Mathematical Institute

Annual Report 2004

Leiden University

MATHEMATICAL INSTITUTE

Leiden University

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Introduction

On March 3, our completely renovated building received a new name, the Snellius. The building owes its new name, Snellius, to Willebrord Snel van Royen (1580 - 1626) who was a professor of Mathematics at the Universiteit Leiden. The official opening was done by our Chairman of the Board of Governors, AW Kist. Gerrit van Dijk gave a multi-media presentation about the life and work of Snellius. After the ceremony there was a reception in the canteen of the new building.

On October 7, the final report of the international review committee of the VSNU that assessed all mathematical research in the Netherlands appeared. The committee considers our Institute as one of the best in the Netherlands and rates the quality of research on an international scale as `good to excellent'. Two out of three research groups received the highest marks. This assessment is important for the position of our Institute and helped to make it possible to appoint three new professors, Ronald Cramer (Cryptography), Jan Hogendijk (History of Mathematics) and Frank den Hollander (Probability). Together with the prestigious VICI grant awarded to Bas Edixhoven to build up a research group in geometry, we will be able to make a significant step to secure the high quality of research in our Institute in the future. The committee expresses concerns regarding the low number of students in Mathematics in the Netherlands. We share these concerns and in reaction a number of new initiatives – including a newly designed web side – aimed at potential students were initiated. We will report on the progress of these efforts in the future.

On June 18, there was an international symposium on the occasion of the 65th birthday and the retirement of Marc Spijker. After the lectures participants and colleagues were joining together for a dinner. In October, Franz Merkl left our Institute in order to become a full professor at the University of Munich.

In order to mark the 65th birthday and the retirement of Gerrit van Dijk, an international workshop was held in the Lorentz Center from August 23 to 26. Gerrit van Dijk, former dean of the Faculty of Mathematics and Natural Sciences, served our Institute as a scientific director since 1997. During the reception after his fare-well address in the Akademiegebouw, Gerrit van Dijk was appointed `Officier in de Orde van Oranje-Nassau'. As a token of appreciation for all his work for the University, Gerrit van Dijk received a replica of the Snellius quadrant, an item from the collection of Museum Boerhaave. The quadrant will be placed near the entrance of the Snellius. The festivities were concluded with a formal dinner offered by the Mathematical Institute.

We were very pleased to have not only one, but two Kloosterman professors this year. The 2003 Kloosterman professor, Noriko Yui (Queen's University, Kingston, Canada) visited our institute from January 15-March 15.
The 2004 Kloosterman professor, Roger Nussbaum (Rutgers University, New Jersey, U.S.A.) visited our institute during April and May. The Kloosterman lectures were, respectively, given on February 5 and April 29 for a general audience.

On November 25, Peter de Kler, who served the Institute as P&O-advisor for many years, passed

away at the age of 59. Several staff members attended the funeral. He was a very well respected and trusted P&O-advisor capable to resolve complex issues concerning conditions of employment.

In June, the new scientific director of the MI was appointed by our dean Frans Saris. In September, the new scientific director was also appointed as scientific director of LIACS, the Leiden Institute of Advanced Computer Science. Wim Aspers was appointed Institute Manager for LIACS and Fred Bakker became Institute Manager for our Institute. Both will be supported by Thijs Dijks for general affairs.

The annual report starts with two research highlights to stress the mission of the Institute.

Leiden, May 2005
Sjoerd Verduyn Lunel
Scientific Director

Runge-type Diophantine Equations

Let

$$P(X,Y) = \sum_{i=0}^{m} \sum_{j=0}^{n} a_{i,j} X^i Y^j,$$

where $a_{i,j} \in \mathbb{Z}$ and $m > 0, n > 0$, which is irreducible in $\mathbb{Q}[X,Y]$. Let $\lambda > 0$. Then the $\lambda-$leading part of $P, P_\lambda(X,Y)$, is the sum of all terms $a_{i,j}X^iY^j$ of P for which $i + \lambda j$ is maximal. The leading part of P, denoted by $\tilde{P}(X,Y)$, is the sum of all monomials of P which appear in any P_λ as λ varies. Then P satisfies Runge's condition unless there exists a λ so that $\tilde{P} = P_\lambda$ is a constant multiple of a power of an irreducible polynomial in $\mathbb{Q}[X,Y]$. One of the first general results on Diophantine equations is due to Runge [13] who proved the following theorem in 1887.

Theorem. *If P satisfies Runge's condition, then the Diophantine equation $P(x,y) = 0$ has only a finite number of integer solutions.*

We present two examples for which the theorem implies the finiteness of integer solutions. The first example is given by

$$P(X,Y) = X^2 - Y^8 - Y^7 - Y^2 - 3Y + 5,$$

where $P_\lambda(X,Y) = X^2, X^2 - Y^8, -Y^8$ according as $\lambda < \frac{1}{4}, \lambda = \frac{1}{4}, \lambda > \frac{1}{4}$, thus $\tilde{P}(X,Y) = X^2 - Y^8 = (X - Y^4)(X + Y^4)$. The second is

$$P(X,Y) = X(X+1)(X+2)(X+3) - Y(Y+1)\cdots(Y+5),$$

where we obtain that $\tilde{P}(X,Y) = X^4 - Y^6$.

If $P(X,Y) = Y^n - R(X)$ is irreducible in $\mathbb{Q}[X,Y]$, R is monic and $\gcd(n, \deg R) > 1$, then P satisfies Runge's Condition. Masser [9] considered equation $y^n = R(x)$ in the special case $n = 2, \deg R = 4$, and Walsh [19] gave a bound for the general case. In [12] Poulakis described an elementary method for computing the solutions of the equation $y^2 = R(x)$, where R is a monic quartic polynomial which is not a perfect square. Szalay [14] generalized the result of Poulakis by giving an algorithm for solving the equation $y^2 = R(x)$ where R is a monic polynomial of even degree. Recently, Szalay [15] established a generalization to equations $y^p = R(x)$, where R is a monic polynomial and $p | \deg R$.

Several authors (for references see e.g.[1],[2],[5]) have studied the question if the equation $F(x) = G(y)$ has finitely or infinitely many solutions in $x, y \in \mathbb{Z}$, where F, G are polynomials with rational coefficients. Bilu and Tichy [2] completely classified those polynomials $F, G \in \mathbb{Q}[X]$ for which the equation $F(x) = G(y)$ has infinitely many integer solutions. The methods used in [1],[2],[5] are ineffective so they do not lead to algorithms to find all the solutions.

Consider the Diophantine equation

$$F(x) = G(y), \tag{1}$$

where $F, G \in \mathbb{Z}[X]$ are monic polynomials with $\deg F = n, \deg G = m$, such that $F(X) - G(Y)$ is irreducible in $\mathbb{Q}[X,Y]$ and $\gcd(n,m) > 1$. Then Runge's condition is satisfied. Bounds for the sizes of the solutions and algorithms for determining all the solutions were given in [16] and [17].

Theorem. *Let $F, G \in \mathbb{Z}[X]$ be monic polynomials with $\deg F = n \leq \deg G = m$, such that $F(X) - G(Y)$ is irreducible in $\mathbb{Q}[X, Y]$ and $\gcd(n, m) > 1$. Let $d > 1$ be a divisor of $\gcd(n, m)$. If $(x, y) \in \mathbb{Z}^2$ is a solution of the Diophantine equation $F(x) = G(y)$, then*

$$\max\{|x|, |y|\} \leq d^{\frac{2m^2}{d}-m}(m+1)^{\frac{3m}{2d}}(\frac{m}{d}+1)^{\frac{3m}{2}}(h+1)^{\frac{m^2+mn+m}{d}+2m},$$

where $h = \max\{H(F), H(G)\}$ and $H(\cdot)$ denotes the classical height, that is the maximal absolute value of the coefficients.

For any given equation of this type the algorithm works efficiently. Some examples are given in the following table.

Equation	# Solutions	CPU time (sec)
$x^2 = y^8 + y^7 + y^2 + 3y - 5$	4	0.16
$x^3 = y^9 + 2y^8 - 5y^7 - 11y^6 - y^5 + 2y^4 + 7y^2 - 2y - 3$	1	0.75
$x^5 = y^{25} + y^{24} + \ldots + y + 7$	1	5.69
$x^2 = y^8 - 7y^7 - 2y^4 - y + 5$	0	4.79
$x^2 = y^4 - 99y^3 - 37y^2 - 51y + 100$	2	1.83
$x^2 - 3x + 5 = y^8 - y^7 + 9y^6 - 7y^5 + 4y^4 - y^3$	6	0.72
$x^3 - 5x^2 + 45x - 713 = y^9 - 3y^8 + 9y^7 - 17y^6 + 38y^5 - 199y^4 - 261y^3 + 789y^2 + 234y$	1	0.38
$x(x+1)(x+2)(x+3) = y(y+1)\cdots(y+5)$	28	0.23

On the Diophantine equation $x^2 + q^{2m} = 2y^p$

Luca [8] solved completely the Diophantine equation $x^2 + 2^a 3^b = y^n$ in non-negative integers $x, y, a, b, n > 2$. Le [6] obtained necessary conditions for the solutions of the equation $x^2 + p^2 = y^n$ in positive integers x, y, n with $\gcd(x, y) = 1$ and $n > 2$ and p fixed prime. He also determined all solutions of this equation for $p < 100$. In [10] Pink considered the equation $x^2 + (p_1^{z_1} \cdots p_s^{z_s})^2 = 2y^n$ in non-negative integers x, y, $z_1, \ldots, z_s$, n, with $n \geq 3$ and $\gcd(x, y) = 1$, where $p_1, \ldots, p_s$ are distinct prime numbers. He gave an explicit upper bound for n depending only on $\max p_i$ and s. The equation $x^2 + 1 = 2y^n$ in integers $x, y, n > 2$ and $n \neq 4$ was solved by Cohn [4]. The case $n = 4$ was solved earlier by Ljunggren [7]. Pink and Tengely [11] considered the equation $x^2 + a^2 = 2y^n$. They gave an upper bound for the exponent n depending only on a, and completely resolved the equation with $1 \leq a \leq 1000$ and $3 \leq n \leq 80$. Consider the Diophantine equation

$$x^2 + q^{2m} = 2y^p, \tag{2}$$

where $x, y \in \mathbb{N}$ with $\gcd(x, y) = 1, m \in \mathbb{N}$ and p, q are odd primes and $\mathbb{N}$ denotes the set of positive integers. Since the case $m = 0$ was solved by Cohn [4] (he proved that the equation has only the solution $x = y = 1$ in positive integers) we may assume without loss of generality that $m > 0$. If $q = 2$, then it follows from $m > 0$ that $\gcd(x, y) > 1$, therefore we may further assume that q is odd. In [17] Tengely proved the following theorem.

Theorem. *There are only finitely many solutions* (x, y, m, q, p) *of* (2) *with* $\gcd(x, y) = 1, x, y \in \mathbb{N}$, *such that* y *is not of the form* $2v^2 \pm 2v + 1, m \in \mathbb{N}$ *and* $p > 3, q$ *odd primes.*

The question of finiteness in case of $y = 2v^2 \pm 2v + 1$ is interesting. The following examples show that very large solutions can exist.

y	p	q
5	5	79
5	7	307
5	13	42641
5	29	1811852719
5	97	22993575370363230255945284717663 99
13	7	11003
13	13	13394159
13	101	22480363734265533023633690933103706711211958360218401799 9
25	11	69049993
25	47	37829305586052202725400160492296 7
41	31	40103338450160604152604 41

All solutions of (2) with small q^m have been determined in [18].

Theorem. *Let* q *be an odd prime and* $m \in \mathbb{N} \cup \{0\}$ *such that* $3 \leq q^m \leq 501$. *If there exist* $(x, y) \in \mathbb{N}^2$ *with* $\gcd(x, y) = 1$ *and an odd prime* p *such that* (2) *holds, then*

$$(x, y, q, m, p) \in \big\{(3, 5, 79, 1, 5), (9, 5, 13, 1, 3), (55, 13, 37, 1, 3), (79, 5, 3, 1, 5),$$
$$(99, 17, 5, 1, 3), (161, 25, 73, 1, 3), (249, 5, 307, 1, 7), (351, 41, 11, 2, 3),$$
$$(545, 53, 3, 3, 3), (649, 61, 181, 1, 3), (1665, 113, 337, 1, 3), (2431, 145, 433, 1, 3),$$
$$(5291, 241, 19, 1, 3), (275561, 3361, 71, 1, 3)\big\}.$$

Consider (2) with given y which is not of the form $2v^2 \pm 2v + 1$. Since $y = u^2 + v^2$ there are only finitely many possible pairs $(u, v) \in \mathbb{Z}^2$. Among these pairs we have to select those for which $u \pm v = \pm q^{m_0}$, for some prime q and for some integer m_0. Thus there are only finitely many pairs (q, m_0). The method of [18] makes it possible to compute (at least for moderate q and m_0) all solutions of $x^2 + q^{2m_0} = 2y^p$ even without knowing y. Let us consider the concrete example $y = 17$.

Theorem. *The only solution* (m, p, q, x) *in positive integers* m, p, q, x *with* p *and* q *odd primes of the equation* $x^2 + q^{2m} = 2 \cdot 17^p$ *is* $(1, 3, 5, 99)$.

Proof. Note that 17 is not of the form $2v^2 \pm 2v + 1$. From $y = u^2 + v^2$ we obtain that q is 3 or 5 and $m = 1$. This implies that 17 does not divide x. We are left with the equations

$$x^2 + 3^2 = 2 \cdot 17^p,$$
$$x^2 + 5^2 = 2 \cdot 17^p.$$

From the previous theorem we see that there is no solution with $q = 3, m = 1, y = 17$ and the only solution in case of the second equation is $(x, y, q, m, p) = (99, 17, 5, 1, 3)$. □

In case of $q = 3$ Tengely [17] obtained the following result.

Theorem. *If the Diophantine equation $x^2+3^m=2y^p$ with $m>0$ and p prime admits a coprime integer solution (x,y), then either*

$$p\in\{3,59,83,107,179,227,347,419,443,467,563,587,659,683,827,947\}$$

or $(x,y,m,p)=(79,5,2,5)$.

Mixed powers in arithmetic progressions

Fermat claimed and Euler proved that there cannot be four squares in arithmetic progression. Note that there are infinitely many arithmetic progressions of three squares. A few examples

$$1^2,5^2,7^2$$
$$1^2,29^2,41^2$$
$$7^2,13^2,17^2$$
$$7^2,17^2,23^2.$$

In [17] some extensions of Fermat's problem on arithmetic progressions of squares are discussed. All arithmetic progressions with integer terms are described which satisfy one of the following conditions

four consecutive terms are of the form x_0^2,x_1^2,x_2^2,x_3^3 or x_0^3,x_1^2,x_2^2,x_3^2,
four consecutive terms are of the form x_0^2,x_1^2,x_2^3,x_3^2 or x_0^2,x_1^3,x_2^2,x_3^2,
four consecutive terms are of the form x_0^3,x_1^2,x_2^3,x_3^2 or x_0^2,x_1^3,x_2^2,x_3^3.

The author has proved in his thesis that in the first two cases the only coprime solutions are the trivial ones and in the third instance the complete solution is given by

$$(x_0,x_1,x_2,x_3)\in\{(-2t^2,0,2t^2,\pm4t^3),(t^2,\pm t^3,t^2,\pm t^3)\}$$

for some $t\in\mathbb{Z}$ or

$$(x_0,x_1,x_2,x_3)\in\{(\pm4t^3,2t^2,0,-2t^2),(\pm t^3,t^2,\pm t^3,t^2)\}$$

for some $t\in\mathbb{Z}$, respectively. We sketch the proof of the latter result.

Let x_0^3,x_1^2,x_2^3,x_3^2 be consecutive terms of an arithmetic progression with $\gcd(x_0,x_1,x_2,x_3)=1$. We have

$$\begin{aligned} x_1^2&=\frac{x_0^3+x_2^3}{2},\\ x_3^2&=\frac{-x_0^3+3x_2^3}{2}. \end{aligned}\tag{3}$$

We note that $x_2=0$ implies $x_0=x_1=x_2=x_3=0$. Assume $x_2\neq0$. Then we obtain from (3) that

$$\left(\frac{2x_1x_3}{x_2^3}\right)^2=-\left(\frac{x_0}{x_2}\right)^6+2\left(\frac{x_0}{x_2}\right)^3+3.$$

Thus it is sufficient to find all rational points on the curve $Y^2=-X^6+2X^3+3$. Using Chabauty's [3] method Tengely found all rational points on this curve.

Theorem. *Let $\mathcal{C}$ be the curve given by*

$$Y^2 = -X^6 + 2X^3 + 3.$$

Then $\mathcal{C}(\mathbb{Q}) = \{(-1, 0), (1, \pm 2)\}$.

Corollary. *If $x_0^3, x_1^2, x_2^3, x_3^2$ are consecutive terms of an arithmetic progression, then $(x_0, x_1, x_2, x_3) \in \{(-2t^2, 0, 2t^2, \pm 4t^3), (t^2, \pm t^3, t^2, \pm t^3)\}$ for some $t \in \mathbb{Z}$.*

Proof. The point $(-1, 0)$ is on the curve $Y^2 = -X^6 + 2X^3 + 3$, hence $\frac{x_0}{x_2} = -1$ and $2x_1x_3 = 0$. It easily follows that $x_0 = -2t^2, x_1 = 0, x_2 = 2t^2, x_3 = \pm 4t^3$ is the only possible solution of the problem. In case of the other two points $(1, \pm 2)$ we have $x_0 = x_2$, which implies $x_0^3 = x_1^2 = x_2^3 = x_3^2$. Thus $x_0 = x_2 = t^2$ and $x_1 = x_3 = \pm t^3$ for some $t \in \mathbb{Z}$. □

The above mentioned results are part of a larger project of Nils Bruin, Kálmán Győry, Lajos Hajdu and Szabolcs Tengely to be published later which yields that there are no non-trivial arithmetic progressions of length four of coprime positive integers consisting of squares and cubes.

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Adaptive numerical methods for PDEs with singularities

J.F. Williams

Abstract

The aim of this note is the briefly sketch the problem of blow-up in parabolic PDEs and an adaptive numerical procedure for its simulation. Details of a scale-invariant r-adaptive procedure are discussed as well as application areas suitable for this approach.

1 Introduction

A wide variety of physical problems may be modelled by semilinear parabolic equations of the form

$$\begin{aligned} u_t &= \nabla^2 u + f(t,x,u,\nabla u), && x \in \Omega \times \mathbf{R}^+ \\ u(x,t) &= g(x,t), && x \in \partial\Omega \times \mathbf{R}^+ \\ u(x,0) &= u_0(x). \end{aligned} \tag{1}$$

A common example is for u to represent the concentration of a reactant such as a fuel diffusing through the domain Ω while at the same time undergoing a reaction modelled by f. For more complicated models of media sometimes nonlinear diffusion effects are important leading to the quasilinear problem

$$\begin{aligned} u_t &= \nabla \cdot D(\nabla u) + f(t,x,u,\nabla u), \qquad x \in \Omega \times \mathbf{R}^+ \\ u(x,0) &= u_0(x) \geqslant 0. \end{aligned} \tag{2}$$

supplemented by either boundary conditions on $\partial\Omega$ or else a free boundary condition at the level set $u(x,t) = 0$. Problems of the form (1) and (2) are well studied for the past 70 years from the modelling, analysis and computational standpoints [9].

Recently, examples of problems with higher-order spatial derivatives have also been introduced and studied. For instance when $n > 0$

$$\begin{aligned} u_t &= -\nabla(u^n(\Delta\nabla u + f(u,\nabla u))) \qquad x \in \Omega \times \mathbf{R}^+ \\ u(x,0) &= u_0(x) \geqslant 0. \end{aligned} \tag{3}$$

can model the flow of a thin film with height $u(x,t)$ moving on a substrate under the effects of surface tension with the term f representing body forces. Again this equation has associated free boundary conditions or else fixed boundary conditions (for example when $n = 0$). See the papers [2, 4] and the references therein for typical examples.

While the tools for the analysis of each of these problems differ dramatically, in certain parameter regimes they do share some key solution behaviours. In particular, all can exhibit finite-time blow-up wherein for certain parameters and initial conditions the solutions are not defined globally in time but rather that there exists a finite $T < \infty$ such that

$$\lim_{t \to T^-} ||u(\cdot,t)|| = \infty \quad \text{and} \quad ||u(\cdot,t)|| < \infty \ \ \forall t < T.$$

Here $\|\cdot\|$ is a suitable normsuch as the $L^\infty-$ norm of the solution or a derivative.

1.1 Finite-time blow-up

The dynamics in the blow-up regime are dominated by scaling invariant operators where all terms balance — if they did not they would be of vanishing importance as blow-up is reached. This motivates the examination of seemingly special cases but which are canonical. In the particular case that f is a mononomial:

$$f(y) = y^p, \qquad p > 1$$

each of these equations (1)-(3) is invariant under a group rescaling of the form

$$t \mapsto \lambda t, \quad x \mapsto \lambda^q x, \quad u \mapsto \lambda^{-r} u, \quad \lambda > 0, r > 0, q \in \mathbf{R}. \tag{4}$$

The exact structure of the rescaling depends on whether the equation is of semi- or quasi-linear type. For example, (1) is invariant under the group rescaling

$$t \mapsto \lambda t, \quad x \mapsto \lambda^{1/2} x, \quad u \mapsto \lambda^{-1/(p-1)} u. \tag{5}$$

A special case of (3) is the unstable thin-film equation

$$u_t = -(u u_{xxx} + (u^p)_x)_x$$

which is invariant under

$$t \mapsto \lambda t, \quad x \mapsto \lambda^{(p-2)/2(2p-3)} x, \quad u \mapsto \lambda^{-1/(2p-3)} u.$$

The spatial character of blow-up is determined by the sign of the rescaling exponent for the spatial variable (q in 4). If $q < 0$ the rescaled variable is spreading which leads to

global blow-up, if $q = 0$ then there is no spatial rescaling as the solution grows leading to regional blow-up and if $q > 0$ then there is focussing to single-point blow-up. It is this last case that we are most interested in.

Associated to scale invariance is the concept of *similarity solution*. That is in certain cases many of the examples mentioned thus far have solutions with the simple form

$$u(x,t) = \frac{1}{(T-t)^r}\varphi(y), \qquad y = \frac{x}{(T-t)^q}$$

(or, in some cases, a generalization of this). These solutions are not arbitrary but rather in many examples are global attractors. More generally, analysis of blow-up solutions is studied in rescaled variables of the form

$$\theta(y,\tau) = (T-t)^r u(x,t), \qquad y = \frac{x}{(T-t)^q}, \qquad \tau = -\ln(T-t). \tag{6}$$

In the case of (1) this leads to a problem of the form

$$\theta_\tau = \nabla_y^2\theta + \theta^p - \frac{1}{p-1}\theta - \frac{1}{2}y\theta_y$$

plus suitable boundary conditions which enforce $\lim_{y\to\infty}\theta(y,\tau) = 0$. Thus while the problem (1) may be posed on a finite physical domain, any finite boundary conditions on $u(x,t)$ lead to conditions at infinity for $\theta(y,\tau)$.

1.2 A brief history of the numerical simulation of blow-up

One of the fundamental questions in the study of finite-time blow-up is to determine the existence or non-existence of similarity solutions. Traditionally this research has initially been guided by careful numerical computation. Unfortunately, in this area there have been many false starts and incorrect conclusions have initially been drawn for many problems. Typically, the first convincing numerical simulations have been performed with methods specifically designed for a single equation with an understanding of the expected behaviour. In this paper, we shall present a method appropriate for the study of all these problems and more for which no information of the structure of specific solutions is required, and for which relative error estimates may be derived which are independent of the solution magnitude. These relative error estimates give one some faith in the numerically computed similarity solutions as a relative error estimate for the computed solution translates to an absolute error for the rescaled solutions. This is especially important for critical cases where exact similarity structure is unavailable such as the semilinear heat equation, the nonlinear Schrödinger equation in two dimensions, harmonic maps, chemotaxis in two

dimensions and for problems where classical analytic techniques do not assist in proving existence or non-existence of certain types of behaviour such as in typical higher-order models and some nonlinear wave equations. Accurate and reliable numerical simulation of singular behaviour is both difficult to carry out and hard to assess. Unfortunately, it is precisely in those cases when numerical methods are most useful that there is no rigorous justification of those methods. There are even numerous examples in the literature of adaptive methods giving the *wrong* behaviour precisely in those critical cases where the asymptotics are the most difficult and rigorous results are not available.

Our goal for the remainder of this paper is to describe the use of *scale-invariant* $r-$adaptive numerical methods for the resolution of single-point finite-time singularities. Much of the analysis will be for the augmented system generated by using $r-$adaptivity in the case of canonical blow-up structures. Demonstrations of the utility of such methods may be found in [5, 4, 10].

2 Generic structure of semilinear blow-up profiles

Throughout the remainder of this paper we will consider only examples which exhibit single point finite-time blow-up. This is because little or no spatial adaptation is required for global and regional blow-up as the governing dynamics occur on a constant spatial scale as the blow-up time is approached. Moreover, we will consider problems only in one (possibly radial) dimension. While the adaptive strategy required for higher dimensions is slightly more complicated, the general ideas and philosophy remain unchanged for working on problems of this type. It should also be noted that from the perspective of adaptivity for blow-up semi-linear problems are typically harder than quasi-linear ones due to the structure of the final time profiles.

To illustrate our ideas we will concentrate our analysis on a generic semilinear problem of the form

$$\begin{aligned} u_t &= \frac{\partial^2 u}{\partial x^2} + u^p, \ x \in (0,L) \times (0,T) \qquad m \geqslant 1, p > 1, \\ u(x,0) &= u_0(x) \geqslant 0, \\ u_x(0,t) &= 0, u(a,t) = 0. \end{aligned} \tag{7}$$

Under suitable conditions of f this equation is invariant under the rescaling (5). Under the change of variable (6) with unknown blow-up time T our generic semilinear wave equation

takes the form

$$\theta_\tau = \frac{\partial^2 \theta}{\partial y^2} + \theta^p - \frac{1}{(p-1)}\theta - \frac{1}{2} y \theta_y. \tag{8}$$

Blow-up at time T in the original variables now corresponds to stabilization as $\tau \to \infty$ to a non-zero stationary state of (8). Denoting such a solution as $\varphi(y)$ we see that

$$\lim_{t \to T^-} u(x,t) = \lim_{t \to T^-} \frac{1}{(T-t)^q} \varphi\left(\frac{x}{(T-t)^r}\right) = \frac{C}{x^{(p-1)/2m}} \qquad \text{with } \; C > 0.$$

Linearizing steady-state solutions to (8) about the zero solution yields

$$\frac{1}{(p-1)}\varphi + \frac{1}{2} y \varphi' \to 0 \quad \text{ as } \quad y \to \infty$$

which leads to precisely the correct asymptotic profile [9]. Thus blow-up solutions tend to a final-time profile of the form

$$\lim_{t \to T^-} u(x,t) = \frac{C}{x^{(p-1)/2}}, \quad |x| > 0.$$

It is of crucial importance to recognize that resolving solutions to (7) arbitrarily close to blow-up means resolving the solution in the similarity variables on an unbounded domain. Study of the formation of finite-time blow-up to (7) then corresponds to studying stabilization in a Cauchy problem for (8) in the similarity co-ordinates.

Our basic goal is to show that adaptivity based on scaling mimics many of the features of studying the problem in the similarity co-ordinates. This of course a perfectly natural transformation to make and is done routinely in the analysis of such problems, but, recall, that *the exact transformation is not known a priori*. The use of scaling allows the use of the emerging similarity structure to guide the adaptive procedure without building the explicit transformation in to the numerical scheme. This allows for methods applicable to a broad class of problems and greater confidence in the observed dynamics.

Based on the preceeding discussion we will consider a general problem of the form (7) and assume that its solution has the structure

$$u(x,t) \simeq \begin{cases} \dfrac{1}{L(t)^{1/(p-1)}} \varphi\left(\dfrac{x}{L(t)}\right) & x \sim \mathcal{O}(L(t)), \\ \dfrac{C}{x^{(p-1)/2m}} & x \gg L(t), \end{cases} \tag{9}$$

where the length scale $L(t)$ tends to zero as t tends to T. This allows for an analysis beyond simply problems with exact self-similarity.

3 Method of Lines

A common way to numerically approximate parabolic PDEs is through the so-called method of lines (MOL). This procedure first discretizes the PDE in space and then solves the resulting system of ODEs with a time-marching method. This approach has the advantage that existing ODE codes may be used for the time integration. Furthermore, this approach allows one to split errors related to the spatial discretization from those related to the temporal discretization. Introducing the notation

$u(x,t)$ is the exact solution at (x,t),

$U_i(t)$ is the approximate solution at $(x_i(t),t)$ discretized in space only,

W_i^n is the approximation to $U_i(t_n)$ discretized in time only

then an approximation for the error may be made as follows

$$\begin{aligned} \|e\| = \|u(x,t) - W_i^n\| &= \|u(x,t) - U_i(t) + U_i(t) - W_i^n\| \\ &\leqslant \|u(x,t) - U_i(t)\| + \|U_i(t) - W_i^n\| \\ &= \text{spatial error} \quad + \quad \text{temporal error.} \end{aligned} \tag{10}$$

It is for this reason that we will consider adaptive strategies in time and space seperately. Both approaches will be motivated by scale invariance. However, because we are interested in solutions which become unbounded in time we will use a *relative* local truncation error

$$\text{RTOL} = \frac{\|e\|}{\|u\|}_{\infty}.$$

4 Temporal adaptivity

Given that we want to use the scaling structure of the PDE to guide the spatial adaptivity of our problem, next we turn to temporal adaptivity. In the context of singular ODEs with scaling structure this approach has been studied in detail in [6] and we review some details from there now.

4.1 The Sundman transformation

One of the first adaptive strategies for the solution of ODEs is due to Sundman [6]. It is simply the chain rule with a carefully chosen change of variable from *computational* time

to *physical* time. Consider the autonomous ODE

$$\frac{du}{dt} = f(u), \qquad f : \mathbf{R}^n \mapsto \mathbf{R}^n \tag{11}$$

suppose now that we consider the independent variable t to be a function of a new computational variable τ such that

$$\frac{dt}{d\tau} = g(u), \qquad g : \mathbf{R}^n \mapsto \mathbf{R} \tag{12}$$

then under the Sundman transformation (11) becomes

$$\frac{du}{d\tau} = g(u)f(u). \tag{13}$$

This procedure identifies natural coordinates during the course of the procedure and has been shown to generate disrecete solutions to scale-invariant singular ODEs in [6] and also that the discrete equations associated to this inherit (as $\Delta\tau \to 0$) the same stability properties as the original continuous ODE.

The idea is to solve the system (12) and (13) simultaneously using a fixed computational step-size $\Delta\tau$. This then corresponds to solving (11) on a nonuniform mesh in physical time. For example, suppose that we wish to solve

$$\frac{du}{dt} = u^p, \qquad u(0) = u_0$$

then motivated by the scaling we choose

$$g(u) = \frac{1}{u^{p-1}}.$$

Under this transformation the system becomes

$$\begin{cases} \dfrac{du}{d\tau} = u, \\ \dfrac{dt}{d\tau} = \dfrac{1}{u^{p-1}}, \\ u(0) = u_0 \;\; t(0) = 0. \end{cases} \tag{14}$$

Defining $T = (p-1)u_0^{p-1}$ and inverting the solution to this system recovers

$$u(t) = \frac{u_0}{T-t} \qquad \tau = -\frac{1}{p-1}\log(T-t)$$

which, recalling (6) shows τ to be precisely the similarity time variable.

4.2 Advantages of scale-invariance

This aproach can easily be used in concert with exisiting ODE solvers which choose time-steps based on local error estimates. But, now the errors are computed in the computational rather than physical time. This is important for problems with finite-time blow-up as now $\Delta t_n \to 0$ as $t_n \to T$ but $\Delta\tau_n$ need not as the computational blow-up time has been mapped to $\tau = \infty$. In fact, all discretizations in physical will halt when

$$\frac{\Delta t_n}{\sum \Delta t_n} \simeq \epsilon$$

where ϵ is the machine precision. This problem does not occur for the transformed system and blow-up may be computed until $u(\tau)$ is on the order of the largest number recognized by the number system being used [3]. This transformation also makes the error indicator more reliable as blow-up approaches making the total computation much quicker. This method also has exceptional error properties which will be discussed in Section 6.

5 Introduction to r-adaptivity

There are typically three approaches to spatial adaptivity known as p, h and r. In $p-$adaptivity higher-order basis functions are used in certain regions as smoothness permits. A-posteriori error estimates typically motivate $h-$adaptivity wherein meshes are locally refined or coarsened until error tolerance criteria are met. The third approach, $r-$adaptivity, moves a (typically) fixed number of nodes as determined by an auxilliary equation. This can be done statically, regridding whenever given conditions are met, or dynamically through the use of a transformation depending continuously on time. While combinations of the different approaches are possible, dynamic $r-$adaptivity is the focus of this note.

Conceptually, $r-$adaptivity continuously maps a suitable computational space Ω_c into the physical one Ω_p wherein the problem will actually be solved. Typically this is done so as to make the equation 'smoother' or better resolved in the computational space. In one dimension this procedure is well understood, being based on the *equidistribution* principle [7]. In it's integral form one poses a *monitor function* $M(x)$ and determines a bijective mapping $x : \Omega_c \to \Omega_p$ such that

$$\int_0^{x(\xi)} M(s)ds = \xi \int_0^a M(s)ds, \qquad \xi \in \Omega_c = [0,1]. \tag{15}$$

Any sensible discrete approximation to (15) will then have the property that the integral of the monitor function is the same over each computational interval. This has the desirable consequence that if the monitor function is taken to be the local error then this method produces the *optimal* mesh with the total error being minimized. Another, more useful geometric interpretation comes from differentiating (15) with respect to ξ once to recover a mapping with specified Jacobian

$$M(x)x_\xi = \int_0^a M(x)dx,$$

or twice to obtain a computationally more tractable form

$$(M(x)x_\xi)_\xi = 0. \tag{16}$$

5.1 Scale-invariant MMPDEs

An adaptive strategy based using equidistribution is to solve the physical PDE and (16) simultaneously[8]. This determines a system of differential algebraic equations for the solution and the grid. In practice, this system is difficult to start and only neutrally stable in time. An extension of this is to use moving mesh PDEs (MMPDEs) whose steady-state solutions in time are identically (16). This is a parabolic regularization of (16) which leads to smoother mesh trajectories in time.

Many different MMPDEs [8] have been proposed and used and the important properties such as stability and prevention of node crossing are well understood. In the context of blow-up problems we will consider only

$$\varepsilon x_{t\xi\xi} = -(M(x)x_\xi)_\xi, \qquad \varepsilon \ll 1. \tag{17}$$

In this formulation the small parameter ε determines the relaxation timescale for convergence to the stationary profile (16). The idea of scale invariant mesh adaptation is to choose a monitor function $M > 0$ which has the same scaling properties as the underlying physical PDE. In terms of time integration this means that the grid and solution should evolve on the same timescale. This means that the mesh should never be seen to "freeze" but should continue to adapt as the the singularity is approached. Given that the physical PDE satisfies the group rescaling (4), we require that the monitor function satisfy the functional equation

$$M(\lambda^{1/2m}x, \lambda^{-1/(p-1)}u, \lambda^{-1/2m-1/(p-1)}u_x) = \lambda M(x, u, u_x). \tag{18}$$

One very natural choice here is to use $M = u^{p-1}$. This approach to adaptivity has been succesfully used to compute blow-up profiles in many cases, see [5, 4, 10] and the references therein.

Unfortunately, it has the undesirable effect of absorbing all available grid nodes into the blow-up region as $t \to T$ and the computations often halt due to lack of resolution in the $\mathcal{O}(1)$ tail region, not the blow-up core! In this note we shall consider a small but vital alteration in order to generate uniform error estimates. We will construct a monitor function

$$M_c \equiv M + \alpha \int_0^a M(x)dx. \tag{19}$$

The standard case with $\alpha = 0$ (and which we shall henceforth denote M_s) has been previously used in the references above for the computation of blow-up. We shall denote the case with $\alpha \geqslant 0$ as M_c for the *corrected* monitor function. This approach was first introduced in [1] for the solution of singularly perturbed BVPs.

By choosing M to satisfy (18) we do not directly use the local truncation error of our spatial discretization method. Such an approach would generate optimal grids in the sense of the smallest constant in an asymptotic error estimate. Unfortunately, this approach would require a very accurate representation of a high derivative of a singular solution which is not always available on non-uniform grids. Instead we use the scaling properties of the solution to let a well resolved aspect of the solution indicate where the grid should be refined. It should be noted however that this approach turns even semilinear PDEs into fully nonlinear systems and so its effectiveness must be in some way justified.

6 Composite scale-invariant adaptivity

To simulate the entire blow-up process we pose transformations both in time and space to the original equation and solve the composite system

$$\begin{cases} \dfrac{dt}{d\tau} = g(u(x,t)), \\ u_\tau = g(u(x,t)) \left(\dfrac{1}{x_\xi} \left(\dfrac{u_\xi}{x_\xi} \right) - x_\tau g(u(x,t)) \dfrac{u_\xi}{x_\xi} + u^p \right), \\ x_{\tau\xi\xi} = \dfrac{g(u(x,t))}{\varepsilon} \left(M_c(u(x,t)) x_\xi \right)_\xi . \end{cases} \tag{20}$$

To ensure that this system has the same symmetry properties of the original equation we require that M satisfies the constraint (18) and

$$g(u(x,t)) = \frac{1}{\|M_c\|_\infty}.$$

The fundamental idea is that we are attempting to have the physical variable move along the level sets of any emergent similarity variable. This can be seen by examining the distribution of nodes as $L(t) \to 0$.

Formal Proposition 6.1. *In the limit* $t \to T^-$ $x_i = x\left(\frac{i}{N+1}\right) \sim C_0(i,N)L(t)$ *with* $C_0(i,N) \sim \mathcal{O}(1)$ *for all* $i \ll N+1$.

That is the computational nodes which resolve the the blow-up region focus at the correct rate. Fortunately not all nodes contract to the blow-up point.

Formal Proposition 6.2. *In the limit* $t \to T^-$ $x_{N/2} \sim \mathcal{O}(\sqrt{L(t)})$, *and* $x_N \sim \mathcal{O}(1)$.

Both these last estimates can be shown to be false when not using the corrected monitor function. In that case all computational nodes may be drawn in to the blow-up region meaning that no uniform error estimates are possible.

If this system is solved using a second-order central finite-difference scheme in the computational variable ξ and any stable Runge-Kutta scheme in time then we have the following [6]

Computational time errors.

Formal Proposition 6.3. *If the system (20) is integrated in time with a method of order* q *then for all* $i = 1, \ldots, N+1$

$$\|U_i(t) - W_i^n\| \simeq C_1(\Delta\tau)^{q+1}\left|\frac{d^{q+1}W_i}{d\tau^{q+1}}\right|$$

and hence

$$\frac{\|U_i(t) - W_i^n\|}{\|u(x,t)\|_\infty}$$

is independent of scale changes in time at leading order as $L(t) \to 0$.

This follows from the scaling properties of the ODE system and standard ODE error estimates.

Computational space errors. Examination of the solution profile and the mesh distribution yields the following estimates.

Formal Proposition 6.4. *If the system (20) is discretized in space using second-order finite differences then as $L(t) \to 0$ we have:*

$$\begin{aligned} &i) \quad \text{if} \quad x_n = \mathcal{O}(L(t)) \quad \text{then} \quad \frac{||u(x,t) - U_i(x_n)||}{\|u(x,t)\|_\infty} \simeq C_2 \left(\frac{x_n}{L(t)} \right) (\Delta\xi)^2 \\ &ii) \quad \text{if} \quad x_n = \mathcal{O}(1) \quad \text{then} \quad \frac{||u(x,t) - U_i(x_n)||}{\|u(x,t)\|_\infty} \simeq C_3 \, (\Delta\xi)^2 \end{aligned}$$

Here $C_2(s) \sim \mathcal{O}(1)$ and $C_3 \sim \mathcal{O}(1)$.

These follow from a careful analysis of the grid structure and solution assuming the form (9). A similar estimate may be derived for $x_n \sim \mathcal{O}(\sqrt{L}(t))$ but this requires the use of smoothing in the MMPDE.

7 Further research

The particular equation described here has been chosen to simplify the exposition. This approach has been used to solve a large array of problems including both second and fourth-order quasilinear equations and also nonlinear wave equations and mixed parabolic/hyprebolic systems. There is also a purpose built code for the solution of fourth-order equations using the methodology described here. There are however still two key challenges remaining.

For a complete understanding of these methods, the long time dynamics of the continuous system (20) need to be fully understood and as well as the convergence properties of its discrete approximation in the limit $\tau \to \infty$. Also a modified equation analysis for this system can be performed to carefully determine the effect that the discretization has on the blow-up profile and behaviour.

These strategies are also readily extended to higher-dimensional problems with the replacement of the MMPDE with a parabolic Monge-Ampere equation

$$P_t = |D^2 P| M(u), \qquad X = \text{grad} P.$$

While the technical details of this formulation of this approach are mostly understood, additional computational challenges still remain.

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Research Programmes

1. *Number Theory, Algebra and Geometry*

    1.1 Number Theory
    1.2 Algebra and Geometry

2. *Analysis*

    2.1 Analysis on Lie Groups
    2.2 Numerical Analysis
    2.3 Analysis, Dynamical Systems and Applications

3. *Stochastics and Operations Research*

    3.1 Probability and Mathematical Statistics
    3.2 Operations Research

4. *Mathematics, Computer Science and Society*

1. Number Theory, Algebra and Geometry

Research Programme 1.1: Number Theory
Programme leaders: H.W. Lenstra and R. Tijdeman

Description of the project

Number theory studies the properties of integers, with a historically strong emphasis on the study of diophantine equations, that is, systems of equations that are to be solved in integers. The methods of number theory are taken from several other branches of mathematics. Traditionally, these include algebra and analysis, but in recent times algebraic geometry has been playing a role of increasing importance as well. It has also been discovered that number theory has important applications in more applied areas, such as cryptography, theoretical computer science, dynamical systems theory and numerical mathematics. These new developments stimulated the design, analysis and use of algorithms, now called computational number theory. They led to a unification rather than diversification of number theory. For example, the applications in cryptography are strongly connected to algebraic geometry and computational number theory; and algebraic number theory, which used to stand on itself, is now pervading virtually all of number theory.
Themes of the program reflect the mentioned research areas. They include finding points on algebraic curves, applications of group theory and algebraic number theory, the theory of finite fields, diophantine approximation, words and sequences, discrete tomography, primality tests and factorization methods, and the development of efficient computer algorithms.

Research results in 2004

The driving force behind the project modularity of Calabi-Yau varieties is Noriko Yui (Queen's University, Kingston, Canada), who visited the Mathematisch Instituut during the period January 15 - March 15, 2004, as the Kloosterman professor for 2003. In dimension one, a Calabi-Yau variety is the same as an elliptic curve, and in dimension two it is the same as a K3 surface. Most attention in the project is given to Calabi-Yau threefolds, which is the case of dimension three. Calabi-Yau threefolds exhibit a phenomenon called 'mirror symmetry', which reflect their importance in theoretical physics. Professor Yui presented several lectures on arithmetic aspects of Calabi-Yau threefols, including the Kloosterman lecture on February 5 and a series of eight lectures in the Intercity Number Theory seminar. The principal results that have been achieved relate to modularity of Calabi-Yau threefolds defined over the field of rational numbers, as predicted by the Langlands program.
Batenburg developed a fast and accurate algorithm for reconstructing 2D and 3D binary images from few tomographic projections.
Batenburg and Palenstijn developed an approach for reconstructing crystal projection data from electron microscopy measurements.
Bröker worked with Stevenhagen on the question of finding an elliptic curve over a finite field with a given number of points. They found an algorithm with a heuristic running time that is almost polynomial in the input size.
Carls finished his PhD thesis on a generalized arithmetic geometric mean and successfully defended it in november 2004. From september to october 2004 he was appointed as a postdoc and worked with Edixhoven.
Cramer worked with Fehr and Stam on methods for black-box secret sharing based on algebraic number theory, with de Haan on polynomial ramp schemes, with Aggarwal on secure message

transmission, with Damgaard and Ishai on pseudo-random secret sharing, with Padro' et al. on connections between secure multi-party computation, error correcting codes and matroids.
Daems started her research on the history of 19th century algebra.
Ekkelkamp experimented with Montgomery's NFS software for factoring very large numbers. In addition, she experimented with Arjen Lenstra's QS program to develop an improvement of the version of QS with two large primes.
Evertse and Ferretti proved a generalization of Schmidt's Subspace Theorem to higher degree polynomials. Further he obtained a new lower bound for the distances between the conjugates of an algebraic umber.
Fuchs investigated arithmetical properties of linear recurring sequences of algebraic numbers and of algebraic functions. Moreover, he solved some families of Thue equations over algebraic function fields in one variable.
Hart completed a project to explicitly determine around forty new Schläfli modular equations for generalized Weber functions. Various new identities for generalized Weber functions were also proved. Other investigations into computing modular equations and class invariants were undertaken.
Hogendijk worked on the edition and translation of early Islamic mathematical and astronomical texts, in particular the treatise by al-Mahani on ratio theory.
Jansen continued his work with Lenstra and De Smit on a fundamental question of Lehmer about the Mersenne prime test. He proved a more general version of Woltman's conjecture. Currently he is proving converse statements, which identify, under certain hypotheses, the exact context in which these results hold.
Lenstra continued his work on the new polynomial time primality test, improving its run time exponent. He also worked on applications of lattice basis reduction and, in cooperation with Rene Schoof (Rome), on algorithmic aspects of infrastructure in algebraic number fields. With Noah Snyder (Berkeley) he obtained results on finite groups with a character of large degree, and with Manjul Bhargava (Princeton) on the problem of counting and classifying orders in number fields. He further considered algorithms for finite fields, partly in cooperation with the Leiden Ph.D. student Christiaan van de Woestijne. Many of these projects, as well as others, will continue for several years.
Lenstra and De Smit worked on the cohomological exercise of finding a converse to the snake lemma: the goal is to identify which exact sequences of length 6 arise in the snake lemma. So far a necessary condition has been formulated in Ext^3 groups, and a sufficient condition in Ext^2 groups, but there is still a gap between them.
Palenstijn and De Smit completed the first goal of their NWO project: an explicit formulation of the Artin primitive root conjecture over arbitrary number fields. A more subtle generalization is being worked on in 2005.
Together with J. Mueller (in Essen), Ritzenthaler gave a description of the invariant ring of ordinary plane quartics in characteristic 2. He worked also on the distribution of the p-rank for certain families of genus 2 curves.
Together with Jim Borger (currently at Max Planck) De Smit identified which lambda rings that are finite etale as Q-algebra's come from lambda rings that are finite flat over Z. Generalizing to number fields is a goal for 2005. With Lara Thomas (Toulouse) De Smit worked on results of Aïba concerning local Galois module structure in characteristic p, and on ramification theory of Artin-Schreier extensions.
Stevenhagen worked on a survey paper on number rings (to be included in the computational number theory volume he is editing with Joe Buhler) and on various problems in explicit class field theory (class invariants in complex multiplication).

Tengely dealt with the Diophantine equation $x^2+q^{2m}=2y^p$ where m,p,q,x,y are integer unknowns with m>0, p and q odd primes and x and y coprime. He also studied some arithmetical progressions of length four consisting of squares and cubes.
Tijdeman worked with Andras and Lajos Hajdu on neighborhood sequences,with Hancl on irrationality of infinite sums, with Shorey and with Fuchs on Diophantine equations,with Alpers on discrete tomography and the Tarry-Escott problem and with Rosema on substitutions and lattices.
Van der Vlugt studied zeta functions of curves over finite fields in co-operation with Van der Geer. Van der Vlugt also worked on the relation between maximal linear sequences and cyclic codes.
Van de Woestijne completed his deterministic algorithm for finding solutions to diagonal equations in many variables over finite fields, and found several applications and side results to this result. His PhD thesis will be defended in 2005.

Research Programme 1.2: Algebra and Geometry
Programme leader: S.J. Edixhoven

Description of the project
Geometers study geometric properties of sets of solutions of systems of equations. According to the possible kinds of equations (continuous, differentiable, analytic, polynomial), and of the structures that one studies, one distinguishes kinds of geometry (topology, differential topology and differential geometry, analytic geometry, algebraic geometry, arithmetic geometry).
In algebraic geometry the equations are given by polynomials. Classically, the coefficients and solutions were complex numbers. Number theorists consider integer or rational coefficients and solutions. The goal of arithmetic geometry is to understand the relations between algebraic geometry and number theory.
Three important notions in arithmetic geometry are "algebraic variety" (abstraction of system of polynomial equations), "zeta function" and "cohomology". Zeta functions associated to algebraic varieties are generating functions defined using the numbers of solutions in finite fields. Cohomology associates vector spaces equipped with certain structures to algebraic varieties. One important aim of arithmetic geometry is to understand the relations between the values of zeta functions at integers and properties of the set of rational solutions. Cohomology plays an important role here. Cohomology also provides representations of Galois groups, which is essential for Langlands's program (relations between such representations and "automorphic" representations of matrix groups). The most striking results obtained in this field are the proof of Weil's conjectures (Dwork, Grothendieck, Deligne), Faltings's proof of Mordell's conjecture, Fontaine's theory (comparison between certain cohomologies), Wiles's proof of Fermat's Last Theorem, and Lafforgue's result on Langlands's conjectures.
Apart from its numerous applications within mathematics, algebraic geometry over finite fields provides error correcting codes and crypto systems, both used in everyday life.

Research results in 2004
Van den Bogaart and Edixhoven have shown that the cohomology of a Deligne-Mumford stack that is proper and smooth over the integers and with the property that its number of points over finite fields is a polynomial in the cardinality of the field is as one should expect. This answers a question by Carel Faber, and it should be useful for computing the cohomology of some moduli spaces of stable *n*-pointed curves.

Edixhoven has made decisive progress (suitable upper bounds for Green functions on modular curves) in his program aimed at generalizing Schoof's algorithm to modular forms of higher weight. More generally, this program aims to make the Langlands correspondence, for GL(2) over the rationals, say, accessible to computational number theory (polynomial time algorithms). He expects to write an article on this important and vast matter in 2005, in collaboration with Jean-Marc Couveignes (Toulouse) and Robin de Jong (in Leiden since January 2005).
A short article has been written on how to apply *p*-adic geometry of modular curves to the study of congruences of traces of modular forms.
Lübke continued his collaboration with A. Teleman (Marseille) in the research on moduli spaces in gauge theory and complex geometry of principal fibre bundles with associated Kähler fibrations; key words are moment maps, stability and Hermitian-Einstein structures. The main result is a "universal" Kobayashi-Hitchin correspondence; wheras previous work by e.g. Mundet i Riera considers only stable objects on Kähler manifolds, they treat the general polystable case on arbitrary Hermitian manifolds. Their article can be found at arXiv:math.DG/0402341.
Wiese has finished and published an article on dihedral Galois representations in the context of Serre's conjecture. He has studied modular symbols mod *p* and their Hecke algebras, and has obtained results on cases when these coincide with Hecke algebras from modular forms mod *p*. These results can be used to compute Hecke algebras of mod *p* modular forms in certain cases, including weight one, with methods from mod *p* linear algebra. He has started a collaboration with T. Mühlenbruch (Clausthal) on the transfer operator for Hecke triangle groups.
Murre continued to study algebraic cycles and motives. In particular he studied properties of the Chow motives attached to products of two algebraic surfaces and proved for such motives part of the conjectures which he formulated in 1991. The results are related to recent work of B. Kahn (Paris) and C. Pedrini (Genova); a joint publication is in preparation.
Oort and Chai have proved the Hecke Orbit Conjecture. As expected, an essential tool was the theory of foliations, and a generalization of Serre-Tate parameters. A final step was performed when Chau-Fu Yu was visiting, and he could perform a final step concerning stratifications of Hilbert-Blumenthal varieties.
Oort and Pink try to describe *p*-adic monodromy in characteristic *p*. They have some conjectures for partial results. A first draft is being prepared in which they apply their ideas to ramification behavior in the construction of isogeny correspondences.
Oort and Zink have given methods for describing *p*-divisible group schemes with constant Newton polygon. The study of "minimal" *p*-divisible groups has given the results they were looking for: for a minimal BT1 group scheme there is a unique (minimal) *p*-divisible group having this as *p*-kernel, for a non-minimal BT1 group scheme there are infinitely many *p*-divisible groups having this as *p*-kernel.

2. Analysis

Research Programme 2.1: Analysis on Lie Groups
Programme leader: G. van Dijk

Description of the project
The main topics studied are: representations of Lie groups, harmonic analysis on homogeneous spaces and quantization. We made special study of canonical representations (in the sense of Gelfand, Graev, Vershik) and oscillator representations (in the sense of R. Howe). Close cooperation exists with research groups in Russia, in particular in Tambov (Molchanov) and Pevzner in Reims (France).

Research results in 2004
We almost completed the textbook on harmonic analysis on hyperboloids in 3-dimensional space, a joint project with Molchanov.
With Pevzner and Aparicio a lot of progress was made in the study of the multiplicity free decomposition of Hilbert spaces invariant under the action of the oscillator representation. With Pevzner product structures on the holomorphic discrete series representations were studied for a special class of Hermitian symmetric spaces.

Research Programme 2.2: Numerical Analysis
Programme leader: M.N. Spijker

Description of the project
Many processes studied in the natural sciences and technology give rise to *initial value problems* for ordinary and partial differential equations. Because in almost all cases it is impossible to obtain an explicit formula for the solution to these problems, numerical approximations are needed to get insight in the quantitative behavior of the solutions. *Step-by-step* methods are indispensable tools in computing these approximations. The judicious construction and the theoretical analysis of these methods are main themes within contemporary numerical analysis.
The research in the programme concentrates on the theoretical analysis of step-by-step methods. This kind of analysis has unexpected links with other parts of mathematics, such as functional analysis and complex function theory. It belongs to an active and fascinating field of mathematical research.
An important aim of the programme is to gain theoretical insight into weaknesses and strengths of step-by-step methods. The emphasis lies on the behavior of the methods in the solution of differential equations, which are more general and realistic than the classical test equations. Important issues comprise the *convergence* and *stability* properties of the numerical methods. There are important open questions and conjectures about these properties. The programme has in view to contribute to the settlement of these questions.

Research results in 2004
In the literature, on the numerical solution of nonlinear time dependent partial differential equations, much attention has been paid to numerical processes which have the favorable property of being total variation bounded (TVB). A popular approach to guaranteeing the TVB property consists in demanding that the process has the stronger property of being total variation diminishing (TVD). However, the above approach requires certain basic assumption which are *not*

fulfilled for various important semi-discrete approximations – see e.g. Shu (1987), Cockborn & Shu (1989).
In 2004, L. Ferracina and M.N. Spijker proposed a general theory which does not require these basic assumptions. In particular, this theory gives stepsize restrictions, for general Runge-Kutta methods, which guarantee total-variation-boundedness in situations where the TVD property cannot be proved.

Research Programme 2.3: Analysis, Dynamical Systems and Applications
Programme leader: S.M. Verduyn Lunel

Description of the project
The research of the group focuses on the analysis of infinite dimensional dynamical systems and applications. Computing the long-term behavior of dynamical systems by solving the initial data problem can be a time consuming and difficult task. It is often essential to combine numerical methods with methods from dynamical systems theory. Rather than solving the equations for fixed values of the physical parameters, we often study solutions as a function of the physical parameters. Specific examples that are investigated include dynamical systems with time delays in the feedback loop (such models arise in engineering, life sciences and semi-conductor lasers), differential equations modeled on a lattice (such as the Ising model and Cellular neural networks (CNN)), and partial differential equations with applications to life sciences and chemical engineering.

Research results in 2004
Calculating Hausdorff dimensions of invariant sets using spectral theory
In this project together with Roger Nussbaum, the Kloosterman professor 2004, we present a new approach to compute the Hausdorff dimension of conformally self-similar invariant sets. The approach is based on a direct spectral analysis of the transfer operator associated with the dynamical system. In the case that the maps defining the dynamical system are analytic, our method yields a sequence of successive approximations that converge to the Hausdorff dimension of the invariant set at a super-exponential rate. This allows us to estimate the dimension very precisely. The results can be illustrated with examples from dynamical systems and from number theory via Diophantine approximations. A number of publications are in progress.

Invariant measures for stochastic delay equations.
This project is devoted to a detailed study of the asymptotic behavior of the solutions of stochastic evolution equations. Such equations are of great importance in the applied sciences, since they are used to model processes with stochastic components, such as white noise. In order to apply methods from ergodic theory to study the limit behavior of the distribution of solutions, it is necessary to have the existence of an invariant measure (or stationary distribution). Existing abstract results regarding the existence of an invariant measure for stochastic evolutionary systems do either require strong smoothness assumptions or a dissipativity condition on the underlying deterministic flow. However, for stochastic delay equations, these conditions fail dramatically and the existence of an invariant measure is not yet known. Our main result avoids smoothness or dissipativity and is based on exponential dichotomies and appeared in 2004. This project is part of the NWO project ‘Stochastic Analysis’.
Applications to Chemical Engineering.
In reaction engineering it is increasingly important to replace steady state processes by periodic processes. In such processes periodic operation may for instance consist of cyclic reaction-

regeneration steps. In particular, those cyclic processes where a steady flow of products is maintained have the potential of becoming of considerable commercial importance. A joint paper with T.L. van Noorden presented algorithms to optimize the dynamic properties of reactors with cyclic reaction-regeneration.

Ginzburg-Landau equation and semi conductor lasers
Lasers are highly nonlinear devices and the competition between nonlinear and dispersive effects can lead to exciting pattern formation, quasi-periodic, chaotic, and blowup structures. Semi-conductor lasers subject to delayed optical feedback can be described by the so-called Lang-Kobayashi equations, that form a three dimensional delay differential system. In work of Rottschäfer, the regions of existence and stability of certain types of solutions for these equations in 3-dimensional parameter-space, thereby laying out the `ECM-backbone' of the LK-equations. Furthermore, using asymptotic analysis combined with numerical simulations, Rottschäfer constructed multi-bump, blowup structures for the Ginzburg-Landau equation considered as a small perturbation of the nonlinear Schrödinger equation. This research is part of the KNAW project of Rottschäfer.

Patterns in nonlinear ordinary and partial differential equations.
The current focus is on the study of specific problems regarding the analysis of elliptic equations with a critical Sobolev growth term, entropy solutions of hyperbolic equations, heat flows of harmonic maps, nonlinear eigenvalue problems for fourth order elliptic equations and dynamical systems in pharmaceutical problems.
In joint work with Brezis, Peletier completed a study of nonvariational solutions of elliptic equations on the sphere S^3, and with Bandle and Stingelin of variational solutions of the p-Laplacian on the sphere S^N. New entropy solutions of the Buckley-Leverett equation were defined and studied in a collaboration of Van Duijn, Pop and Peletier. In a collaboration involving Sandstrom, Visser and Gabrielsson, a new model was developed for the dynamics underlying the circadian rhythm in rats.
In joint work with Mimura, Ohnisi (both Hiroshima) and Hilhorst (Paris-Sud), van der Hout is studying a model describing the behavior of "Liesegang rings", periodic patterns occurring in many reaction-diffusion systems where a precipitation reaction is included.

C*-algebras and topological dynamical systems
A long-term cooperation between De Jeu in Leiden and Silvestrov in Lund has been established. Within this cooperation, various analogues of the transformation group C*-algebra which is associated with a topological dynamical system have been defined, and the relation between the simplicity of these algebras and the maximality of the canonical commutative subalgebras on the one hand and the topological structure of the dynamical system on the other hand has been considered.

Applications to Life Sciences
This research project concerns the modeling, analysis and simulation of discrete and continuous dynamical systems that occur in the Life Sciences. It has three main lines of research: (1) a functional analytic understanding of approximation of dynamical systems, e.g. discrete systems by continuum models, limits related to singular perturbation like diffusion and hydrodynamic limits; (2) analysis of the dynamics of large, hybrid, multiscale models and simulation of such systems, and (3) data oriented system's analysis, in which system properties (e.g. attractors) are numerically approximated based on experimental data, without explicit modeling of the

underlying 'complex' system. The project takes the self-organizing and individual movement behavior of the amoeba Dictyostelium discoideum as prototype biological system.
In 2004, the research has been focused on the first part. Some preliminary general functional analytics results on continuity of restrictions of infinite dynamical systems have been obtained, which have been submitted for publication. Moreover, first results on well-posedness of a family of hybrid infinite dimensional continuous systems modeling aggregation of D. discoideum have been established. These will be published in 2005.

3. Stochastics and Operations Research

Research Programme 3.1: Probability and Mathematical statistics
Programme leader: S.A. van de Geer

Description of the project
Mathematical nonparametric statistics provides a theoretical background for the techniques and algorithms that are used to analyze today's large and complicated data sets. It allows one to address questions such as convergence of the outcome of a procedure when the training set grows without limit, optimal rates of convergence, lower bounds for the performance of any procedure, and information theoretic descriptions of complexity.
In this project, the mathematics of statistical learning is a key focus point. We propose probabilistic models for problems coming from the machine learning community, and derive probabilistic statements for algorithms such as empirical risk minimization, boosting, and support vector machines. This allows one to compare the procedures and analyze their generalizability.
As probabilistic tools, we develop new results for stochastic processes indexed by functions. Probabilistic theory for random walks in various contexts is studied as well
We also consider the application of the procedures, for example to traffic flow data, and protein transcription data. In collaboration with the department of Medical Statistics of the Leiden University Medical Center, statistical techniques were studied for analyzing the large amount of data per patient that are produced by the micro-array technology**.**

Research results in 2004
Goeman has extended the global test to the case where pathways are taken into account, to the situation of survival data, and to the logistic model with more than two categories.
Mohammadi developed asymptotic theory for binary classification problems when the model is parametric. She also considered the case where the feature space is the real line, but with a priori no bound on the number of label changes along the line. She derived rates of convergence when this number is penalized and the probability of a label stays away from the coin tossing case.
Merkl has developed new results for edge reinforced random walks and random walks in a random environment.
Merkl and Mohammadi further investigated lower bounds in classification, with one- and higher dimensional feature space. In the process, they developed very general mathematical techniques for the derivation of lower bounds in statistics.
Tarigan and van de Geer derived probability inequalities for the estimation error of support vector machines. This estimation error depends in a complicated way on the underlying unknown distribution of the training set. This means that complexity regularization, which implicitly requires the estimation of the estimation error, is not easy in this context. Tarigan and

van de Geer have shown that the l_1 complexity penalty can overcome this problem.
Van de Geer has made an overall approach to oracle inequalities. This gives a unifying viewpoint on model selection problems, and explains in what sense a procedure behaves as its noiseless counterpart. As probabilistic tools, some results for weighted empirical process were established.
E. van Zwet and Hadjicharalambous studied a Gaussian model for traffic flows on a network. The problem is to estimate the traffic between any node pair, when only the traffic on the edges is observed. Their goal is to develop a fast method to compute - or at least approximate - the maximum likelihood estimator. They developed a new version of the EM algorithm for this problem.
E. van Zwet also worked on other problems associated with the analysis of traffic data. Moreover, he studied a biological problem. Together with colleagues at UC Berkeley, he developed a method that uses structural knowledge about a given DNA binding protein to help identify its binding sites.

Research Programme 3.2: Operations Research
Programme leader: A. Hordijk

Description of the project
The research in Operations Research is concentrated on Markov chains, Markov decision processes, Markov games and stochastic networks.

Research results in 2004
Gaujal (ENS Lyon and INRIA Grenoble), Hordijk and Van der Laan (VUA and INRIA Grenoble) continued their study of regular policies and their performance properties for polling systems. Using multimodularity properties of such systems, they have shown how to allocate the server optimally to two queues under deterministic assumptions. Surprisingly, the optimal allocation rates to the two queues can be rather intricate, exhibiting a fractal behavior when the load grows close to instability. They have also solved the exponential case numerically, using a kernel method to compute the stationary behaviour of the two-dimensional Markov chain describing the system.
Gaujal (ENS Lyon and INRIA Grenoble) and Hordijk studied dropping sequences in the Random Early Detection Algorithm. It is a mechanism for congestion control in communication networks that try to anticipate on losses. At any node in the network, any incoming packet can be rejected with some probability, before the queue fills up. They have shown that the best way to reduce the queue length is to throw packets away according to a regular pattern, called a Sturmian sequence, instead of using a Bernoulli sequence.
Gaujal (ENS Lyon and INRIA Grenoble) and Hordijk have proved in their recent book with Altman (INRIA Sophia-Antipolis), that telecommunication networks forming stochastic event graphs are multimodular with respect to the arrival sequences. The proof was based on a max-plus property of the evolution of the system. During the last months, they realized that those max-plus equations could capture more general models, in particular for those including routing mechanisms. They have constructed such equations for networks made of several subsystems forming a tree-like structure, as well as for a simplified model of the standard communication protocol.
Gaujal (ENS Lyon and INRIA Grenoble), Hordijk and Thierry (ENS Lyon) studied a Markovian model of the congestion of many connections for a wireless network under a recently proposed protocol. This model uses an assumption of stochastic independence of the behavior of the global system with respect to a single station. They have proved that under some assumptions, the Taylor

series expansion of the stationary probabilities without the independence assumption approaches that of the independent series.
Heidergott (VUA) and Hordijk studied measure-valued differentiation of Markov chains with a random horizon. A technical paper with minimal sufficient conditions is in preparation.
Heidergott (VUA), Hordijk and Van Uitert (VUA) studied the series expansion for finite-state Markov chains. Numerical algorithms are derived for the sensitivity analysis with respect to perturbations and for the analysis of the functional dependence of the parameter. A technical paper is in preparation.
Hordijk prepared a revision of a part of his joint research with Gajrat on the structure of the optimal server control for fluid networks.
Kallenberg, besides his activities as Scientific Director of the LNMB, spent his sparse research time on the study of stochastic dynamic programming problems.
Spieksma continued her research on the stability analysis of priority queueing networks with deterministic routing, she has been writing a long and technically complicated paper on this topic. She also prepared a revision of her joint paper with Hordijk and Popov on discrete scattering.

4. Mathematics, Computer Science and Society

Research Programme 4
Programme leader: F.A.J. Birrer

Description of the project
Research area:
Mathematics & Society, Computer Science/Chemistry/Science & Society.

Mission/themes:
Understanding and supporting ethics and argumentative and procedural quality in debate and decision making that relate to and/or draw upon science, in particular the role of mathematical models and statistics, information technology, environmental issues, and biotechnology.

Research results in 2004:
Various case studies were undertaken that apply and extend frameworks developed earlier. Ethical codes for statisticians were examined with respect to the role of the statistician they presuppose, and the adequacy of these presuppositions. Potential effects of evaluation-based research funding were described, with special attention for the effects that by their nature are hard to measure, and the implications of such lack of measurability. The norms for scientific practice formulated by Merton more than 50 years ago were examined for their relevance today. New research activities were initiated in the area of the biosciences, with an examination of the implications of industrial biotechnology in relation to user-producer interaction, and another article tracing the obstacles on the road towards sustainable agriculture down their fundaments.

International and National Programmes

European Programmes:

RTN: Galois Theory and Explicit Methods in Arithmetic
2000 – 2004
Cooperation with: Besançon, Bordeaux, Lille, Paris (France), Barcelona (Spain), Bonn, Essen, Heidelberg (Germany), Leiden (The Netherlands), Nottingham (U.K.), Rome (Italy), Tel Aviv (Israel)
Project leaders: H.W. Lenstra, B. de Smit.

Socrates program: Number Theory. 2001-2005
Cooperation with Ostrava (Czech Republic)
Project leader: R. Tijdeman.

Austrian Science Foundation FWF, Sept. 2004 - Aug. 2005
Ineffective and Effective Methods for Diophantine Problems
Project leaders: C. Fuchs (temp. Leiden), R.Tijdeman.

RTN: Arithmetic Algebraic Geometry
Cooperation with Barcelona (Spain), Bonn (Germany), Cambridge (England), Durham (England), Jerusalem (Israel), Milano (Italy), Münster (Germany), Padova (Italy), Paris 11 (France), Paris 13 (France), Regensburg (Germany), Rennes (France), Strasbourg (France), Tokyo (Japan).
Coordinator: S.J. Edixhoven.

RTN: EAGER – European Algebraic Geometry Research Training Network
October 2000 – September 2004
Cooperation with Barcelona (Spain), Bayreuth (Germany), Hannover (Germany), Nice (France), Oslo (Norway), Roma (Italy), Bar-Ilan (Israel), Torino (Italy), Utrecht (The Netherlands), Warszawa (Poland), Warwick (UK), Zürich (Switzerland).
Coordinators: M. Lübke, J.P. Murre, F. Oort.

Erasmus Mundus Master program Algebra, Geometry And Number Theory
Cooperation with Bordeaux and Padova
See: www.math.u-bordeaux1.fr/ALGANT/.
Coordinators: P. Stevenhagen, S.J. Edixhoven.

RTN: Classical Analysis, Operator Theory, Geometry of Banach Spaces, their interplay and their applications.
2000-2004.
Coordinator: S.M. Verduyn Lunel.

"PASCAL" European Network of Excellence
December 2003- December 2005
Cooperation with France Telecom, INRIA, France; University of Ulm, Germany; Cambridge University, University of Newcastle upon Tyne, Heriot-Watt University, UK; Technion,

University of Haifa, Israel; Eindhoven University of Technology, CWI, Netherlands.
Coordinator: S.A. van de Geer.

Van Gogh Programme: Discrete event systems and optimisation
October 2003- December 2005
Cooperation with: INRIA-Grenoble, Lyon, Nancy (France)
Project leader: A. Hordijk.

National Programmes:

NWO SPINOZA-premie
1999 - 2008
Project leader: H.W. Lenstra.

Computational Number Theory
Cooperation with CWI
Project leader: R. Tijdeman.

NWO PIONIER-subsidie: Analysis, dynamical systems and applications
1/3/1999 – 1/3/2006
Project leader: S.M. Verduyn Lunel.

NWO-program Stochastic Analysis: self-interacting random processes, measure-valued diffusions and stochastic evolution equations
January 1, 2001 – January 1, 2005
Cooperation with: TU Delft, EURANDOM
Project leader: S.M. Verduyn Lunel.

Netherlands Genomics Initiative, Center of Excellence
"Center for Medical Systems Biology"
"A latent candidate gene model"
2004-2007
Cooperation with LUMC
Coordinator: S.A. van de Geer.

MASTERS THESES

DHR. M. G. ENGELS
title: Portfolio optimization: beyond Markowitz
advisor: prof.dr. L.C.M. Kallenberg
date: 19-01-2004
Note: This Master Thesis has awarded the VVS Prize for the best Master Thesis 2004 in the area of Stochastics and Operations Research.

DHR. W.J. PALENSTIJN
title: Galois action on division points
advisor: dr. B. de Smit
date: 29-03-2004

DHR. L.C. VAN BEEK
title: Finite time blow-up for a singular parabolic problem
advisor: prof.dr. R. van der Hout
date: 06-07-2004

Ph.D. Theses

José Antonio Rodríguez June 9, 2004	Patterns described by discrete and continuous dynamical systems Thesis advisor: Prof. dr. ir. L.A. Peletier Leiden University
Federica Benedetta Pasquotto June 24, 2004	On the geography of symplectic manifolds Thesis advisor: Prof. dr. H. Geiges Leiden University
Leila Mohammadi Khankahdani October 6, 2004	Estimation of thresholds in classification Thesis advisor: Prof. dr. S.A. van de Geer Leiden University
Robert Carls November 26, 2004	A generalized arithmetic geometric mean Thesis advisors: Prof. dr. H.W. Lenstra, Prof. dr. M. van der Put (RUG), dr. J. Top Groningen University

Publications

1. Number theory, Algebra and Geometry

1.1 Number Theory

Papers in Journals and Proceedings

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Batenburg, K.J., Palenstijn, W.J., On the reconstruction of crystals through discrete tomography, *in: Reinhard Klette and Jovisa Zunic (eds.), Proceedings of the 10th International Workshop on Combinatorial Image Analysis, IWCIA 2004, Auckland, New Zealand, December 1-3, 2004, LNCS 3322, Springer-Verlag Berlin Heidelberg, 2004*, *23-37.*

Bérczes, A., Evertse, J.-H., Győry, K., On the number of equivalence classes of binary forms of given degree and given discriminant, *Acta Arith. 113 (2004)*, *363-399*.

Berthé, V., Tijdeman, R., Lattices and multi-dimensional words, *Theor. Comput. Sci. 319 (2004)*, *177-202*.

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Evertse, J.-H., Linear equations with unknowns from a multiplicative group whose solutions lie in a small number of subspaces, *Indag. Math. (NS) 15 (2004)*, *347-355*.

Evertse, J.-H., Distances between the conjugates of an algebraic number, *Publ. Math. Debrecen 65 (2004)*, *323-340*.

Hancl, J., Tijdeman, R., On the irrationality of Cantor series, *J. reine angew. Math. 571 (2004)*, *145-158*.

Hancl, J., Tijdeman, R., On the irrationality of Cantor and Ahmes series, *Publ. Math. Debrecen. 65 (2004)*, *371-380.*

Ritzenthaler, Ch., Point counting on genus 3 non hyperelliptic curves, *Algorithmic Number Theory Symposium VI, Springer Lecture Notes in Computer Science, vol 3076, 2004*, 379-394.

Smit, B. de, Relations between jacobians of modular curves of level p^2, (with I. Chen and M. Grabitz), *J. Théor. Nombres Bordeaux 16, (2004), 95-106*.

Smit, B. de, On arithmetically equivalent fields with distinct p-class numbers, *Journal of Algebra 272 (2004)*, *417-424*.

Stevenhagen, P., Triangles, squares, oranges and cuboids, *Mathematical Adventures for Students and Amateurs, D. F. Hayes & T. Shubin (eds.), MAA Spectrum Series*, (2004), *51-63*.

Stevenhagen, P., Cox, D.A., McKay, J., Principal moduli and class fields, *Bull. London Math. Soc. 36*, *no. 1*, *(2004), 3-12*.

Tengely, Sz., On the Diophantine equation $x^2 + a^2 = 2y^p$, *Indag. Math. (N.S.), 15 (2004)*, *291-304.*

Ph. D. Theses

Robert Carls, A generalized arithmetic geometric mean, Rijksuniversiteit Groningen, November 26.

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Alpers,A., Tijdeman, R., The two-dimensional Prouhet-Tarry-Escott problem, www.math.leidenuniv.nl/~tijdeman/altijd2.ps.

Batenburg, K.J., An evolutionary algorithm for discrete tomography, to appear in: *Discrete Applied Mathematics, 2005.*

Cramer, R., Fehr, S., Stam, M., Primitive Sets in Number Fields and Optimal Black-Box Secret Sharing.

Cramer, R., Daza, V., Gracia, I., Jiménez Urroz, J., Leander, G., Martí-Farré, J., Padró, C., On Codes, Matroids and Secure Multi-Party Computation from Linear Secret Sharing Schemes.

Cramer, R., Damgaard, I., Ishai, Y., Share Conversion, Pseudorandom Secret-Sharing and Applications to Secure Computation, to appear in: *Proceedings of Theory of Cryptography Conference (TCC '05), MIT, Boston, USA, Springer Verlag LNCS, February 2005*.

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Evertse, J.-H., Zannier, U., Linear equations with unknowns from a multiplicative group in a function field, Report MI 2004-01.

Fuchs, C., Pethö, A., Effective bounds for the zeros of linear recurring sequences over function fields, to appear in: *J. Theor. Nombrés Bordeaux*.

Fuchs, C., Ziegler, V., On a family of Thue equations over function fields, to appear in: *Monatsh. Math*.

Hart, W.B., Evaluation of the Dedekind Eta Function, with Robin Chapman, to appear in: *Canadian Mathematical Bulletin*.

Hart, W.B., Schläfli Modular Equations for Generalized Weber Functions, www.math.leidenuniv.nl/~wbhart

Hajdu, A.,Hajdu, L., Tijdeman, R., General neighborhood sequences in Z^n, www.math.leidenuniv.nl/~tijdeman/hht_discapplmath.pdf

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Hancl, J., Tijdeman, R., On the irrationality of factorial series, www.math.leidenuniv.nl/~tijdeman/hanti3.ps

Hogendijk, J., Applied mathematics in 11th century Spain: Ibn Mu`adh al-Jayyani and his computation of astrological houses and aspects, to appear in: *Centaurus*.

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Ritzenthaler, C., Automorphism group of C: $y^3+x^4+1=0$ in characteristic p, to appear in: *J. Algebra Number Theory Appl.*

Rosema, S.W., Tijdeman, R., The Tribonacci substitution, www.math.leidenuniv.nl/~tijdeman/rotij7.ps

Other publications

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Daems, J., Het vermoeden van Catalan, Nieuw Archief voor Wiskunde, Sept. 2004

Hogendijk, J., Vedic mathematics and the calculations of Guru Tirthaji, Pi in the Sky

Jansen, B., Het invullen van Eschers Prententententoonstelling, in: Structuur in schoonheid, CWI Syllabus 53.

Lenstra, H.W., Escher en het Droste-effect, in: Natuurkundige Voordrachten, Nieuwe Reeks 82, Diligentia, 's-Gravenhage.
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1.2 Algebra and Geometry

Papers in Journals and Proceedings

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Oort, F., Foliations in moduli spaces of abelian varieties, *Journ. Amer. Math. Soc. 17* (2004), *267-296*.
Wiese, G., Dihedral Galois representations and Katz modular forms, *Documenta Mathematica, Vol. 9* (2004), *123-133.*

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Federica Pasquotto, On the geography of symplectic manifolds, Leiden University, June 24.

Books

Barth, W.P., Hulek, K., Peters, C.A.M., Ven, A. van der, Compact Complex Surfaces Series: Ergebnisse der Mathematik und ihrer Grenzgebiete. 3. Folge / A Series of Modern Surveys in Mathematics. January 2004.

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Cornelissen, G., Oort, F., Problems from the workshop on "Automorphisms of Curves" (Leiden, August; 47 pp. To appear in: *Rendiconti del Seminario Matematico, Padua*.
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Lübke, M., Teleman, A., The universal Kobayashi-Hitchin correspondence on Hermitian manifolds. arXiv:math.DG/0402341.
Murre, J.P., On the Chow motive attached to the product of two surfaces, In: Report no. 15, "Motives and Homotopy Theory of Schemes", Oberwolfach Reports, Vol.1 ,2004.
Oort, F., Minimal *p*-divisible groups, to appear in: *Annals of Mathematics*.
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Other publications

Edixhoven, S.J., van piramides tot modulaire krommen, Inaugural lecture, Leiden, January 2004, printed version, 20 pages. Also: Nieuw Archief voor Wiskunde, June 2004, 98-105.
Edixhoven, S.J., Bogaart, Th. Van den, opschudding over veeltermen.
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2. Analysis

2.1 Analysis on Lie groups

Papers in Journals and Proceedings

Aparicio, S., Pevzner, M., Dijk, G. van, Invariant Hilbert subspaces of the oscillator representation, *Indag. Math. 14, 309-318 (2003) (appeared in 2004).*

Dijk, G. van, Molchanov, V.F. (eds.), Representations of Lie groups, harmonic analysis on homogeneous spaces and quantization, *Acta Appl. Math. 81 No. 1-3*

Reports and Preprints

Aparicio S., Complex Generalized Gelfand Pairs, Report MI 2004-05

Aparicio S., Harmonic Analysis on SO(n,C)/SO(n-1,C), n>2, Report MI 2004-03

Other Publications

Dijk, G. van, Dat was afgesproken, afscheidsrede

2.2 Numerical analysis

Papers in Journals and Proceedings

Ferracina L. & Spijker M.N., Stepsize restrictions for the total-variation-diminishing property in general Runge-Kutta methods, *SIAM J. Numer. Anal. 42 (2004), 1073-1093*.

Hout, K.J. in 't & Zubik-Kowal, B., The stability of Radau IIA collocation processes for delay differential equations, *Mathem. Computer Modelling 40 (2004), 1297-1308.*

Reports and preprints

Ferracina L. & Spijker M.N., Stepsize restrictions for total-variation-boundedness in general Runge-Kutta procedures, Report nr. MI 2004-06.

2.3 Analysis, Dynamical Systems and Applications

Papers in Journals and Proceedings

Aarts, A.C.T., Hout, R. van der, Paasschens, J.C.J, Scholten, A.J., Willemsen, M., Klaassen, D.B.M., Capacitance Modeling of laterally non-uniform Mos-devices. *Proceedings IEDM, 2004*.

Brezis, H., Peletier L.A., Elliptic equations with critical exponents on S^3: new nonminimising solutions, *C. R. Acad. Sci. Paris I Vol 339 (2004) 391-394*.

Budd, C.J., Fokkink, R., Hek, G., Kamp, P. van der, Pik, D., Rottschäfer, V., Hanging a carillon in a broek-system, *Proceedings 45th Eur. Study Group Ind., eds. D.R. Pik, V. Rottschäfer, (2004), 71-90.*

Gaans, O.W. van, Verduyn Lunel, S.M., Long term behavior of dichotomous stochastic differential equations in Hilbert spaces, *Commun. Contemp. Math. 25* (2004), *349-376*.

Galaktionov, V.A., Williams, J.F., On very singular similarity solutions of a higher-order semilinear parabolic equation, *Nonlinearity 17 (2004), 1075-1099*.

Hilhorst, D., Peletier, L.A., Rotariu, A.I., Sivashinsky, G., Global attractor and inertial sets for a nonlocal Kuramoto-Sivashinsky equation, *Discrete and Continuous Dynamcial Systems, Vol 10 (2004), 557-580.*
Jeu, M.F.E. de, Subspaces with equal closure, *Constr. Approx.20 (2004), no. 1, 93-157.*
Noorden, T.L. van, Verduyn Lunel, S.M., A Broyden rank p+1 update continuation method with subspace iteration, *SIAM J. Sci. Comput. 25 (2004), 1921-1940.*
Peletier, L.A., Rottschäfer, V., Pattern selection of solutions of the Swift-Hohenberg equation, *Physica D, Vol 194 (2004), 95-126.*
Peletier, L.A., Rodriguez, J.A., Homoclinic orbits to a saddle-center in a fourth-order differential equation, *Journal of Differential Equations Vol 203 (2004), 185-215.*
Peletier, L.A., Rodriguez, J.A., Fronts on a lattice, *Differential and Integral Equations, Vol 17 (2004), 1013-1042.*
Rottschäfer, V., Krauskopf, B., A three-parameter study of external cavity modes in semiconductor lasers with optical feedback, *Proceedings of the Fifth IFAC Workshop on Time-Delay Systems (2004).*
Verduyn Lunel, S.M., Basic theory for linear delay equations, In: Advances in time-delay systems, *Lect. Notes Comput Sci Eng 38 Springer, Berlin, 2004, 3-27.*
Zuideveld, K.P., Graaf, P.H. van der, Newgreen, D., Thurlow, R., Petty, N., Jordan, P., Peletier, L.A., Danhof, M., Mechanism based Pharmacokinetic-Pharmacodynamic modeling of 5-HT_1A receptor agonists: Estimation of in vivo affinity and intrinsic efficacy on body temnparature in rats, *The Journal of Pharmacolgy and Experimental Therapeutics, Vol 308 (2004), 1012-1020.*

Ph.D. Theses
J.A. Rodiguez, Patterns described by discrete and continuous systems, Leiden University, June 2004.

Books
Pik, D.R., Rottschäfer, V. (eds.), Proceedings of the 45th European Study Group with Industry, ISBN 90-9017846-5 (2004).

Reports and preprints
Bandle, C., Peletier, L.A., Stingelin, S., Best Sobolev constants and quasi-linear elliptic equations with critical growth on spheres, MI 2004-16.
Jeu, M.F.E. de, Some remarks on a proof of geometrical Paley-Wiener theorems for the Dunkl transform, MI-2004-08.
Jeu, M.F.E. de, Paley-Wiener theorems for the Dunkl transform, MI-2004-09.
Peletier, L.A., Ordinary differential equations in pharmacodynamics, MI 2004-10.
Peletier, L.A., Gabrielsson, J., Haag, J. den, Is the peak shift in response an inherent feature of the turnover (indirect response) model? MI 2004-15.

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Rottschäfer, V., Wiskunde voor de rozenkweker, Nieuwe wiskrant, 23e jaargang, nr. 3, (2004) pp. 37-41.

3. Stochastics and Operations Research

3.1 Probability and Mathematical statistics

Papers in Journals and Proceedings

Bucchianico, A. di, Huskova, M., Klasterecky, P., Zwet, W.R. van, Performance of control charts for specific alternative hypotheses. *COMPSTAT 2004, Proceedings in Computational Statistics, J. Antoch editor, Physica Verlag, Heidelberg, New York, 903-910.*

Eilers, P.H.C., Goeman, J.J.,'Enhancing scatterplots with smoothed densities', *Bioinformatics, 20 (5) 623-628.*

Fiocco, M., Zwet, W.R. van, Maximum likelihood estimation for the contact process. *Festschrift for Herman Rubin, IMS Lecture Notes-Monograph Series 45 (2004), 309-318.*

Geer, S.A. van de, Houwelingen, J.C. van, High-dimensional data: $p >> n$ in mathematical statistics and bio-medical applications. *Bernoulli 10, 939-942.*

Geer, S.A. van de, Zeker toeval. *Natuurkundige voordrachten 82, 55-62.*

Goeman, J.J., Sessie, S. le, Baatenburg de Jong, R.J., Geer, S.A. van de, Predicting survival using disease history: a model combining relative survival and frailty. *Statistica Neerlandica 58, 21-34.*

Goeman, S., Geer, S.A. van de, de Kort, F., Houwelingen, J.C. van, A global test for association of a group of genes with a clinical outcome. *Bioinformatics 20, 93-99.*

Goetze, F., Merkl, F., Random Spectral Distributions, *Interacting Stochastic Systems, J-D. Deuschel and A. Greven (editors)*

Kechris, K.J., Zwet, E. van, Bickel, P.J., Eisen, M.B., Detecting DNA regulatory motifs by incorporating positional trends in information content. *Genome Biol. 5(7).*

Litvak, N., Zwet, W.R. van, On the minimal travel time needed to collect n items on a circle. *Ann. Appl. Probab. 14, 881-902.*

Pyke, R., Zwet, W.R. van, Weak convergence results for the Kakutani interval splitting procedure. *Ann. Probab. 32, 380-423.*

Matzinger, H., Merkl, F., Loewe, M., Reconstructing a Multicolor Random Scenery seen along a Random Walk Path with Bounded Jumps. *Electronic Journal of Probability, Vol. 9, Paper 15, 436-507.*

Rice, J.A., Zwet, E.W. van, A simple and effective method for predicting travel times on free-ways. *IEEE Transactions on Intelligent Transportation Systems, Volume: 5, Issue: 3, 200-207.*

Zwet, E.W. van, Laslett's line segment problem. *Bernoulli 10, no. 3, 377-396.*

Zwet, W.R. van, Niets nieuws onder de zon. *STAtOR 5-2 (2004), 21-29.*

Ph.D. theses

Leila Mohammadi, Estimation of Thresholds in Classification, Leiden, October 6.

Reports and preprints

Geer, S.A. van de, Oracle inequalities and regularization. To appear in EMS lecture notes.

Geer, S.A. van de, Least squares estimators. To appear in: *Encyclopedia Statistics in the Behavioral Sciences, Eds. B. Everitt and D. Howell, Wiley.*

Geer, S.A. van de, Estimation (overview). To appear in: *Encyclopedia Statistics in the Behavioral Sciences, Eds. B. Everitt and D. Howell, Wiley.*

Merkl, F., Rolles, S., Asymptotic behavior of edge-reinforced random walks. Preprint.

Merkl, F., Rolles, S., Edge-reinforced random walk on a ladder. To appear in: *the Annals of Probability.*

Tarigan, B., Geer, S.A.van de, Adaptivity of support vector machines with l_1 penalty. Techn.

Report MI 2004-14, University of Leiden.
Tsybakov, A.B., Geer, S.A. van de, Square root penalty: adaptation to the margin in classification and in edge estimation. To appear in: *The Annals of Statistics*.

Other publications
Alberts, G., Zwet, W.R. van, Pythagoras in de Tweede Kamer. Nieuw Arch. Wisk. 5/5, 212-217.
Zwet, E.W. van, Reistijden voorspellen op snelwegen. Nieuw Archief voor Wiskunde vol. 5 nr. 2, 115-118.

3.2 Operations Research

Papers in Journals and Proceedings
Borovkov, A.A., Hordijk, A., Characterization and sufficient conditions for normed ergodicity of Markov chains. *Advances in Applied Probability 36 (2004) 227-242*.
Heidergott, B., Hordijk, A., Single-run gradient estimation via measure-valued differentiation. *IEEE Transactions on Automatic Control 49 (2004) 1843-1846*.
Hordijk, A., Laan, D.A. van der, The unbalance and bounds on the average waiting time for periodic routing to one queue. *Mathematical Methods of Operations Research 59 (2004) 1-23.*
Hordijk, A., Laan, D.A.van der, Periodic routing to parallel queues and billiard sequences. *Mathematical Methods of Operations Research 59 (2004) 173-192*.

Reports and Preprints
Gajrat, A., Hordijk, A., On the structure of the optimal server control for fluid networks. Preprint.
Gaujal, B., Hordijk, A., On dropping sequences for RED (Random Early Detection Algorithm). Preprint.
Gaujal, B., Hordijk, A., Laan, D.A. van der, On the optimal policy for deterministic and exponential polling. Preprint.

4. Mathematics, Computer Science and Society

Papers in Journals and Proceedings
Birrer, F.A.J., Statistical evidence: Responsibilities and the burden of proof, *in*: *Cor van Dijkum, Jörg Blasius, Henk Kleijer, Branko van Hilten (eds.): Recent developments and applications in social research methodology, SISWO, Amsterdam.*
Birrer, F.A.J., Subliminal enticement and the ethics of sustainable agricultural production*, in: Johan de Tavernier, Stefan Aerts (eds.): Science, ethics & society (EURSAFE 2004), Katholieke Universiteit Leuven, Leuven, 190-193.*
Paula, L., Birrer, F., Bonnet, H., Hasselt, J. van, Osseweijer, P., Lemkowitz, S., A socially inclusive perspective on the biobased economy, *Science, ethics & society (EURSAFE 2004), Katholieke Universiteit Leuven, Leuven, 221-224.*

Reports and Preprints
Birrer, F.A.J., Evaluation-based research funding and the subliminal enticement scenario, Technical Report 2004-10, LIACS, Leiden University.

Workshops, Seminars a.o.

This chapter summarizes the workshops, seminars and others (co-) organised by (researchers of) the Mathematical Institute. The following data are given:
- Title
- City and date
- (Co-) organisers

Intercity number theory seminar
Various universities, bi-weekly
B. de Smit

Twenty-Ninth Conference on the Mathematics of Operations Research
Lunteren, January 13-15
L.C.M. Kallenberg

Seminar On-line methods: Challenges for the OR in a real-time world
Lunteren, January 15
L.C.M. Kallenberg

Seminar Probability and Statistics
Leiden, March 18
S.A. van de Geer

Statistische Dag
Amsterdam, April 27
S.A. van de Geer

Fourth Annual Meeting of the European Research Network Analysis and Operators
Dalfsen, May 1-7
S.M. Verduyn Lunel

Stability of numerical methods for time-dependent differential equations
Leiden, June 18
F. Bakker

Workshop Discrete tomography and its application to materials science
Amsterdam (CWI), June 28
K.J. Batenburg

Automorphisms of curves
Leiden, August 16-21
F. Oort

Harmonic Analysis and Homogeneous Spaces
Leiden, August 23-26
S. Hille, M.F.E. de Jeu, F. Bakker

Algebraic Cycles and Motives, EAGER annual Conference 2004
Leiden, August 30-September 3
S.J. Edixhoven

Notions of Complexity
EURANDOM, Eindhoven, October 7-9
S.A. van de Geer

Geometry Seminar
Leiden, October
S.J. Edixhoven

Explicit methods in number theory
Banff, Canada, November 13-18
H.W. Lenstra, P. Stevenhagen

Twente Lie Group Conference
Enschede, 13-15 December
G. van Dijk

Invited lectures

1.1 Number theory

K.J. Batenburg
- Discrete tomography and its application to materials science, Antwerpen, Belgium, November 19.

R. Bröker
- Constructing elliptic curves with a given number of points, Leuven, Belgium, February 25.
- How to construct an elliptic curve with a given number of points, Nijmegen, The Netherlands, March 26.
- Elliptic curves with a given number of points, Burlington, USA, June 14.
- p-adic complex multiplication techniques, Toulouse, France, June 24.
- Constructing elliptic curves in polynomial time, Paris, France, December 6.
- Constructing elliptic curves in polynomial time, Leiden, The Netherlands, December 21.

R. Carls
- Descent of line bundles along Frobenius and Verschiebung, Groningen, The Netherlands, April 2.

R. Cramer
- Information-theoretically secure cryptography, Leiden The Netherlands, September 30.
- Pseudo-random secret sharing and its applications to secure computation, Paris, France, November 5.
- Pseudo-random secret sharing and its applications to secure computation, Luminy, France, November 9.

J.H. Evertse
- On the number of equivalence classes of binary forms of given degree and given discriminant, Leiden, The Netherlands, March 5.
- Linear equations with unknowns from a multiplicative group of finite rank whose solutains lie in a few subspaces, Toronto, Canada, June 22.
- Linear equations with unknowns from a multiplicative group in a function field, Banff, Canada, November 22.

B. Hart
- Evaluation of Eta Quotients, Leiden The Netherlands, March 5.
- Schläfli Modular Equations for generalized Weber functions, Exeter, UK.
- Generalized eta-function modular equations, Dagstuhl, Germany.
- What is the non-commutative Iwasawa Main Conjecture?, Leiden, The Netherlands, October 8.

J. Hogendijk
- Omar al-Khayyam, Leiden, The Netherlands, September 6.

B. Jansen
- Escher en het Droste-effect, Utrecht, The Netherlands, January,22.
- Escher en het Droste-effect, Leiden, The Netherlands, April 20.
- Classical Iwasawa theory, Leiden, The Netherlands, October 8.

H.W. Lenstra
- Escher and the Droste effect, New Zealand, January 4.
- three lectures on "Primality testing with Gaussian periods", Nelson, New Zealand, January 5-9.
- Reken mee met ABC, Noordwijkerhout, The Netherlands, February 7.
- Ten-adic numbers, Poughkeepsie, USA, March, 24.
- Harmonic numbers and the ABC conjecture, Poughkeepsie, USA, March 25.
- Riemann, Escher en Droste, Haarlem, The Netherlands, May 15.
- What is the logarithmic class group?, Dagstuhl, Germany, May 19.
- Escher and the Droste effect, Toronto, Canada, June 22.
- New algorithms for finite fields, Toronto, Canada, June 25
- Escher and the Droste effect, Cambridge, USA, July 13.
- Het invullen van Escher's Prentententoonstelling, Amsterdam, The Netherlands, August 28.
- Het invullen van Escher's Prentententoonstelling, Eindhoven, The Netherlands, September 4.
- The nesting depth of radical expressions, Paris, France, October 15.
- Hersenen bewijzen onmogelijkheid, Leiden, The Netherlands, October 24.
- Over de fabricage van priemgetallen, The Netherlands, October 25.
- Algorithms for finite fields, Paris, France, November 1, 8, 22, 29.
- Groups with a character, Eindhoven, The Netherlands, November 5.

Ch. Ritzenthaler
- Point counting on genus 3 non hyperelliptic curves, Burlington, USA, June 13.
- Automorphism group of modular curves X(N) in characteristic p, Utrecht, The Netherlands, March 19.

B. de Smit
- Escher and the Droste effect, Kassel, Germany, January 12.
- Escher en het Droste-effect, Utrecht, The Netherlands, January 22.
- Escher en het Droste-effect, Noordwijkerhout, The Netherlands, February 7.
- The elliptic curve in Escher's Print Gallery, Utrecht, The Netherlands, February 26.
- The elliptic curve in Escher's Print Gallery, Bremen, Germany, March 3.
- Escher en het Droste-effect, Delft, The Netherlands, March 18.
- Snakespotting, Utrecht, The Netherlands, March 19.
- Escher's Print Gallery and the Droste Effect, Nijmegen, The Netherlands, March 25.
- The elliptic curve in Escher's Print Gallery, Nottingham, UK, May 12.
- Escher, Droste, en de kwadratische camera, Lunteren, The Netherlands, August 19.
- Escher en het Droste effect, Leiden, The Netherlands, October 18.
- Computing Artin constants, Banff, Canada, November 18.
- Escher en het Droste-effect, Delft, The Netherlands, November 29.

P. Stevenhagen
- La face cachée des mathémathiques, Paris, France, March 18.
- Elliptic curves with a given number of points, Rome, Italy, April 2.
- Constructing elliptic curves by p-adic methods, Rennes, France, May 7.

- Elliptic curves with a given number of points, Dagstuhl, Germany, May 20.
- Birthday curves and cryptography, Copenhagen, Denmark, September 4.
- Efficient construction of elliptic curves, San Diego, USA, October 7.
- Escher und der Droste-Effekt, Erlangen-Nürnberg, Germany, October 15.
- Elliptic curves in polynomial time, Groningen, The Netherlands, November 26.

R. Tijdeman
- Discrete tomografie en de Chinese reststelling, Delft, The Netherlands, March 11.
- De wiskunde van Koksma na Koksma, Amsterdam, The Netherlands, April 21.
- Irrationality of infinite sums of rational numbers, Waterloo, Canada, June 18.
- Rauzy substitutions and lattices, Strobl, Austria, September 29.
- Long nonconstant sequences with coprime periods, Thessaloniki, Greece, October 20.
- Het leven van Paul Erdös, Leiden, The Netherlands, November 9.

Ch. Van de Woestijne
- An algorithm for solving $\sum_{i=1}^{n} a_i x_i^n = b$ over finite fields, Oberwolfach, Germany, December 7.
- Introduction to Magma, Göttingen, Germany, December 11.
- Deterministic equation solving in finite fields, Göttingen, Germany, December 13.

1.2 Algebra and Geometry

S.J. Edixhoven
- Sur le calcul du corps de définition d'un point de torsion d'une jacobienne d'une courbe de genre quelconque, Rennes, France, January.
- Stacks, Leiden, The Netherlands, February.
- Mijn favoriete rekenmachine is gratis, Noordwijkerhout, February.
- Stacks: sheaves and cohomology, Utrecht, The Netherlands, February.
- The André-Oort conjecture, Ascona, Switzerland, May.
- On certain l-torsion points of $J_1(l)$, Essen, July.
- Computation of mod l Galois representations associated to modular forms, Oberwolfach, Germany, August.
- Une majoration de fonctions de Green sur des courbes modulaires, Rennes, France October 28.
- Formes modulaires et representations p-adiques I, II, Toulouse, December 15-16.

J.P. Murre
- On the Chow motive of the product of two surfaces, Oberwolfach, March.
- On the work of U.Morin on the unirationality of algebraic varieties, Turin, November.

G. Wiese
- Mod p modular forms of weight one and Galois representations: computational and theoretical aspects. Workshop on L-functions and p-adic cohomology: computational perspectives, Far Hills (Québec), Canada, January, 4.
- Formes modulaires de Katz et représentations diédrales, La Grande Motte, France, March 30.
- Dihedral Galois representations and Katz modular forms, May, 14.

- Katz-Modulformen und Dieder-Galoisdarstellungen, Heidelberg, Germany, September, 14.
- Mod p modular symbols, Banff, Canada, November.
- Modulformen, Heckeoperatoren und Anwendungen in der Zahlentheorie, Clausthal, Germany, December, 8.

2.1 Analysis on Lie groups

S. Aparicio
- Complex Generalized Gelfand Pairs, Leiden, May 26.

G. van Dijk
- Generalized Gelfand Pairs: a survey, Mahdia, Tunesia, March 16.

2.2 Numerical analysis

L. Ferracina
- Total variation bounded Runge-Kutta Processes, Providence, USA, June 22.

M.N. Spijker
- General monotonicity properties in Runge-Kutta procedures, Tempe, USA, May 18.

2.3 Analysis, Dynamical Systems and Applications

R. van der Hout
- Harmonic map heat flows and liquid crystals, Eindhoven, October.

L.A. Peletier
- The Brezis-Nirenberg problem on the sphere S^3, Bremen, Germany, February 9.
- Ordinary differential equations in pharmacodynamics AstraZeneca, Sodertalje, Sweden, April 16.
- New entropy solutions of the Buckley-Leverett equation, New Brunswick, USA, October 19.
- New entropy solutions of the Buckley-Leverett equation, New York, USA, October 21.
- Modelling pharmacodynamic processes Bristol, UK, November 10.

V. Rottschäfer
- Modelling the growth of roses, Eindhoven, The Netherlands, June 21-25.

S.M. Verduyn Lunel
- Forward-backward functional differential equations, holomorphic factorization and applications, Berlin, Germany, February 9.
- Calculating Hausdorff dimensions of invariant sets using spectral theory, Berlin, Germany, February 12.
- Delay equations and infinite dimensional systems, Dalfsen, The Netherlands, May 1-7.

- New completeness results for classes of operators, Newcastle upon Tyne, UK, July 12.
- Computing travelling waves in discrete media, Banff, Canada, November 10.

3.1 Probability and Mathematical statistics

S.A. van de Geer
- Learning with l_1 regularization, Tilburg, The Netherlands, April 16.
- Adaptive methods in classification, Göttingen, Germany, May 19.
- Learning with l_1 classification, Montpellier, France, May 26.
- Oracle inequalities and regularization, Laredo, Spain, August 30-September 3.
- Support vector machine loss with l_1 penalty, Eindhoven, The Netherlands, October 7.
- Adaptive support vector machines, Oberwolfach, Germany, November 17.

J. J. Goeman
- The Global Test: Testing Association of a Pathway With a Clinical Variable Using a Single Test, Heidelberg, Germany, January 12.

F. Merkl
- Moderate deviations for longest increasing subsequences of random permutations, Los Angeles, USA, February.
- Recent results on edge reinforced random walks, Los Angeles, USA, February.
- Recent results on edge reinforced random walks, Santa Barbara, USA, February.
- Recent results on edge reinforced random walks, Stanford, USA, March.
- Selbstverstärkte Irrfahrten, Tübingen, Germany, May.
- Edge-reinforced random walks, Utrecht, The Netherlands, June.
- Edge-reinforced random walks, Barcelona, Spain, July.
- Selbstverstärkte Irrfahrten, Berlin, Germany, November.

L.Mohammadi
- Convergence of empirical risk minimizers in threshold estimation, Amsterdam, The Netherlands, January 20.
- Convergence of empirical risk minimizers in threshold estimation, Eindhoven, The Netherlands, February 13.
- Some algorithms in threshold estimation, Hilversum, The Netherlands, May 11.
- Estimation of thresholds in classification, Leiden, The Netherlands, September 7.
- Optimal lower bounds in the statistical estimation of thresholds, Eindhoven, The Netherlands, October 8.

B. Tarigan
- Adaptivity of SVM with L1 penalty, Berder Island, France, September 12-25.

W.R. van Zwet
- Kakutani's interval splitting scheme, Eindhoven, The Netherlands, January 10.
- Maximum likelihood estimation for the contact process, Leuven, Belgium, May 26.
- Statistics and the law, Leiden, The Netherlands, November 4.

3.2. Operations Research

A. Hordijk
- Taylor series expansions for stationary Markov chains, Lyon, France, March 16.
- Taylor series expansions for stationary Markov chains, Grenoble, France, March 25.

4. Mathematics, Computer Science and Society

F.A.J. Birrer
- Statistical evidence: Responsibilities and the burden of proof, Amsterdam, The Netherlands, August.
- Evaluation-based research funding and the subliminal enticement scenario, Paris, France, August.
- Subliminal enticement and the ethics of sustainable agricultural production, Leuven, Belgium, September.
- A socially inclusive perspective on the bio-based economy, Leuven, Belgium, September (together with L.E. Paula)
- Norms at the interface of science and society, Amsterdam, The Netherlands, November.

Memberships of editorial boards

R. Cramer
- Journal of Cryptology

S.J. Edixhoven
- Compositio Mathematica (managing editor)
- Journal de Théorie des Nombres de Bordeaux
- Journal of Number Theory
- Expositiones Mathematicae

J.H. Evertse
- Compositio Mathematica

S.A. van de Geer
- The Annals of Statistics (associate editor)
- Bernoulli (co-editor)

J. Hogendijk
- Ganita-Bharati
- Istoriko-Matematicheski Issledovaniya
- Suhayl
- Centaurus
- Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften

A. Hordijk
- Journal of Applied Probability
- Advances of Applied Probability
- Mathematical Methods of Operations Research
- Probability in the Engineering and Informational Sciences

H.W. Lenstra
- Indagationes Mathematicae
- Ergebnisse der Mathematik und ihrer Grenzgebiete
- Experimental Mathematics
- Arab Journal of Mathematical Sciences
- Foundations of Computational Mathematics
- Journal of the European Mathematical Society

J.P. Murre
- Indagationes Mathematicae

L.A. Peletier
- Advances in Differential Equations
- Applied Mathematics Letters
- Asymptotic Analysis
- Communications in Applied Analysis
- Differential and Integral Equations
- Journal of the European Mathematical Society
- Fixed point theory and applications
- Progress in Nonlinear Differential Equations and their Applications (Series of monographs, Birkhauser)

D. Pik
- Nieuw Archief voor Wiskunde (Managing editor)

M.N. Spijker
- Journal of Computational and Applied Mathematics
- International Journal of Engineering
- Applicationes Mathematicae
- CWI-Publications

R. Tijdeman
- Acta Arithmetica
- Indagationes Mathematicae

S.M. Verduyn Lunel
- Integral Equations and Operator Theory (Managing editor)
- Archiv der Mathematik (Associate editor)
- Functional Differential Equations
- Operator Theory Advances and Application (Series of monographs, Birkhauser)

W.R. van Zwet
- Bernoulli (Editor-in-chief)

Honors

G. van Dijk
- Officier in de Orde van Oranje-Nassau

A. Hordijk
- Visiting professor, March 2004, Ecole Normale Superieure de Lyon

L.C.M. Kallenberg
- Ridder in de Orde van Oranje-Nassau

J.P. Murre
- Workshop at the occasion of 75-th birthday, 30 August-3 September, Leiden.
- Elected Foreign Member Accademia delle Scienze di Torino

Foreign visitors

The following data are given:
name, place and country of the visitor
name(s) of the host(s)

1. Number theory, Algebra and Geometry

1.1.Number theory
Hoang Le Thai, Paris, France, P. Stevenhagen.
Lara Thomas, Toulouse, France, B. de Smit.
Ulrich Vollmer, Darmstadt, Germany, B. de Smit.
Ronald van Luijk, Berkeley, U.S.A, H.J. Lenstra.
A. Alpers, München, Germany, R. Tijdeman.
L. Hajdu, Debrecen, Hungary, R. Tijdeman.
J. Hancl, Ostrava, Czech Republic, R. Tijdeman.
T.N. Shorey, Mumbai, India, R. Tijdeman.

1.2.Algebra and Geometry
M. Hughes, Columbia University, USA, S.J. Edixhoven.
Ch. Peters, Grenoble, France, S.J. Edixhoven/J.P. Murre.
A. Conte, Torino, Italy, J.P. Murre.
P. Parent, Bordeaux, France, S.J. Edixhoven.
A. Yafaev, London, England, S.J. Edixhoven.

2. Analysis

2.1. Analysis on Lie groups
J. Faraut, Paris, France, G.van Dijk.
G. Heckman, Nijmegen, The Netherlands, G. van Dijk.
S. Helgason, Cambridge, United States, G. van Dijk.
R. Howe, New Haven CT, United States, G. van Dijk.
T. Kobayashi, Kyoto, Japan, G. van Dijk.
T. Koornwinder, Amsterdam, Netherlands, G. van Dijk.
V.F. Molchanov, Tambov, Russia, G. van Dijk.
H. Ochiai, Nagoya, Japan, G. van Dijk.
B. Orsted, Odense, Denmark, G. van Dijk.
G. Olafsson,Baton Rouge, United States, G. van Dijk.
T. Oshima, Tokyo, Japan, G. van Dijk.
A. Pasquale, Metz, France, G. van Dijk.
M. Pevzner, Reims, France, G. van Dijk.
H. Schlichtkrull, Copenhagen, Denmark, G. van Dijk.
E. Thomas, Paterswolde, Netherlands, G. van Dijk.
E. van den Ban, Utrecht, Netherlands, G. van Dijk.

A. Vershik, St. Petersburg, Russia, G. van Dijk.
M. Wakayama, Fukuoka, Japan, G. van Dijk.
G. Zhang, Gothenburg, Sweden, G. van Dijk.

2.2. Numerical Analysis
M. Crouzeix, Rennes, France, M.N. Spijker.
C. Palencia, Valladolid, Spain, M.N. Spijker.

2.3 Analysis, Dynamical Systems and Applications
S. Silvestrov and C. Svensson, Lund, Sweden, M.F.E. de Jeu .
R.D. Nussbaum, USA, S.M. Verduyn Lunel.
B. Cahlon, Rochester, USA, S.M. Verduyn Lunel.
F. Izsak, Budapest, Hongary, S.M. Verduyn Lunel.
M. Smith, York, UK, S.M. Verduyn Lunel.
M. Riedle, Berlin, Germany, S.M. Verduyn Lunel.
S. Piskarev, Moscow, Russia, S.M. Verduyn Lunel.

3. Stochastics and Operations Research

3.1 Probability and Mathematical Statistics
Prof. G. Lugosi, Barcelona, Spain, S.A. van de Geer.
Dr. S. Rolles, University of Bielefeld, Germany, F. Merkl.
Prof. M. Wegkamp, Tallahassee, Florida, S.A. van de Geer.

3.2 Operations Research
B. Gaujal, Grenoble, France, A. Hordijk.
E. Thierry, Lyon, France, A. Hordijk.

Research Staff

1. Number theory, Algebra and Geometry

1.1 Number theory

permanent staff:

prof.dr. R.J.F. Cramer	(from June 1)
prof.dr. J.P. Hogendijk	(from September 1)
prof.dr. H.W. Lenstra	
prof.dr. P. Stevenhagen	
prof.dr. R. Tijdeman	
dr. J.-H. Evertse	
dr. B. de Smit	
drs. M.A.J.G van der Vlugt	

Kloosterman professor

prof.dr. N. Yui	(January 15 – March 15)

postdocs:

dr. W.B. Hart MSc.	(from March 1)
dr. C.L.J. Ritzenthaler	(March 1 – October 1)

Ph.D. students:

drs. K.J. Batenburg	(CWI)
drs. R.M. Bröker	
R. Carls, Dipl. Math.	(UL/RUG)
drs. J.L.A.H. Daems	(from November 1)
drs. W.H. Ekkelkamp	(CWI, from February 1)
drs. B.J.H. Jansen	
drs. W.J. Palenstijn	(NWO, from April 1)
drs. S.W. Rosema	
S. Tengely, MSc.	
drs. C.E. van de Woestijne	(from September 1)

guest researchers:

dr. J. Bouw	
dr. C. Fuchs	(from December 1)

1.2 Algebra and Geometry

permanent staff:

prof.dr. S.J. Edixhoven
dr. M. Lübke

emeriti:
prof.dr. J.P. Murre
prof.dr. A.J.H.M. van de Ven

Ph.D. students:
drs. Th. van den Bogaart
drs. G. Wiese, Dipl. Math.
drs. J.G. Bosman (from June 1)

guest researcher
prof.dr. F. Oort

Analysis

2.1 Analysis on Lie Groups

permanent staff:
prof.dr. G. van Dijk (till September 1)

emeritus
prof.dr. G. van Dijk (from September 1)

Ph.D. student:
S. Aparicio Secanellas, MSc.

2.2 Numerical Analysis

permanent staff:
prof.dr. M.N. Spijker (till August 1)
dr. J.A. van de Griend

emeritus
prof.dr. M.N. Spijker (from August 1)

Ph.D. student:
drs. L. Ferracina

2.3 Analysis, Dynamical Systems and Applications

permanent staff:
prof.dr. S.M. Verduyn Lunel
prof.dr. R. van der Hout
dr. S.C. Hille
dr. M.F.E. de Jeu

Kloosterman professor
prof.dr. R.D. Nussbaum (April 1 – June 1)

emeritus
prof.dr.ir. L.A. Peletier

postdocs:
dr. D.R. Pik
dr. V. Rottschäfer (KNAW fellow)
dr. J.F. Williams (UL/CWI)

guest researcher:
dr. B. Hanzon

Ph.D. students:
H.J. Hupkes
M. Muskulus Dipl.Math. (NWO, from August 1)
M. Santini Frasson, MSc.

3. Stochastics and Operations Research

3.1 Probability and Mathematical statistics

permanent staff:
prof.dr. S.A. van de Geer
prof.dr. W.Th.F. den Hollander (from September 1)
dr. F. Merkl (NWO, till October 1)
dr. E.W. van Zwet

emeritus:
prof.dr. W.R. van Zwet

postdoc
dr. L. Mohammadi (NWO) (UL/Eurandom) (from November 1)

Ph.D. students:
drs. J.J. Goeman
G. Hadjicharalambous, MSc. (from May 1)
L. Mohammadi, MSc. (till November 1)
B. Tarigan, MSc. (NWO)

3.2 Operations Research

permanent staff:
prof.dr. A. Hordijk
prof.dr. L.C.M. Kallenberg
dr. F.M. Spieksma

4. Mathematics, Computer Science and Society

permanent staff:
drs. F.A.J. Birrer

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dr. J. Finkelnberg
dr. R.J. Kooman

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M.F. Feleus
R. Huizer (from September 16)
K.F.D. Rietveld

computer helpdesk:
drs. F.J.E. van Bemmelen (till September 1)
R. Huizer (till September 1)
M. van der Meer (till February 1)
W.J. Palenstijn (till April 1)

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R. van der Waal

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T.H. Bakker-Bouma

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P.J. Bruin
B. van Dalen (from September 1)
M. van der Schans
A.P. Stolk
P. Tibboel (till June 1)
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D. Worm

student assistants pr:
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