The three of us actively participated at a workshop in Gent in early June. We plan to host a similar workshop in Groningen in May 2000.

\textit{ad (5).}

Analytic aspects on differential and difference equations have been studied by van der Put in cooperation with Braaksma, Immink and others, over a long period. As a sequel to B. Faber Ph.D. thesis on 6-2-1998 a joint paper (authors B. Faber and M. van der Put) has been completed and is accepted for publication. Algebraic and analytic aspects of differential equations have been studied as well. They include: differential Galois theory, the connection of the differential Galois theory with the “Stokes matrices” et cetera. The paper: “M. van der Put - Singular complex differential equations. An introduction - Nieuw Archief 1995” gives an impression of this research. This research is the project of a book written in cooperation with M.F. Singer. Hopefully this book will be in final form in 2000.

Algorithmic aspects of linear differential equations have been the theme for joint
work with F. Ulmer. A finished joint paper has been accepted by Journal of Algebra and is maybe already in print.

The discontinued Ph.D. work of W.R. Oudshoorn on Lie-symmetries of ordinary differential equations has resulted in a joint paper (authors W.R. Oudshoorn and M. van der Put) which is accepted for publication in “Mathematics of Computation”.

ad (6).

Theory and practice of symbolically solving linear differential (or difference) equations has resulted in papers and preprints. Another aspect is the behaviour of differential equations in characteristic $p$ and reductions modulo $p$ of differential equations. This resulted in a recent preprint by van der Put. R. Vidunas successfully completed his PhD thesis on algorithmic aspects of differential equations and the algorithmic theory of splines.

1.4 Research subjects

R. Auer: a general orientation in algebraic geometry; function fields and related subjects.

M. Berkenbosch: a general orientation in algebraic geometry; algebraic aspects of differential equations.

G.-J. van der Heiden: a general orientation in algebraic geometry, Drinfeld modules, rigid geometry et cetera; compactifications of Drinfeld curves.


M. van der Put: rigid analytic geometry, Drinfeld modules, differential equations, difference equations, computer algebra.

J. Scholten: the arithmetic of elliptic curves and elliptic surfaces. Calculations on examples of Galois representations related to $GL(3)$.

J. Top: arithmetical algebraic geometry in particular: elliptic curves, Galois representations, number theory, Drinfeld modules.


1.5 Publications

Dissertations


**Articles in scientific journals**


**Other publications**


### 1.6 Further information

*Top* and *Van der Put* organized a successful Spring School (April and May) on the theme “Aspects of differential equations”. This was a “concentrated form” of an MRI masterclass. The Spring school ended by an international conference of a week on the same theme.

*Top* and *Van der Put* gave a masterclass “Arithmetic of elliptic curves and Riemann surfaces” in the first semester of 1999-2000.

*Top* obtained a NWO-postdoc position for R. Auer. *Top* and *Van der Put* obtained a NWO-OIO position for G.-J. van der Heiden.

*Van der Put* actively participated and lectured at many international conferences, e.g. the International Conference on Valuation Theory (Saskatoon, Canada, July 24 to August 12) and MSRI Berkeley (U.S.A, November 1 to December 2).

*Top* also made several international visits, e.g., to the Institut Henri Poincaré in Paris during February.
2 Programme 2: Analysis

2.1 Programme members

Prof.dr.ir. A. Dijksma
Prof.dr.ir. H.S.V. de Snoo
Prof.dr. E.G.F. Thomas

2.2 Promovendi, postdocs and long-time visitors

Drs. G.R. Kuik (Ph.D. student, IWI, supervisor: B.L.J. Braaksma (emeritus),
G.K. Immink (Econometrics, RUG))

Long-time visitors

Prof. D. Alpay (Ben-Gurion University of the Negev)
Prof. T.Ya. Azizov, Voronezh State University, Russia (six months, NWO scholar-
ship)
Dr. Seppo Hassi (University of Helsinki)

2.3 Research Program

Mathematical Analysis is one of the oldest branches of mathematics and one that
traditionally has the closest ties with applied mathematics and physics. It is a large
area of which we can cover only small portions. At present our interest is mainly
in topics within the global areas of: A. Operator Theory, B. Functional Analysis.

Professor Braaksma has retired but he has agreed to continue the supervision of the
PhD work of G.R Kuik, who has been appointed as AIO on 1-9-98. Kuik’s project
is entitled: Exact asymptotics for a class of singular partial differential equations
with applications to the analytic classification of nonlinear analytic ordinary differential equations and resonant vector fields.

Dijksma and De Snoo continue their work in the area of operator theory.

The research of Dijksma concerns in part interpolation and moment problems,
mostly in an indefinite setting (that is, for classes of meromorphic functions) and its
interplay with extension theory, commutant lifting and reproducing kernel spaces.
Another part of the research- also within the context of operator theory in spaces
with an indefinite metric—concerns factorization of continuous operator functions into factors with specified spectral properties. Here earlier work on the defect of noncontractive operators in a Krein space plays an important role. In the coming years the connection between indefinite interpolation and canonical systems, nonstationary analogs of the representation formulas for Schur and Herglotz functions as transfer functions of certain systems and Brune sections for nonstationary systems will be investigated.

De Snoo works on the function theoretic description and spectral analysis of generalized finite rank perturbations, both in the setting of definite and indefinite metrics. Also on the following topics: the description of selfadjoint extensions via exit spaces. The connection between Titchmarsh-Weyl functions and Q-functions and general boundary conditions for canonical systems and Sturm-Liouville equations with floating singularities.

In the field of functional analysis Thomas continues work on his theory of path distributions which seems now to be very close to the goal of giving a correct mathematical description of the Feynman ‘path integral’. This notion introduced heuristically by R. Feynman in 1948, and in spite of numerous efforts, still does not have a satisfactory mathematical definition. We hope that René Jofriet, no longer employed by the University, will continue work on his planned dissertation on discrete space path integrals.

On a different topic Thomas has continued work with J. Faraut (Paris VI) involving a new application of the nuclear integral representation theorem to Harmonic Analysis on complex manifolds.

### 2.4 Research subjects

**A. Dijksma:** Spectral and extension theory for differential operators (with applications to quantum mechanics), indefinite interpolation and moment problems and nonstationary representations of Herglotz functions.

**G.R. Kuik:** exact asymptotics for a class of singular partial differential equations with applications to the analytic classification of nonlinear analytic ordinary differential equations and resonant vector fields.

**H.S.V. de Snoo:** spectral analysis, (in)definite metrics, realization theory for a class of operator valued functions.

**E.G.F. Thomas:** the theory of path distributions; applications of the theory of integral representation.
2.5 Publications

Articles in scientific journals


Articles in conference proceedings


Other publications


2.6 Research - specific aspects

*De Snoo* was granted a NWO visitor grant for Y. Arlinskii (Lugansk) and a NATO grant for collaboration with E. Tsekanovskii (Buffalo).

*Dijksma* was awarded a Harry T. Dozor Fellowship at the Ben-Gurion University of the Negev in Beer Sheva, Israel, from June 18–July 18.
2.7 Further information

*Dijksma* attended the Toeplitz Lectures in Tel Aviv and a workshop in honor of Prof. Harry Dym in Rehovot, where he gave an invited lecture (2 weeks in March). He went to Berlin and Leipzig where he gave two invited colloquia (1 week in November).

*De Snoo* gave lectures in Vienna (TU Wien, June 1999); at the B. Sz.-Nagy Memorial Conference in Szeged (Augustus 1999); at the Banach Center in Warschau (August 1999); and at the International Functional Conference in Helsinki (September 1999).

*Thomas* was invited to lecture for the Academy Colloquium “Infinite-dimensional stochastic analysis” which was held in Amsterdam 11-12 February 1999. He gave invited lectures for the American Mathematical Society Meeting Las Vegas, Special Session on Invariants, Distributions, Differential Operators and Harmonic Analysis (10-11 April 1999) and for the International Conference on Feynman Integrals and Related Topics, Yonsei University, Seoul (July 12 – 15, 1999).

The Special Session of the AMS mentioned above, was officially motivated by three papers, one of which was work by Thomas, of 15 years ago.
Direct volume rendering is a technique for visualizing 3-D data by modelling the transmission of light through the volume data. Light rays are sent into the data, and values encountered along the ray are combined. Several properties, such as colour and opacity, are assigned to the data points. For CT (computerized tomography) data, these properties can be derived from physical substances, such as bone, soft tissue, and fat in the musculoskeletal system. The data shown in this image originate from a CT scanner. The skin has been made almost fully transparent, whereas bone has been made almost fully opaque. This image illustrates the visualization process. The 3-D data are displayed in the box in the middle, and the plane in front represents the screen. One light ray emanates from the plane into the data, and the intensity profile along the ray is shown above the box. (Work carried out by Roerdink and Westenberg of programme 9, see e.g. Nieuw Archief voor Wiskunde, vol 17, 1999.)
3 Programme 3: Dynamical Systems

3.1 Programme members

Prof. dr. H.W. Broer
Prof. dr. F. Takens (till 1 December 1999)

3.2 Promovendi, postdocs and long-time visitors

Drs. M. van Noort (Ph.D. student, NWO-FOM/SWON; supervisor: Broer, jointly with Vegter of programme 9, and Hovelijn)
Drs. E.A. Verbitski (Ph.D. student, NWO-SWON; supervisor: Takens)
Drs. R. Vitolo (Ph.D. student, IWI; supervisors Broer, Simó (Univ. of Barcelona), and Hovelijn)
Dr. A.L. Hagen (postdoc of programme 9: joint project with programme 3; NWO-SWON)

Collaborative Ph.D. projects: Drs. K.A. Blom (with Van Maanen and Van Streun of programme 7); R. Bakker (Chemical Engineering, TUD, collaboration with Takens).

Promotions (Ph.D. defenses)


3.3 Research program

In this program we investigate mathematical models describing time evolution of deterministic systems. As a very simple example one may think of an oscillator (or a pendulum). Already the slightly more complicated example of two oscillators with (weak) interaction gives an illustration of most of the questions on which the present research concentrates:
– will each oscillator still keep its own (independent) frequency (in this case we speak of multiperiodic dynamics), or;

– will the combined system assume one globally periodic state so that the frequency of the apparent motions of the individual oscillators is a multiple of this global frequency (here one speaks of resonance);

– it turns out that there is a third possible dynamical state: there may be a continuous range of frequencies present in the dynamics (in this case the motion is called chaotic).

It is the occurrence of, and transitions between, these states (multiperiodic, resonant, and chaotic) which is the central theme of research in this program — not only for a few coupled oscillators but for a wide class of systems. These questions are studies on three different levels:

– on the most general level on considers all possible systems (where we restrict ourselves to deterministic systems with finite dimensional state space) — one is interested in what is logically possible or impossible;

– for specific systems, e.g. systems proposed as mathematical model by some scientist, it is often important to obtain information about the dynamical states which can occur — here we are interested in the development of algorithms which will help in such an analysis;

– interpretation of measured data: recorded data of the time evolution of a system can often be used to determine the dynamical state of the system, or they can provide an indication that there are (partially) random effects involved.

It is clear that the different levels interact strongly: in order to know where to look for in a special case, one has to know what one can expect and what is logical possible or impossible.

There is cooperation with groups in other sciences on the analysis of specific systems (Physics, VU Amsterdam and Department of Engineering, University of Bristol: co-authoring with B. Krauskopf and Spring school over Fundamental Aspects of Laser Dynamics), meteorology (KNMI, cooperative research of promovendi Vitolo (RUG) and van Veen (KNMI)), and on interpretation of experimental data (Chemistry, TUD, on neural networks and fluid bed reactors, and Physiology,
RUL, all jointly supervising Ph.D. students). The theoretical work is internationally oriented and involves intensive cooperation with a.o. the universities of Dijon, Barcelona, and with IMPA in Rio de Janeiro, resulting in joint publications at a regular basis.

3.4 Research subjects

H.W. Broer: Perturbation and KAM-theory, bifurcation theory: integrability, non-integrable and resonance phenomena, applications of singularity theory, exploration of complicated systems.

A.L. Hagen: see programme 9.

M. van Noort: Resonance phenomena with inverted pendulum as a case study, combination of analytical and both formal and numerical methods, bifurcations ‘at infinity’.

F. Takens: Analysis of time series, in particular the extension of methods for deterministic systems to situations with (weak) stochastic noise; extension of thermodynamical formalism for the dimension spectrum to the entropy spectrum.

E.A. Verbitski: Ergodic theory of differentiable dynamical systems, in particular different types of entropy and entropy and multifractal spectra.


3.5 Publications

Dissertations


Books

Articles in scientific journals


Other publications


3.6 Research: specific topics

A KNAW-fellowship has been awarded (360 kf). Appointment of Dr H.P. Bruin is to be expected at July 1st, 2000.

3.7 Further information

*Takens* is editor of Springer *Lecture Notes in Mathematics*, member of the Royal Academy of Sciences (KNAW) and chairman of the ‘Akademie Raad Wiskunde’.

*Broer* is editor of *Epsilon Uitgaven* and associate editor of *Dynamics Reported*.

In the FOM-programme *Mathematical Physics* again an OIO-position (240 kf) has been awarded (requested by Broer and Vegter of group 9). Expectedly this vacancy will be filled Spring 2001.

In the KNAW-programme *Wetenschappelijke Samenwerking Nederland–Indonesië*, in particular the priority programme *Applied Mathematics*, a PhD-position is awarded.

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1Published in 1999
Broer is executive coordinator of a *Dynamical Systems* project, also including a PhD-position at Utrecht University. Total funding 500 kf.
4 Programme 4: Systems and Control

4.1 Programme members

Prof.dr. R.F. Curtain
Dr. H.L. Trentelman
Prof.dr.ir. J.C. Willems

4.2 Promovendi, postdocs and long-time visitors

M.N. Belur (Ph.D. student, IWI; supervisor: H.L. Trentelman)
T. Cotroneo (Ph.D. student, NWO-SWON; supervisor: J.C. Willems)
Dr. H.K. Pillai (postdoc, NWO; supervisor: J.C. Willems)
A. Sasane (Ubbo Emmius Ph.D. student; supervisor: R.F. Curtain)
Dr. S. Shankar (Postdoc, NWO/IWI)

Long-time visitors

Prof. H. Sussmann (Rutgers University, NJ, USA)

Promotions (Ph.D. defenses)


4.3 Research Program

The aim of the research in the Systems and Control group is the development of mathematical tools for the modelling of open dynamical systems and of algorithms for their control. The emphasis is on two lines of research:

- The behavioral approach to systems and control (Willems, Trentelman, Pillai, Cotroneo, Belur, Shankar)
- Infinite-dimensional systems theory (Curtain, Oostveen, Sasane)
4.3.1 The behavioral approach to systems and control

The basic purpose of systems theory is the study of dynamical systems that interact with their environment. Viewing systems as embedded in their surroundings should be a normal feature of models in physics, engineering and economics, but, in mathematics it is rather uncommon to formalize this interaction. Examples of areas where this aspect is essential are signal processing and control, and it is this last area which is emphasized in our research.

The traditional way of modelling a dynamical system is by an input-output map or relation. However, physical systems in general do not exhibit the information flow direction that is pre-supposed by the input-output structure. This objection has led us to develop the behavioral approach. In this setting, all manifest system variables are a priori treated on an equal footing. The model then specifies a subset of the set in which the manifest variables take their values as being possible. This subset is called the behavior of the system. However, when modelling systems as interconnection of standard components, as is common practice in computer-assisted object-oriented modelling tools, one invariably encounters (auxiliary) latent variables in addition to the manifest variables that the model aims at. Our approach is based on this triptych: manifest variables, behavior and latent variables.

Many questions are studied in this setting. Controllability, pole placement, observability, observers and Lyapunov stability are some classical questions that we are pursuing in this novel framework. Further, state construction and LQ- and H-infinity control. Most of the work aims at linear differential systems.

Ongoing work

H-infinity control in a behavioral setting (Trentelman, Willems) Development of the behavioral approach to H-infinity- and robust control, dissipative systems, quadratic differential forms, Lyapunov theory for systems described by high order differential equations. We start with polynomial matrix representations of a dynamical system (either a kernel or an image representation) and obtain analogous representations of the controller. This problem leads to interesting interactions between polynomial matrices in one and two variables. A complete solution of the H-infinity in a behavioral setting was obtained in 1999. This led to a 3-part paper that has recently been submitted for publication.

Control in a behavioral context (Belur, Cotroneo, Trentelman, Willems) The purpose of this research project is the formulation of control and representation problems and algorithms in the context of behaviors. The starting point is a set of behavioral equations, for example a system of differential equations \( R\left( \frac{d}{dt} \right) w = 0 \)
with $R$ a polynomial matrix. We view control as interconnection, that is, adding a new system of differential equations $C \left( \frac{d}{dt} \right) w = 0$. The resulting closed loop system has been studied w.r.t. stabilization, pole assignment, invariant factor assignment, etc.

Systems described by PDE’s (Pillai, Shankar, Trentelman, Willems) This program deals with studies on controllability, observability of systems on constant coefficient PDE’s through the behavioral approach. Special emphasis is on the extension of the concept of dissipative distributed parameter systems to the multidimensional case.

### 4.3.2 Infinite-dimensional systems theory

In many application areas, systems are most accurately described by partial differential equations or delay difference equations, for example, large scale flexible space structures, noise suppression in large cavities and process control, where there are considerable delays in control implementation. Control problems for such systems can be formulated in an analogous way to those for lumped parameter systems (those described by ordinary differential equations) in state-space form, if one introduces a suitable infinite-dimensional space and suitable operators, instead of the usual matrices. Infinite-dimensional systems theory is concerned with the extension of more familiar theory to this more general setting, insofar this is possible. Control design in this context is a synthesis of this theory, taking into account numerical, physical and implementational aspects.

The questions studied for these system in this project are related to abstract linear systems, robust control for dissipative systems and to adaptive control and observation.

### 4.4 Research subjects

**M. Belur**: Control in a behavioral framework.

**T. Cotroneo**: Applications of Gröbner bases to studying representations and properties of linear systems. Applications of LMI’s to problems involving quadratic differential forms.

**R.F. Curtain**: Infinite dimensional systems where the input operator is unbounded; absolute stability problems and applications to tracking for well-posed linear systems.

**H. Pillai**: Behavioral approach to n-D linear systems; controllability, observability
of systems on constant coefficient PDE’s; dissipative distributed parameter systems.

**A. Sasane**: New inertia results for operator Lyapunov equations. Relations between the negative eigenvalues of the solution and the unstable eigenvalues of the generator. Approximation theory for the Pritchard-Salamon class of infinite-dimensional systems.

**H.L. Trentelman**: Control in a behavioral setting; synthesis of dissipative systems and $H_{\infty}$ control; the algebraic Riccati equation; algorithms for polynomial J-spectral factorization; theory of dissipative systems.

**J.C. Willems**: The behavioral approach to systems and control; modelling and representation questions; controllability and observability and their implications; LQ- and $H_{\infty}$-control; identification.

### 4.5 Publications

**Dissertations**


**Edited books**


**Contributions to books**


- H. Pillai, Conservative and dissipative distributed systems. In: J.W. Polderman and H.L. Trentelman (eds), *The Mathematics of Systems and Con-


Articles in scientific journals


**Articles in conference proceedings**


### 4.6 Specific Points

The Systems and Control group of the RUG collaborates with the Dutch Institute for Systems and Control (DISC). Willems ended his 5 year term as chair-person of the board of DISC in 1999.

Trentelman and Willems collaborate on the NWO 'Groot Project': *Modelling and Control of Open Dynamical Systems* (coordinator: A.J. van der Schaft, UT). OIO T. Cotroneo and postdoc H. Pillai are funded by this project.

The collaboration with H. Logemann, of the University of Exeter, UK, is supported by Grant GRIL78086, project JRP530 by the UK-DUTCH Joint Scientific Research programme and the UK EPS.

Members of the group are part of several networks sponsored by the EU Science Program or by the ESF (European Science Foundation): Willems participates in the European Research Network on System Identification (ERNSI); Willems and Trentelman participate in the European Science Foundation Network on Control of Complex Systems (COSY); and Curtain participates in the European Network for Infinite Dimensional Systems.

Trentelman obtained a NWO visitor grant on behalf of Dr. S. Shankar of IIT Bombay, India. He also obtained funds from NWO in order to organize the conference ‘The Mathematics of Systems and Control: from Intelligent Control to Behavioral Systems’.
4.7 Further information

Curtain served as a member of the appointments committee for the professorship in control at the University of Lund, Sweden.

Trentelman organised the Workshop ‘The Mathematics of Systems and Control: from Intelligent Control to Behavioral Systems’, held in Groningen on 17 and 18 September 1999, on the occasion of J.C. Willems’ 60th birthday. During 1999 Trentelman served as Associate Editor of SIAM Journal on Control and Optimization.

Willems was associate editor of Systems and Control Letters and member of the editorial boards of Acta Applicandae Mathematicae and Multidimensional Systems and Signal Processing. He was an invited speaker in a number of international conferences, among them he gave a special evening lecture at the conference on Robust Control in Hong Kong in June 1999, he was a plenary speaker at the IFIP conference on Systems Modelling and Optimization in Cambridge UK in July 1999, and he gave the opening lecture at the conference on Advances in Systems Theory in Cambridge, MA in October 1999.
Scanning electron micrograph of the diatom Diploneis spp. Diatoms are single-cell algae which build ornate silica shells. The ADIAC project in which we are involved aims to automate identification of these organisms (project of Roerdink and Wilkinson of programme 9).
5 Programme 5: Probability and Statistics

5.1 Programme members

Prof.dr. H.G. Dehling
Dr. T. Mikosch
Prof.dr. W. Schaafsma

5.2 Promovendi, postdocs and long-time visitors

Drs. C. Albers (Ph.D. student; supervisor: Schaafsma)
Drs. B. Basrak (Ph.D. student, NWO; supervisor: Mikosch)
Dr. R. de Bruin (external promovendus, RC; supervisor: Schaafsma)
Dr. D.M. Salopek (postdoc, NWO (till September 1, 1999); supervisors: Dehling, Mikosch)
Drs. A. Stegeman (Ph.D. student, NWO-SWON; supervisor: Mikosch)
Dipl.Math. D. Straumann (Ph.D. student, NWO/IWI; supervisor: Mikosch)

Collaborative Ph.D. projects:
C. Dechsiri, M.Sc. (with Dehling (jointly with dr. A.C. Hoffmann, Department of Chemical Engineering, RUG))

Long-time visitors
F. Matarise, M.Sc. (University of Zimbabwe, Harare)
Prof.dr. G. Samorodnitsky (Cornell University, Ithaca)
Dr. O. Sharipov (Academy of Sciences of Uzbekistan, Tashkent)
Dr. C. Stărică (Chalmers University, Gothenburg)

5.3 Research Program

The group continued its research on foundations of statistical inference, on probability theory and stochastic processes in general, and was involved in applications. The research of the group centers around two themes:

– Applied probability theory and stochastic processes
– Foundations of statistical inference
**Applied probability theory and stochastic processes**

The main task of applied probability theory is modelling of random phenomena in Science, Technology, Economics and Life Sciences, and the subsequent mathematical analysis of the resulting models. Mostly, modelling is done with a concrete purpose in mind. This can range from the classical tasks of prediction and control of a stochastic process to modern applications in Financial Mathematics like assessment of financial risks, valuation of contingent claims and design of portfolio management schemes.

A major portion of the research activities in Groningen is directed towards the modelling of time series. During the past decade there has been increasing awareness of shortcomings of traditional linear Gaussian time series. Models incorporating nonlinearity, heavy-tailedness and long-range dependence have subsequently been proposed as alternatives. The Groningen research on time series mainly focusses on the analysis of these nonstandard models. Issues like model identification, prediction and spectral analysis are being studied.

The mathematical analysis of stochastic models often requires asymptotic techniques, like various types of limit theorems. In most cases the underlying random variables are either not independent or have infinite variance, and thus often new techniques have to be developed. This fundamental research has a strong history in the work of the Groningen group. It turns out that various, seemingly unrelated, applications require the same type of mathematical tools. It is one of the aims of the group to find probabilistic structures which allow one to solve different problems from a unifying point of view. In particular, methods and techniques from empirical process theory have been used successfully.

In addition to time series analysis, the Groningen group is involved in several other projects. One of them is the attempt to provide a rigorous analysis of neural network learning algorithms, which leads to questions of stochastic approximation theory. Another project is the stochastic modelling of transport phenomena in chemical reactors, done in cooperation with a group in the Chemical Engineering Department.

*Foundations of Statistical Inference.*

Concrete applications to areas like physical anthropology (human growth, craniofacial growth, human evolution), biology, cytology, clinical decision making, diagnosis and prognosis, experimental neurology, etc., provided the motivation for the more fundamental research in statistical inference carried out in Groningen.
The work done in hypothesis testing during the sixties resulted in a deadlock: the Neyman-Pearson-Wald approach is not satisfactorily conclusive if more than 2 hypotheses have to be considered. One would like to assign ‘probabilities’ to these hypotheses but, at that time, such concepts were not allowed. The physical–anthropological problem of making sex diagnoses on the basis of skeletal material provided the motivation to concentrate the attention on the less controversial problem of estimating (reasonably) well-defined posterior probabilities. The POSCON project thus initiated had its own foundational crisis. Work done by meteorologists and Bayesian statisticians generated the idea that the properness of loss functions is essential in extending the Neyman-Pearson-Wald approach such that the ‘forbidden’ probabilities become ‘respectable’. This led to (relatively) new theories of hypothesis testing ($q$-values instead of $p$-values) and of distributional inference. This work is still in progress. Meanwhile other work was initiated. The research project of the physical anthropologist Williams about human evolution generated a new definition of size and shape which will be applied to human growth, craniofacial growth in particular (by De Bruin), and human evolution (by Williams and Van Vark). The project is entitled ‘Size and Shape of Man and Ape’.

Schaafsma wants to complete his scientific career by publishing two books, one about distributional inference (summarizing the work done by a large number of researchers including Ambergen, Kroese, Van der Meulen, Salomé, Van der Sluis) and one about size and shape in man and ape (co-authored with De Bruin, Van Vark, Steerneman and others).

### 5.4 Research Subjects

**C. Albers:** Distributional inference, a ‘new’ approach.

**B. Basrak:** Sample autocorrelations of non-linear processes.

**H.G. Dehling:** Asymptotics of dependent processes, U-statistics, neural networks, stochastics in general.

**T. Mikosch:** Analysis of financial time series, modelling of heavy-tailed phenomena.

**D.M. Salopek:** Mathematical finance.

**W. Schaafsma:** Distributional inference, applied statistics, human growth (with R. de Bruin), human evolution (with Williams and Van Vark).

**A.W. Stegeman:** Shot noise processes, teletraffic workload process.

**D. Straumann:** Analysis of financial return series in changing markets
5.5 Publications

Articles in scientific journals


Further publications

5.6 Research: specific topics

Contract research was conducted for Shell Research Lab (Amsterdam) (40 kF) and for the Radiocommunications Agency of The Netherlands (Groningen) (33 kF). These projects gave rise to interesting research problems as well as future employment for two Masters’ students.

5.7 Further information

Mikosch continued his work as coordinator of the Stochastic Finance Group at the European research institute for probability and statistics EURANDOM (Eindhoven). In this function, he was co-organizer of a course on Financial Derivatives and Portfolio Theory and of two workshops, one on Non-Linear Modelling in Finance and one on Financial Risks. Jointly with Ole Barndorff-Nielsen (Aarhus University), he organised a thematic period on Lévy Processes and Pathwise Integration for the Research Centre MAPHYSTO (Aarhus), including an advanced special course on Pathwise Stochastic Integration and an International Conference on Lévy Processes.

Mikosch, jointly with Claudia Klüppelberg (TU München), gave a course on Financial Risks at the Annual Joint Statistics Meeting of the International Statistical Institute and the American Statistical Association in Baltimore. He was invited speaker at the Oberwolfach Meeting on Risk Theory, at the Annual Meeting of the Belgian Statistical Society in Nieuwpoort and at the EURANDOM workshop on Heavy Tails and Stochastic Networks. He gave talks at the universities of Vienna, Lausanne (EPFL), Zürich (ETH), Copenhagen, Aarhus, Ft. Collins, Ithaca (Cornell), Braunschweig.


The book Modelling Extremal Events for Insurance and Finance by P. Embrechts, C. Klüppelberg and T. Mikosch received the 1999 Best Publication Award (Honorable Mention) of the Applied Probability Section of INFORMS (Institute for Operations Research and the Management Sciences).

Dehling gave talks in the mathematics colloquia at the universities of Oldenburg and Paderborn and at Oregon State University. Moreover, he was invited to the Oberwolfach conference Mathematische Stochastik and to the conference Rencontres Mathematiques de Rouen 1999 on Ergodic Theory in Rouen, France. He is
associate editor of 'Statistica Neerlandica' and of ‘Communications in Statistics - Stochastic Models’.

Salopek was invited speaker at the workshop on Product Integrals and Pathwise Integration at the university of Aarhus and at a Financial Derivatives Meeting at EU-RANDOM. She gave invited colloquium talks at the universities of Aarhus, Berlin (Humboldt), Frankfurt. She organized two workshops on Stochastic Analysis and the Mathematics of Finance at the Fields Institute, Toronto.
6 Programme 6: Computational Mechanics and Numerical Mathematics

6.1 Programme members

Dr. E.F.F. Botta  
Prof.dr.ir. H.W. Hoogstraten  
Prof.dr. A.E.P. Veldman  
Dr.ir. R.W.C.P Verstappen  
Dr.ir. F.W. Wubs

6.2 Promovendi, postdocs and long-time visitors

Ir. E.G.M. Coenen (Ph.D. student, IWI funds group Computational Mechanics; supervisor: A.E.P. Veldman)  
Ir. G. Fekken (Ph.D. student, MARIN; supervisor: A.E.P. Veldman)  
Ir.drs. J. Gerrits (Ph.D. student, SRON; supervisor: A.E.P. Veldman)  
Ir.drs. G.E. Loots (Ph.D. student); supervisors: H.W. Hoogstraten, A.E.P. Veldman)  
Ir. E. Tiesinga (Ph.D. student, NWO; supervisors: A.E.P. Veldman, F.W. Wubs)

Collaborative Ph.D. and postdoc supervision:
Dr. M. Hencka (postdoc, Chemical Engineering, RUG; with Veldman)  
Ir. P.F. Rozendal (Chemical Engineering, RUG; with Hoogstraten)  
Ir. H. Scherpenkate (Chemical Engineering, RUG; with Veldman)  
Ir. A. Tverda (Applied Physics, TUD; with Veldman)  
Drs. M.P. de Vries (Biomedical Technology, RUG; with Veldman)

6.3 Research Program

With the continuing progress in numerical mathematics and computer technology, the impact of computer simulation on society is rapidly increasing. Our group is active part of this dynamic scientific computing scene: we specialize in the numerical simulation of fluid dynamics and transport phenomena (Computational Fluid Dynamics CFD). On the one hand research is focussed on basic advancement of numerical algorithms; on the other hand - through extensive cooperation with ex-
ternal research groups - these methods are made available to advance knowledge in other (applied) areas of science and technology.

A main area of research concerns turbulent flow. Industrial simulation methods make use of turbulence models to keep the required computational effort within reasonable limits, but a price is paid in terms of accuracy. Thus research into direct numerical simulation methods (DNS) which resolve all length and time scales (i.e. no modelling errors) is essential. Our group concentrates on improving numerical techniques (space discretization and time integration) with which the price of DNS reduces significantly (several orders of magnitude). Recent workshops in 1996-99 have revealed that, for moderate Reynolds numbers, our newly developed DNS methods can compete with current industrial flow solvers, yet yielding more accurate results. For the visualization of the large amounts of data involved we cooperate with CWI.

Another main research area concerns research into the dynamics of sloshing liquids, including the interaction between liquid and container. In cooperation with NLR and international space agencies, an experiment is being prepared with a free flying spacecraft; our group will give theoretical support. This research has already led to a spin-off in other projects featuring moving liquid boundaries, such as the study of wave-impact loading on ships (with MARIN) and a 1998-started PhD project on fluid-structure interaction in arterial blood flow (with UU). Basic knowledge carrier is the in-house developed simulation method ComFlo.

The repeated solution of one or more systems of equations is part of any CFD method. Therefore the quest for improved matrix solvers is another major research area. A method (MRILU) is being pursued which can cover a broad class of matrices: symmetric or non-symmetric, structured or unstructured. Current applications imply the investigation of stability (bifurcation analysis) of flow patterns in global ocean circulation (with UU-IMAU) and in laminar-turbulent flow transition.

A large number of CFD applications is supported. Next to the ones already mentioned, we report scientific projects in the areas of anatomy (arterial blood flow; with UU and with AZG), biophysics (artificial organs, cupular and cochlear mechanics) and chemical engineering (fluidized beds, extruder flow). Further, in 1999 industrial projects with Biddle B.V. (indoor climate control), Gasunie (turbulent heat transfer) and a consortium consisting of Kvaerner-Buss, SRTC, DSM and AKZO (venturi loop reactors) deserve mentioning. A number of these projects are carried out as a joint-PhD cooperation. Cooperation with technological institutes is strengthened through our participation in HPCN-NICE (Netherlands Initiative for CFD in Engineering). With NLR a long-term cooperation exists covering a large
variety of flow problems (ranging from aerodynamic design to spacecraft dynamics). Cooperation with MARIN has led to the funding of a PhD research project on ship slamming that started in 1999.

6.4 Research subjects

**E.F.F. Botta**: Development of effective solution methods (algebraic multi-level ILU preconditioners) for sparse systems of equations in structured and unstructured problems.

**E.G.M. Coenen**: Viscous-inviscid interaction methods for aerodynamic flow.

**G. Fekken**: Numerical simulation of ship slamming (with MARIN).

**J. Gerrits**: Theoretical and experimental investigation of coupled liquid/solid-body dynamics of spacecraft (SloshSat experiment in cooperation with NLR, ESA and NASA).

**H.W. Hoogstraten**: Application of CFD techniques to problems from anatomy (arterial blood flow), chemical engineering (fluidized beds, extruder flow) and biophysics (cupular and cochlear mechanics).

**G.E. Loots**: Fluid-structure interaction in viscous flows, with application in hemodynamics (with UU).

**G. Tiesinga**: Sparse matrix solvers for continuation methods; application to bifurcation analysis of global ocean circulation (with UU-IMAU) and laminar-turbulent flow transition.


**R.W.C.P. Verstappen**: Development of simulation methods for turbulent flow (direct numerical simulation DNS), analysis of DNS data.

**F.W. Wubs**: Development of a multi-level ILU preconditioner for sparse systems; application to eigenvalue and continuation problems.

6.5 Publications

**Articles in scientific journals**


- A.E.P. Veldman and R.W.C.P. Verstappen: Higher-order discretization meth-


**Articles in conference proceedings**


### Other publications


### 6.6 Research - specific aspects

Our research policy focusses on strengthening the link between fundamental developments in mathematics and the scientifical and technical needs from society; in-house developed software plays an essential role in knowledge transfer.

### External funding

In 1999, four out of our five IWI PhD projects and all joint PhD projects are being funded by either the national science foundation (NWO) or by industry. Each project involves cooperation with research groups outside the discipline of mathematics. Externally funded projects that started in 1999 are with MARIN (kf 300 for ship slamming), NWO-NCF (kf 45 for parallelization of MRILU), and with Bidde BV (kf 100 for the design of air curtains, funded by the Ministry of Economic Affairs).
International contacts

Various bilateral contacts exist with research groups outside the Netherlands, leading to e.g. traineeships for our Masters’ students and/or to joint publications. On a multilateral scale, a major project is the cooperation with NLR, Estec, NASA (and some smaller European firms) on the design and exploitation of an experimental satellite: SloshSat. Further, we have joined an EC-funded network on ‘Liquid management in space’ (coordinated by the University of Bremen; approved in 1999 and starting in 2000). Also approved in 1999 is the 5th-framework project ‘ASICA’ on aircraft-cabin climate (coordinator Cerfacs, Toulouse); our group acts a subcontractor to NLR, the project will start early 2000. Another European cooperation is the INTAS project ‘Bubbly flows’ (coordinator INPG, Grenoble).

6.7 Further information

Veldman is member of the Scientific Committee NIVR-NLR, appointed by the Netherlands Agency for Aerospace Programs (NIVR). Further he is a scientific consultant at the National Aerospace Laboratory NLR (Amsterdam). He also is member of the editorial boards of Journal of Engineering Mathematics and of Computers and Fluids.

Hoogstraten is editor of the Journal of Engineering Mathematics.

In 1999, group members presented a total of 11 lectures on national and international conferences. An animated impression of our research can be found at our website http://www.math.rug.nl/~veldman/cfd-gallery.html.
Water waves can cause heavy damage to offshore platforms, ships and coastal structures, making understand wave impact a major design issue. The research group Computational Mechanics and Numerical Mathematics (programme 6) is developing numerical simulation methods (CFD) with which impact forces can be predicted. The picture shows a big wave smashing over the foredeck of a ship (‘green water’), investigated in cooperation with MARIN. Other free-surface flow research in the group CM&NM concerns, amongst others, liquid management on board spacecraft and biomedical applications involving fluid-structure interaction.
7 Programme 7: Teaching and History of Mathematics

7.1 Programme members

Dr. A. van Streun  
Dr. J.A. van Maanen

7.2 Promovendi, postdocs and long-time visitors

Drs. K.A. Blom (Ph.D. student, IWI-NWO; supervisors: Van Streun and Van Maanen jointly with Broer of programme 3)

Collaborative Ph.D. projects:
J.F. Deinum (Dept. of Educational Studies, RUG; with Van Streun),
B. Zwanenveld (Dept. of Mathematics, Dutch Open University; with Van Streun),
E. Welling (TU Twente; with Van Streun),
B. van Amerom (Dept. of Mathematics, Utrecht; with Van Maanen), S. la Bastide-van Gemert (Dept. of History, RUG; with Van Maanen)

7.3 Research Program

The programme ‘Teaching and History of Mathematics’ studies the overlap of the fields ‘Teaching’ and ‘History’ as well as both fields separately.

In the overlap the central topic is the integration of the history of mathematics in mathematics teaching. Currently research is done and set out for the next few years about the question whether introducing historical elements in the teaching of the standard curriculum at secondary school may improve this teaching. Blom focuses on this question with respect to the domain of geometry, and Van Amerom at Utrecht, who is in the final stage of the research, with respect to algebra. This topic is of great international concern, since the 4-years Study of the International Commission on Mathematics Instruction (ICMI) is devoted to the “Role of the History of Mathematics in the Teaching and Learning of Mathematics”. Van Maanen is co-chairing this large project, which will report in a state-of-the-art book to the International Congress on Mathematical Education (ICME-9, in Tokyo in the year 2000), to be published by Kluwer Academic Publishers (Dordrecht).

As to the separate field of ‘Teaching’ the present changes in Dutch secondary ed-
ucation require substantiation and critical evaluation from the side of educational research. Our programme contributes considerably to this process, as can be seen in the various topics that have been researched, and that will be continued:

- ‘Teaching plane geometry’. The report by Jacolien van Dijk and Iris Gulikers, two former students of Van Streun, has had a major influence on the development of the new national vwo-curriculum. Also Van Streun has implemented results of research done in our programme in a widely used series of secondary school books *Moderne Wiskunde*.

- The effects of graphic and symbolic calculators and software (including Cabri and Derive) in secondary education and the development of computer aided instruction (joint work with GION, the Institute of Research in Education, University of Groningen).

- Development and research of Instructional Design Models to improve the concept of the “Studiehuis” in havo-vwo (the ‘Study-house’ involves a lot of independent seat work and self-reliant learning next to classroom teaching, and is introduced in the three final years of Dutch secondary schools as of 1998).

- ‘Optional subjects’. The curriculum change in the upper secondary school (vwo) re-introduces optional subjects. The research topics involved are: “What subjects are suitable for the stream preparing for academic studies in the domain of Nature and Health?” and “What type of resource material should be available?”

The separate field of ‘History’ is continued at a slightly lower pace, because of the increasing attention for the overlap with ‘Teaching’. The themes that were researched in recent years (the Bernoulli family, the pre-history of the calculus, mathematics in the Netherlands in the 17th and 18th century), have been of continued interest, and resulted in two publications during 1999.

7.4 Research subjects

K.A. Blom: Re-invention of geometry; the effect of introducing historical elements in the teaching of geometry; themes from the history of geometry, design and evaluation of classroom materials in which geometry is taught with the use of historical elements.
J.A. van Maanen: Role of the History of Mathematics in the Teaching and Learning of Mathematics (ICMI study); the relation between the history of mathematics and mathematical education in the Netherlands.


7.5 Publications

Articles in scientific journals


Other publications


7.6 Research - specific aspects

The project ‘Reinvention of geometry’ is financed for 50% by a NWO-grant.
The research related to the improvement of mathematics teaching has considerable impact within society, which is acknowledged by the involvement of the researchers in the design of school books, the discussions about the mathematics curriculum, and the national mathematics examinations.

### 7.7 Further information

Van Maanen is member of the International Commission on the History of Mathematics (Dutch representative), chair of the International Study Group on the Relations between History and Pedagogy of Mathematics, co-chair of the ICMI-Study on the ‘Role of the History of Mathematics in the Teaching and Learning of Mathematics’, member of the board of Gewina (the Dutch Society for the History of Medicine, Mathematics, Natural Sciences and Technical Sciences), member of the Programme Committee of the ‘Nationale Wiskundedagen’, member of the Programme Committee of the annual ‘CWI-Vakantiecursus’, chair of the governmental committee that approves of the national Dutch mathematics examinations (havo-B and vwo-B), and co-chair of a ‘Working Group for Action’ at the 9th International Congress on Mathematical Education (ICME–9, Tokyo 2000).

The teaching tasks of Van Streun, together .8 fte (full-time-equivalent), are allocated at the Faculty level (Dept. of Initial Science Teaching) and at the Groningen UCLO (Central Institute of Teacher Education and Training). His research commitment is .2 fte.
8 Programme 8: Fundamental Computing Science

8.1 Programme members

Prof.dr. W.H. Hesselink
Prof.dr. G.R. Renardel de Lavalette
Dr. R. Smedinga
Dr. J. Terlouw

8.2 Promovendi, postdocs and long-time visitors

Drs. H.P. van Ditmarsch (Ph.D. student, 0.2 fte IWI; supervisor: G.R. Renardel)
Drs. J.E. Jonker (promovendus; supervisor: W.H. Hesselink)
Drs. B.P. Kooi (Ph.D. student, IWI; supervisor: G.R. Renardel)
Drs. E.H. Saaman (external promovendus, ECCOO; supervisor: G.R. Renardel)
Dr. A.A. Al-Falou (postdoc, EU-TCM, since October 1999; supervisor R. Smedinga)
Dr. S. Lifsches (postdoc, EU-TCM, until May 1999; supervisor: R. Smedinga)

8.3 Research Program

The objective of this programme is to contribute to the understanding of the logical and mathematical foundations of computing science and to realize a two-way transfer between this fundamental research and more applied subdisciplines of computing science.

In the foundational research of this programme, the following themes are studied: lambda calculus, dynamic logic, equational reasoning, fixpoint semantics.

Lambda calculus is an abstract theory of computation: our research focuses on specific behavioural properties of computations, e.g. involving termination.

Dynamic logic is an extension of traditional predicate logic so as to reason over the effect of change (e.g. by executing a computer programme or by adding information to a knowledge base); we try to unify different proposals for such a logic.

Equational reasoning is a well-known kind of mathematical reasoning that is practised e.g. in algebra and in many correctness proofs. Its standard formalisation is equational logic, a simple but very general reasoning system that is often used in computing science, e.g. in algebraic specification and rewrite systems (Mathematica is a well-known example). Proof theory for this logic, addressing structural properties of equational proofs, hardly exists, and we try to fill in the gap.
Fixpoint semantics is the elegant and powerful approach of defining the meaning of computer programs in mathematical terms. Dealing with recursion is the difficult part, and this involves the use of fixed points of certain functions, i.e. values $x$ satisfying $f(x) = x$.

The following research projects have a stronger focus on applicability: programming methodology, formal specification, hybrid systems.

For programming methodology, we aim to contribute to the development of an effective design methodology for computer programs (sequential, parallel, and distributed). The methodology should result in a rational adaptable design with complete arguments for its correctness; when the requirements and specification change afterwards (as is often the case), the design must allow modification accordingly.

Formal specification is part of the upcoming formal methods approach in software engineering: we develop a compact and general formal specification language and software tools for developing and checking formal specifications, and apply it in case studies.

Hybrid systems are dynamical systems that combine discrete and continuous aspects, which are often studied apart. In the TMR-project ALAPEDES (The ALgebraic Approach to Performance Evaluation of Discrete Event Systems) we continued research on the mathematical description of these systems and their control.

### 8.4 Research subjects

**A.A. Al-Falou**: ALAPEDES project on hybrid systems control.

**H.P. van Ditmarsch**: Logical analysis of knowledge games.

**W.H. Hesselink**: soundness proof for the correctness rule for recursive procedures with local variables, and a mechanical proof for the correctness of Bloom’s register implementation; algorithms for the Euclidean distance transform; extendable concurrent hash tables.

**J.E. Jonker**: delay-insensitive synchronisation and on thread synchronisation.

**B.P. Kooi**: logical analysis of reasoning with uncertain and incomplete knowledge, the extension of epistemic logic with probabilities.

**S. Lifschis**: Hybrid systems and related control problems using tree automata.

**I. Polak**: Application of theorem provers to reasoning about DI-algebra; the use of normal forms of expressions to decide equality.

**G.R. Renardel**: Novel approach to proof theory (with a first application in equational logic) and on an alternative semantics for modal and dynamic logic.

**E.H. Saaman**: Definition of the specification language AFSL, including tool development and case studies.
**R. Smedinga**: (Logical) discrete event dynamical systems and hybrid systems; object oriented techniques in relation to discrete event systems.

**J. Terlouw**: Lambda calculus and type theories, proofs for strong normalisation; application of type theory in the area of functional and imperative programming.

### 8.5 Publications

#### Contributions to books


#### Articles in scientific journals


#### Articles in conference proceedings

- H.P. van Ditmarsch, The logic of knowledge games: showing a card. In: *Proceedings of the Netherlands/Belgium Conference on Artificial Intelligence (BNAIC 99)*. Maastricht University, 1999, 35–42

Other publications


8.6 Research - specific aspects

External support

The HCM-project DeStijl (Design and Specification through Interfacing and Joining Languages), with Renardel as programme leader, came to an end in 1999. The final report has been accepted by the EU Commission in Brussels.

The participation in the TMR-project ALAPEDES (The ALgebraic Approach to Performance Evaluation of Discrete Event Systems), with Smedinga a local project leader, was continued with a new postdoc (Al-Falou) after the leave of Lifsches. The duration of the project has been extended until October 2001.

The project proposal *Requirements Engineering for medical realtime advice systems* by Renardel and Ballast (RUG, Anesthesia) has been approved by NWO for financial support (406 kF). It involves a postdoc (2 years) and a Ph.D. student (4 years), and it will start in 2000.

8.7 Further information

Renardel is chairman of the board of the Dutch Research School in Logic, and member of the Board of the Dutch Society for Theoretical Computer Science. He was also co-organiser of the Symposium on Constructivism in Mathematics and Computing (Noordwijkerhout, 16-18 September 1999).

Smedinga is member of the TMR-project ALAPEDES (ALgebraic Approach to Performance Evaluation of Discrete Event Systems).
The presence of a grating in the upper left image (a) suppresses the perception of a triangle in this image: while the two triangle sides which have orientations different from the orientation of the grating are clearly seen, the line segment which makes the third side of the triangle and has the same orientation as the grating is ‘lost’ in the grating. As illustrated by the upper right image (b), the triangle is well perceived if the other lines of the grating are removed. People are more likely to decompose the input image (a) into a grating and two lines (c – d) rather than a grating and a triangle (e – f).

This psychophysical effect can be explained by a model proposed by Petkov and Kruizinga according to which visual information is split into form and texture information in the early, preattentional stages of the visual system (Biol. Cybernetics, vol. 76, no. 2, 1997). The anatomical and physiological bases of these channels are sets of so-called bar and grating cells. The texture processing properties of grating cells were studied by Kruizinga and Petkov of programme 9 (IEEE Trans. on Image Processing, vol. 8, no. 10, Oct. 1999).
9 Programme 9: High Performance Computing and Imaging

9.1 Programme members

Dr. H. Bekker (0.2 fte)
Prof.dr.sc.tech. N. Petkov
Dr. J.B.T.M. Roerdink
Dr. G. Vegter
Dr. M.H.F. Wilkinson (since July 1, 1999)

9.2 Promovendi, postdocs and long-time visitors

C. Grigorescu (Ubbo Emmius Ph.D. student; supervisor Petkov)
S.E. Grigorescu (Ubbo Emmius Ph.D. student; supervisor Petkov)
Dr. A.L. Hagen (postdoc, NWO; supervisor Vegter jointly with Broer)
P. Kruizinga (researcher, NWO, till August 31, 1999; postdoc BCN since September 1, 1999; supervisor Petkov)
A. Meijster (researcher, IWI, till July 1, 1999; supervisor Roerdink)
L. Muresan (Ph.D. student; supervisor Roerdink)
M.A. Westenberg (Ph.D. student; supervisor Roerdink)
M.H.F. Wilkinson (postdoc, European Commission, till July 1, 1999; supervisor Roerdink)

Collaborative Ph.D. projects: G.A. Lunter and M. van Noort of programme 3 and R. Vidunas of programme 1 (all with Vegter)

Promotions (Ph.D. defenses)


9.3 Research Program

Part of the research activities concerns the development of computer models of the visual cortex. The purpose of this research is to understand how man sees and to employ principles of natural vision in artificial vision systems. New work in this direction was the modelling of the function of infero-temporal neurons by graph-
based methods. The properties of various texture processing operators, among them the grating cell operator, were studied and compared. A new quantitative comparison method, which is based on Fisher’s criterion and Mahalanobis distance, was applied for this purpose. The results were presented at ICPR’99 and published in IEEE Transactions on Image Processing.

In the area of visualization, research has concentrated on the use of wavelets for visualization of 3D data sets. Frequency domain volume rendering by a combination of wavelets with the X-ray transform was investigated, and extended by with view interpolation for enhanced efficiency. A new approach to the splatting volume rendering technique, called two-stage splatting, was developed, and used in multiresolution volume visualization through hierarchical wavelet splatting. In the area of morphological image processing, an exact linear-time algorithm for the Euclidean distance transform was developed, efficient algorithms for morphological area and attribute operations were developed, and similarity measures based on Minkowski addition were studied. In the ADIAC project on automatic identification of diatoms, diatom contour analysis using morphological curvature scale spaces were studied. A new PhD project was started on pattern detection and estimation in functional neuroimaging, within the context of GNIP (Groningen NeuroImaging Project) in collaboration with the Academic Hospital (AZG) and the local research school BCN (Behavioural, Cognitive and Neurosciences). Another PhD project on the application of wavelets in functional neuroimaging, funded by NWO and part of a national project on ‘Wavelets and their Applications’, will start in 2000.

Recent research in the area of geometric computing is focused on the design of algorithms for representation, manipulation and visualization of curves, surfaces and general manifolds, in the tradition of Computer Aided Geometric Design. On the theoretical side progress has been made in the study of spline spaces. A general framework has been developed, generalizing and simplifying several of the classical results and algorithms of, e.g., De Casteljau and De Boor in CAGD. This research is applied in the project on computation and visualization of invariant manifolds in dynamical systems (cooperation with H.W. Broer, M. van der Put and co-workers), and in ongoing research with groups in France (J.-D. Boissonnat, M. Pocchiola).

An important new direction of research called bioinformatics is emerging in collaboration with groups in Departments of Biology and Chemistry. Bioinformatics involves application of pattern recognition, visualisation, data mining, and simulation in biology and biochemistry, especially in fields concerned with understanding interactions between biomolecules and regulatory networks within cells. A proposal for a new Centre for Bioinformatics has been drawn up together with the
9.4 Research subjects

H. Bekker: problems related to similarity measures based on methods from mathematical morphology (Minkowski addition).
C. Grigorescu: Graph concepts were applied to the problem of modelling inferotemporal neurons.
S.E. Grigorescu: A new method for the comparison of texture operators and features, previously developed in the group, was applied to a broader class of texture operators.
A.L. Hagen: algorithms for invariant manifolds, numerical and computational issues; general applicability and visualization.
P. Kruizinga: texture analysis properties of grating cells.
A. Meijster: parallel implementation of morphological image operators on shared memory computers.
N. Petkov: design of hypersystolic parallel algorithms; non-linear texture operators; a graph-based approach to texture discrimination.
J.B.T.M. Roerdink: mathematical morphology; parallel watershed algorithms; wavelet based volume rendering; medical image processing.
M.A. Westenberg: scientific visualization (direct volume rendering) using wavelets.
G. Vegter: geometric computing and modeling; algorithms and schemes for curves, surfaces and manifolds; symbolic and numerical methods; visualization.

9.5 Publications

Dissertations


Contributions to books

Articles in scientific journals


Articles in conference proceedings


A satellite conference of the 52nd ISI session in Helsinki, August 6–9, Uppsala, Sweden, book of abstracts, 1999, p. 27. (also submitted to Pattern Recognition Letters)

Other publications


Patents


9.6 Research - specific aspects

The National Research Foundation (NWO-SWON) granted a Ph.D. position to Roerdink for a project on ‘Wavelet-Based Signal Detection in Functional Neuroimaging’ (200 kF). This is part of a national research project on Wavelets and their Applications (other partners H. Heijmans, CWI, H. ter Morsche, TUE, and C. Traas, UT).

With respect to the project ADIAC - Automatic Diatom Identification and Classification, funded by the European Commission, local project leader Roerdink, Wilkinson has been funded until July 1, 1999, when he was appointed as assistant professor at IWI. A Ph.D. student, to be appointed in early 2000, will continue the research, partially funded by the EC budget.

Vegter participates, with several groups in France (INRIA Lorraine, INRIA Rhône-Alpes, INRIA Sophia Antipolis, Ecole Normale Supérieure Paris), in a joint project
(Action de Recherche Coopérative) on ‘Three dimensional visibility: theory and applications’, which has been awarded 450 k francs (150 kf) for 2000-2001.

The summer school on Architecture and Programming of Parallel and High Performance Computers, financed by the EU, was given for the third time in July 1999 (Petkov and Wilkinson). It attracted 21 young researchers from 8 EU countries (budget 1999 – 65 kf).

9.7 Further information

Petkov is member of editorial boards of Parallel Computing (North Holland), Parallel Algorithms and Applications (Gordon and Breach) and Real-Time Imaging (Academic Press). He was member of the programme committee of ParCo’99 (International Conference on Parallel Computing), August 1999, Delft, The Netherlands. Petkov took part in a fact finding trip to Japan in connection with the selection of a new national supercomputer on behalf of Foundation National Computing Facilities of NWO. He also participated in the preparation of the new ICT trend rapport of Foundation SURF, the collaboration body of Dutch universities in the area of ICT.


Vegter was invited as a one-month visiting professor at the Ecole Normale Supérieure of Paris (July 1999).

Wilkinson is sub-topic coordinator on model systems for studying the colonization resistance of the gut ecosystem, within European concerted action CA98-4230, headed by Professor Bourlioux, Université de Paris-Sud.
10 Programme 10: Systems Technology

10.1 Programme members

Prof.dr.ir. L.J.M. Nieuwenhuis (extra-ordinarius) (till April 1, 1999)
Dr.ir. J.A.G. Nijhuis
Prof.dr.ir. L. Spaanenburg

10.2 Promovendi, postdocs and long-time visitors

Ir. S. Achterop (promovendus; supervisor: Spaanenburg)
Drs. W.C. Mallon (Ph.D. student, IWI; supervisors: Udding, Spaanenburg)
Drs. J.H. Stevens (Ph.D. student, Holec; supervisors: Nijhuis, Spaanenburg)
Drs. M. van Veelen (Ph.D. student; supervisors: Nijhuis, Spaanenburg)

Long-time visitors

W. Peng Msc. (Zhengzhou Institute, TCC; supervisor: Nijhuis)

Promotions (Ph.D. defenses)


10.3 Research Program

The accelerated pace of microelectronic developments makes information-processing systems increasingly hard to design, test and maintain. Such systems will be based on distributed computing, either in a network of computers or in an ensemble of computing elements. The processed data range from sensors to multi-media systems and are distributed over the system parts. The programme aims to research tools, methods and standards that allow to raise the quality of such designs.

In the section “Intelligent modeling” the structured design of intelligent systems,
based on neural networks and fuzzy logic, is researched. The main thrust is currently in the on-line handling of information from a variety of knowledge sources for natural processes. The nature of static learning problems is identified by Barakova, while Venema has chartered similar issues in time-series prediction.

This line of research has successfully spawned a patent on fuzzy/neural knowledge merging. In a further advance towards modular intelligent structures, Achterop is establishing the requirements for neural objects in collaboration with tenBerg (Philips Research) and Diepenhorst is elaborating the hardware relevance, while Jansen is looking at fuzzy neural networks.

Another and related direction in the research on “Intelligent modelling” aims to extract knowledge from images through the use of fuzzy logic and neural networks. It has been shown that images specified by morphological expressions can be transformed to cellular neural networks. This work is progressing slowly towards a further automation of the technology mapping process as the construction of the VIPUR license-plate recognition system has taken much effort. Meanwhile, Stevens is looking at poor quality images, as are often resulting from non-obtrusive medical monitoring. Two patent applications on annealing de-fuzzification have been filed. Recently, attention moved to exploiting the same technology in document understanding.

Where so far system complexity was viewed as a problem in intelligent information processing, the section “Embedded systems” aims to exploit process algebras for the formalisation of inter-process communication. Mallon has extended his operational semantic for DI-algebra towards the symmetrical DI-model of Verhoeff. He has created a number of automated design & verification tools to support other researchers. With the coming of Lang the focus will shift in the direction of intelligent agents with embedded implementations.

In the long run, the formal and the intelligent approach are meant to become ingredients in the design of complex multi-media and/or data-mining systems. Such a complex assembly will occur in the maturization of Electronic Commerce. The coming years will therefore show an in-flow of the theoretical developments in formal communication and local intelligence to the benefit of managing process interaction in distributed computing.

10.4 Research subjects

S. Achterop: functional languages for the CoDesign of microelectronic systems.
W.C. Mallon: design of an operational semantic for DI-algebra and extension of the symmetrical DI-model of Verhoeff.


W. Peng: DSP code generation for intelligent software.

L. Spaanenburg: intelligent software agents for network computing, such as large-scale data-mining in Electronic Commerce.

J.H. Stevens: intelligent systems for the 3-D diagnosis of scoliosis patients; dynamic optimisation of geometrical objects with fuzzy relations.

M. van Veelen: on-line training of neural networks.

10.5 Publications

Dissertations


Contributions to books


Articles in scientific journals


Articles in conference proceedings


Other publications


Patents


10.6 Research - specific aspects

Externally funded research

The VIPUR system for real-time license-plate recognition has been successfully presented to the Dutch government during the field-tests at Utrecht and will be commercialized by Volker-Stevin.

External contacts

In November 1999, Spaanenburg paid a visit to the University of Iasi to arrange a further exchange of M.Sc. and Ph.D. students and gave seminars.

W. Peng received a scholarship from TCC to finance his scientific work at Groningen University.

10.7 Further information

Nijhuis received an invitation for an invited paper for the CASYS’99, held in Namen (Belgium). He is member of the editorial board of PT Embedded Systems
(Uitgeverij tenHagen&Stam); he is a member of "Begeleidingscommissie ICT sectordoorlichting Noord"; he is RUG representative at TCN.

Spaanenburg is on the Executive Committee of MicroNeuro; Institute for Programming and Algorithmics (IPA); and Vereniging Artificiële Neurale Netwerken (VANN, president). He is on the Programme Committee of the Belgisch/Nederlandse AI Conferentie BNAIC; the VDI Fachtagung "Computational Intelligence und industrielle Anwendungen" and KESS’2000. He is on the Editorial Board of VLSI Design Journal (Gordon and Breach Publishers). He is also member of KIVl Raad voor Wetenschap en Techniek; VDI/GMA Fachausschuss 4.5 "Neuronale Netze"; ITG Fachgruppe 8.4.9 "Mikroelektrotechnik neuronaler Netze"; Colleghie Ubbo Emmius; and IEEE TC on CNN.

Van Veenen has received a Best Presentation Award during the International Joint Conference on Neural Networks, Washington D.C.