Annual progress report ALAPEDES

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0 Introduction

0.1 The network

ALAPEDES is the acronym for ALgebraic Approach to Performance Evaluation of Discrete Event Systems. The theory of discrete event systems deals with dynamical systems that are *event-driven* as opposed to *time-driven*; usually their state variables take on only discrete values. Several approaches exist to study discrete event systems; of these the "logical" approach, where the *ordering* of the events is of interest, and the "timed" approach, where the *timing* of the events is also of interest for the mainstreams form the research within ALAPEDES. In both streams the structure of algebraic systems plays a dominant rôle.

In ALAPEDES eight partners from four different countries work together in ten strongly interrelated subprojects, to develop new theory, applications and software tools within the algebraic approach to discrete event systems. ALAPEDES is a network in the framework of the TMR programme, European Commission, Directorate General XII, network contract no. ERB–FMRX–CT 96–0074.

0.2 The report

This report describes the activities of the network ALAPEDES during the fourth year of its official existence (the commencement date was October 1, 1996). The report is written to inform the European Union on the progress of the ALAPEDES network, but equally serves as an information source on ALAPEDES for the network partners (and maybe for interested outsiders as well).

The report consists of five parts. This first (*Section 0*) serves as an introduction to it; included are the acronyms of the partners and a list of the subprojects.

Section 1 describes the progress of the ALAPEDES network against the objectives set out in the work programme. It gives the scientific results (1.1) per subproject, relating them, whenever possible, to the text in previous annual reports, gives scientific highlights (1.2) for the general reader, reports on networking and coordination activities undertaken (1.3), introduces the researchers funded by the network (1.4), gives information about contacts with industry (1.5), and lists difficulties experienced with environmental constraints (1.6).

Section 2 gives factual information on the network activities. The scientific specialities of the partners are listed (2.1), according to the codes that the European Union uses, the research staff involved is listed (2.2), introducing the researchers funded by the network (2.3), presents publications that have emerged or will emerge from the network activities (2.4) and acknowledges secondments between partners (2.5).

Section 3 stresses the collaboration within the ALAPEDES network. In it a list of joint publications is given (3.1) and a description of the way contacts and coordination were sustained (3.2).

The report has five appendices. *Appendix A* tries to list the names of all researchers involved in ALAPEDES in one way or another. *Appendix B* gives an extensive list of publications. *Appendix C* gives additional information about the network, that is not explicitly required according to the reporting guidelines. Furthermore, one finds in *Appendices D and F* the programme of the ALAPEDES workshops held in Delft (The Netherlands) and Hamburg (Germany), respectively.The programme of a meeting of the so-called Tropical Days has been made available in *Appendix E*, while *Appendix G* gives the reader the occasion to learn about a special issue of the Journal of Theoretical Computer Science, devoted to $(\max, +)$-algebra.

0.3 Legend

0.3.1 Partners

The ALAPEDES network consists of eight partners (one of which comprises two locations). They are frequently referred to, in which the following acronyms are utilized.

TUD – Technische Universiteit Delft, Delft, Nederland;
scientific teamleader: G.J. Olsder; g.j.olsder@math.tudelft.nl

ENPC (replacing ARMINES) – École Nationale des Ponts et Chaussées, Champs-sur-Marne, France;
scientific teamleader: G. Cohen; guy.cohen@mail.enpc.fr

INRIA – Institut National de Recherche en Informatique et en Automatique) has two research teams involved in ALAPEDES:

INRIA - Sophia Antipolis (near Nice), France;
scientific teamleader: F. Baccelli; francois.baccelli@inria.fr

INRIA - Rocquencourt (near Paris), France;
scientific teamleader: J.-P. Quadrat; jean-pierre.quadrat@inria.fr

KUL – Katholieke Universiteit Leuven, Leuven, België;
scientific teamleader: B. De Moor; bart.demoor@esat.kuleuven.ac.be

HP – Hewlett Packard Limited, Basic Research Institute in the Mathematical Sciences (BRIMS), Bristol, United Kingdom;
scientific teamleader: J.H.C. Gunawardena; jhcg@hplb.hpl.hp.com

LIAFA (formerly **LITP**) – Université Paris VII, Laboratoire d'Informatique Algorithmique: Fondements et Applications, Paris, France;
scientific teamleaders: J. Mairesse; mairesse@liafa.jussieu.fr and D. Krob; krob@liafa.jussieu.fr

RUG – Rijksuniversiteit Groningen, Groningen, Nederland;
scientific teamleader: R. Smedinga; rein@cs.rug.nl

UCL (replacing ULG) – Université catholique de Louvain, Center for Systems Engineering and Applied Mechanisms (CESAME), Louvain-la-Neuve, Belgique;
scientific teamleader: V. Blondel; blondel@inma.ucl.ac.be

As per 1 September two scientists-in-charge moved to another employer. During the period reported on, their old employers — ARMINES and ULG — were contractually replaced by the new employers — ENPC and UCL —. See Appendix 1.3.1 for further details.

0.3.2 Subprojects

The ALAPEDES network is structured into ten closely related subprojects. As for instance noticed at the mid-term review meeting, the split up of the research according to these ten subprojects has not always been very strict. We prefer, however, to keep reporting according to this structure as much as possible. Whenever practicable activities and accomplishments in the sequel will be brought in relation with these subprojects; for ease of reference they are summarized below (the text utilizes the accompanying codes).

Cross-Fertilisation on The Theoretical Level

T-1 Representation problems
T-2 Stability problems
T-3 Optimisation problems
T-4 Control of automata
T-5 Large systems problems

Applications

A-1 Transportation systems
A-2 Manufacturing systems
A-3 Communication networks

Software

S-1 Investigation and critical analysis of existing software
S-2 Development of new software

0.3.3 Glossary

In the report the term (ALAPEDES) *partner* is used for the organizations that were listed in § 0.3.1; students preparing their graduation are called *undergraduates*, graduated students working for a doctoral degree are referred to as *postgraduate*s or *doctoral students*, researchers having a doctoral degree are called *postdocs*; the term ALAPEDES *researcher* is reserved for those (mostly postdocs) who are paid by the network funds, and ALAPEDES *member* applies to researchers working for some ALAPEDES partner, but paid from other funds.

1 Progress

During the year of this (fourth) annual report, two ALAPEDES meetings (conventions as we call them) have been organised; one in Delft (the Netherlands, organised by the contractor TUD), and one in Hamburg-Harburg (Germany, hosted by the Universität zu Hamburg; the local organiser was Daduna). See further § 1.3.3.

The researchers within ALAPEDES were happy to learn that their request for an extension of the contract with the European Commission from four to five years had been granted. The main reason for this request was the difficulty in finding postdocs for entering the project. The improvement in the number of postdocs employed within ALAPEDES, of which traces were already visible during the third year of its existence, continued during the fourth year. It is doubted, however, whether all associated contractors will have used all their planned postdoc months at the end of the contract period (being September 30, 2001). See also § 1.4.1.

Two teamleaders changed employer last year (Cohen from ARMINES to ENPC and Blondel from ULG to UCL), the legalisation of which within the ALAPEDES framework and the TMR programme took more paperwork than anticipated. See further § 1.3.1.

Apart from the two successful conventions mentioned above, the exchange and mutual visits of postdocs to other (associated) contractors were rather limited, with the exception of the contacts between the French associated contractors being located in or near Paris.

The time spent by the network coordinator on ALAPEDES issues is unfortunately less than before since he has become vice-rector of TUD (from September 1, 1999 to date).

All ALAPEDES postdocs seem to be locally well integrated.

1.1 Scientific results

The description of the scientific results is structured according to the ten subprojects. Activities which belong to more than one subproject, have been mentioned under one of them and a reference from the other subproject(s) to that description is given. Frequently names of persons are mentioned; names with an ALAPEDES connection appear in Appendix A where more particulars, such as home institution and the rôle in ALAPEDES can be found. Next to these descriptions, there is a separate one (§ 1.1.11) on milestones. Cross-references with the previous annual progress report, whenever appropriate, are sometimes given.

1.1.1 T-1

In the last three years, the $(\max, +)$-working group at INRIA (composed of Quadrat, Gaubert, and Cohen — formerly with ARMINES, now with ENPC) has been involved in trying to understand geometric issues in idempotent semimodules like $\mathbb{R}^n$. In particular, the notions of images and kernels of residuated or linear operators, and that of projection onto an image parallel to a kernel were introduced. Further progress has been achieved this year regarding the notion of *orthogonal projections* (namely, projections onto an image parallel to the kernel of the residual operator which plays the rôle of the adjoint operator). It has been shown that this notion of projection can be related to a *separation theorem* which states that an hyperplane, orthogonal to the direction of projection, strictly separates the projected point from the target image whenever the point does not belong to that image. The statement of such a result requires introducing several new notions which are, in idempotent semimodules, the analogues of *scalar products* and *linear forms* of standard vector spaces. A notion of *convex subset* has also been introduced and projections onto such subsets is under study at this moment. This opens the roads to several potential results which are generally derived from the Hahn-Banach separation theorem of convex sets (e.g., subdifferential calculus for convex functions or optimality conditions in convex programming). A preliminary

account of such results can be found in [24].

Haar (INRIA) obtained new results on timed discrete event systems. In [47], he showed, through an explicit translation, the equivalence between a class of timed automata and a class of timed Petri nets.

Haar and Gaujal (INRIA) have continued their investigationon non-ambiguity in Petri nets. In a paper presented at WODES 2000 [38], they have shown that the limit policy (immediate transitions are seen as timed transitions with a timing interval going to 0) provides such a non-ambiguous policy, provided the net is bounded and does not contain uncontrolled cycles of immediate transitions.

Baccelli (INRIA) and Haar are jointly working on evolution equations for competition based networks. The main results obtained so far are monotonicity results. The main motivation is the study of multiclass networks.

Haar pursues the investigation of Occurrence (Petri) Nets on two levels: their structural theory and their interpretation in *branching unfolding semantics* of Petri Net systems, and has brought new results as well, in particular the introduction of new classes of partial order logics of high expressivity [44]. Moreover, occurrence nets show how the situation of confusion (indirect influence by concurrent events) can be structurally characterized in terms of net clusters; at the same time, clusters turn out to provide a new partial order semantics with potential application in performance evaluation.

Haar is currently working on probabilistic semantics for occurrence net processes. In two different cooperations, one with the Humboldt Universität zu Berlin, and the other with IRISA at Rennes, he is working on the probabilistic investigation of logical and quantitative properties in concurrent processes. He presented first results of this approach at the ALAPEDES convention in Hamburg in July, 2000.

There exists a collaboration between the group of Sakarovitch at ENST, Paris and LIAFA on the topic of idempotent semirings. Lombardy (ENST) has been working on the decidability of the determination of automata with multiplicities in the $(\max, +)$–semiring. On a one letter alphabet, he found a decision algorithm based on the structure of a given automaton that realizes the $(\max, +)$-function and an improvement on the subset construction to obtain a deterministic automaton, if it exists. Results hold for a large class of $(\max, +)$- or $(\min, +)$-semirings. This work has been presented at the conference Descriptional Complexity of Automata, Grammars and related Structures in London, Ontario.

Model predictive control (MPC) is a very popular controller design method in the process industry. An important advantage of MPC is that it allows the inclusion of constraints on the inputs and outputs. Usually MPC uses linear discrete-time models. As a project, De Schutter (KUL research fellow) and Van den Boom (TUD) extend MPC to a class of discrete event systems.

They have developed an MPC framework for $(\max, +)$-linear discrete event systems. In general, the resulting optimization problem is nonlinear and nonconvex. However, if the control objective and the constraints depend monotonically on the outputs of the system, the MPC problem can be recast as a problem with a convex feasible set. If, in addition, the objective function is convex, this leads to a convex optimization problem, which can be solved very efficiently.

Recently, they have extended these results to discrete event systems and hybrid systems that can be described by models in which the operations maximization, minimization, addition and scalar multiplication appear.

Topics for future research are the extension of the current MPC framework to nondeterministic $(\max, +)$-algebraic models, the development of efficient methods to solve this extended problem, a thorough investigation of the effects of the tuning parameters in $(\max, +)$-algebraic MPC, and determination of rules-of-thumb for selecting appropriate values for the

tuning parameters.

Publications within ALAPEDES which are relevant to this part of the subproject are [28, 19, 20, 29, 27].

Olsder (TUD) and De Schutter (KUL), as joint authors of an overview paper of (minimal) state space realisations starting from Markov parameters, still must decide as where to submit this article.

1.1.2 T-2

In a joint effort by LIAFA and UCL, Mantaci (LIAFA) has been working with Blondel (UCL) and Mairesse (LIAFA) on iterates of bilinear functions over the $(\max, +)$-semiring.

Equivalently, the object of study can be viewed as recognizable tree series over the $(\max, +)$-semiring. In this semiring, a fundamental result associates the asymptotic behaviour of the iterates of a linear function with the maximal average weight of the circuits in a graph, naturally associated with the function. There is an analog result for the "iterates" of bilinear functions. Furthermore, it is possible to give an explicit description of a triple recognizing the formal power series of the worst case behaviour. This work is linked to results by Gaubert (ENSTA and INRIA - Rocquencourt) on the growth of coefficients in an algebraic series over the $(\max, +)$-semiring.

A publication within ALAPEDES which is relevant to this part of the subproject is [59].

Hong (INRIA) defended his thesis [51] on expansions for Lyapunov exponents. The main results bear on the asymptotic behaviour of iterates of random functions, in particular monotone and homogeneous functions, and more particularly $(\max, +)$-linear functions, concerning three types of questions: 1. existence, 2. performance evaluation or approximation by power series, and 3. analyticity with respect to parameters of the distribution.

Two classes of networks are studied in the continuation of these questions: TCP type window flow control model (see § 1.1.8), and slotted Jackson fluid model. This latter example is a stochastic recurrence system which is monotone but not homogeneous.

A survey paper on the computation of Lyapunov exponents was presented at the Allerton conference [5]. Two papers by Baccelli (INRIA) and Hong have appeared or will soon appear in applied probability journals [7, 6]. Another paper by Gaubert (INRIA) and Hong is submitted for publication [37].

Spectral Theory of Monotone Homogeneous Maps. Both the HP research group (Gunawardena) and the INRIA - Rocquencourt research group (Gaubert, Akian, Cochet-Terrasson) work on this topic. Dynamical systems of monotone homogeneous maps naturally arise as models for the time behaviour of discrete event systems. Performance evaluation issues lead to a few questions of pure analysis, such as characterizing the asymptotic behaviour of the orbits and characterizing the existence of eigenvectors.

In the last four years, several papers of Gunawardena, Gaubert, and Cochet-Terrasson gave precise asymptotic results in the special case of min-max-functions, and more generally, for piecewise affine maps. This year, Gaubert and Gunawardena showed that the existence of eigenvectors of a monotone homogeneous map, acting on the positive cone, is controlled by a family of digraphs, built by an aggregation procedure. This refines several known theorems of this kind, due to Bather, Nussbaum, and Oshime. Another recent, rather surprising, fact is the following: if the recession function of a monotone homogeneous map f has only fixed points on the diagonal, then f has an eigenvector. These new results are presented in the revised version of the article written last year [36].

Additionally, there are several recent theoretical progresses. Gaubert and Gunawardena proved the existence of the cycle time vector for a wide class of monotone homogeneous maps introduced by Nussbaum, combining a density argument with a previous existence result for the cycle time of piecewise affine monotone homogeneous maps. Akian and Gaubert studied

eigenspaces of convex monotone homogeneous maps, and extended the $(\max,+)$-spectral theorem to this case. In particular, this characterizes the dimension of the eigenspace in non-singular cases.

Cochet-Terrasson, Gaubert and Gunawardena are now working with Akian to use this new result to generalize their policy iteration algorithm given in a previous paper on min-max-functions. This recent work was started during the visit of Akian and Gaubert at HP, during July, 2000, and pursued while attending at the HP-Microsoft workshop, Bristol, during September, 2000 (see also § 1.3.4).

A publication within ALAPEDES which is relevant to this part of the subproject is [23]. Van der Woude and Subiono (TUD) have obtained various results with respect to eigenvalues of $(\min,\max,+)$-systems and with respect to numerical algorithms to calculate these eigenvalues and corresponding eigenvectors. Especially for bipartite $(\min,\max,+)$-systems concrete results were obtained. Subiono finished writing his doctoral thesis which was successfully defended on June 29, 2000. Supervisors were Olsder and Van der Woude.

Publications within ALAPEDES which are relevant to this part of the subproject are [74, 75, 77, 76, 73].

Katirtzoglou (TUD) worked on a class of functions, defined on the cone of nonnegative vectors in $\mathbb{R}^n$, that are homogeneous and order preserving. Such maps, which she calls HOPe functions, are nonexpansive (with respect to Hilbert's projective metric) and continuous.

She gave an asymptotic characterization of the (cone) spectral radius. More precisely, she showed that $\rho(F) = \lim_{k\to\infty} \max_{1\le i\le n} (F^k(x))_i^{\frac{1}{k}}, \quad x \in (\mathbb{R}^n_+)^\circ$. As an immediate conclusion she got that the maximum component of the cycle time vector $\chi(F) = \lim_{k\to\infty} (F^k(x))_i^{\frac{1}{k}}$, whenever it exists, of such maps is equal to their spectral radius. The latter is consistent with earlier results concerning the cycle time vector of specific HOPe functions.

Furthermore she studied the question of existence of eigenvectors in the interior of the cone, a question that so far has a satisfactory answer only for certain classes of HOPe functions.

Publications within ALAPEDES which are relevant to this part of the subproject are [53, 52].

Katirtzoglou did some joint work with Van Egmond (TUD) on nonexpansive mappings. This collaboration ended rather early when Van Egmond suddenly decided to leave the university (he did not finish his doctoral research).

Soto y Koelemeijer (TUD) worked with Heidergott, currently working at Eurandom, Eindhoven, and found good upper bounds for the coupling time of $(\max,+)$-linear systems. This research resulted in [70].

In [67], Soto y Koelemeijer linked two algorithms in the $(\max,+)$-semiring, namely the power algorithm and the policy iteration algorithm.

Related publications are [69, 68].

1.1.3 T-3

Mairesse (LIAFA) has been collaborating with Bousch (CNRS, Université Paris-Sud, Paris) on the following problems.

Given an Iterated Function System (IFS) of topical maps satisfying some conditions, they prove that the asymptotic height optimization problems are equivalent to finding the extrema of a continuous functional, the *average height*, on some compact space of measures. They give general results to determine these extrema, and then apply them to two concrete problems. First, they give a new proof of the theorem that the densest heaps of two Tetris pieces are balanced (see also below). Second, they construct an explicit counterexample to the Lagarias-Wang finiteness conjecture. Given a finite number of square matrices (in the usual algebra), the *joint spectral radius* is defined as $\rho_{\max} = \limsup_n(\max(\rho(\text{products with } n \text{ factors})^{1/n}))$, where $\rho(A)$ is the spectral radius of the matrix A. It has been conjectured by Lagarias and

Wang, and also by Gurvits (Institute for Advanced Studies, Princeton), that the supremum in the above equation be always attained. This statement is known as the *finiteness conjecture*.

The joint spectral radius and the conjecture are particularly relevant in wavelet theory, as shown by Daubechies and Lagarias. In their work, Bousch and Mairesse provide a counterexample to the conjecture consisting of two 2×2 matrices.

In a Tetris heap model, one lets pieces pile up according to the Tetris game mechanism. Mairesse and Vuillon (LIAFA) proved in 1998 that in a model with two types of pieces, the densest heaps are always balanced (periodic or Sturmian). This work was first reported in the second annual progress report. The corresponding paper has been accepted for publication and completely reworked in 2000. It now contains a proof of the existence of optimal sequences for all $(\max, +)$-automata, as well as a counterexample, showing that for a general $(\max, +)$-automaton (i.e. not necessarily a heap automaton), optimal sequences are not necessarily balanced. Sparrow (HP) has recently proposed an alternative proof of the result on balanced densest heaps.

Publications within ALAPEDES which are relevant to this part of the subproject are [21, 58].

Together with Nichitiu and Cassaigne (IRM, Marseille), Blondel (UCL) has constructed an example of a dynamical system that disproves Kurka's conjecture on the dynamics of Turing machines. A publication within ALAPEDES which is relevant to this part of the subproject is [15].

In a paper to be presented during the CDC 2000 [3], Altman, Gaujal (INRIA) and Hordijk present the notion of multimodular triangulation from a new geometrical point of view. They also show the link with multimodular functions by a new proof of the convexity theorem. This is used to define a partial ordering, compatible with multimodularity, called the *cone ordering*. An application to admission control in queues has also been derived.

Gaujal and Hyon (INRIA) have considered the problem of routing customers to one of two parallel queues where inter-arrival times and service times are deterministic in [39]. They provide an explicit formula for the average waiting time of the customers sent to one of the queues if the routing policy is an upper mechanical word. This formula is based on a special continued fraction decomposition of the service time in the queue. Using this formula they provide an algorithm computing the optimal routing policy for two queues. In general, this policy is an upper mechanical word with a rational ratio, and hence is periodic.

1.1.4 T-4

In collaboration with Droste, Gastin (LIAFA) has continued his work on formal power series in partially commuting variables. Formal power series over non-commuting variables have been investigated as representations of the behaviour of automata with multiplicities. Here they introduce and investigate the concepts of aperiodic and of star-free formal power series over semirings and partially commuting variables. They prove, that if the semiring K is idempotent and commutative, or if K is idempotent and the variables are non-commuting, then the product of any two aperiodic series is again aperiodic. They also show that, if K is idempotent and the matrix monoids over K have a Burnside property (satisfied, for instance, by the tropical semiring), then the aperiodic and the star-free series coincide. This generalizes a classical result of Schützenberger (1961) for aperiodic regular languages and covers a result of Guaiana, Restivo and Salemi (1992) on aperiodic trace languages.

A publication within ALAPEDES which is relevant to this part of the subproject is [32].

In a paper, to appear in IEEE Transactions on Systems, Man and Cybernetics [2], Alpan and Gaujal (INRIA) have presented a new point of view on supervisory control of Petri nets by using routing functions in stead of the traditional control places. They first show the relation between the two notions. In the second part of the paper they illustrate the

use of routing functions by showing how to compute a routing function in order to avoid starvation in general Petri nets. This control uses a continuous version of the net and a description of the evolution of the net under the form of linear algebraic equations. As for the computational part, they use algebraic polynomial geometry in the continuous case and Diophantine equations for the discrete version of the Petri net under study.

1.1.5 T-5

The work on infinite tandem queueing networks (reported in the previous reports) has continued. Queues with finite buffers and greedy lattice animals have been investigated by Martin (INRIA). This work has involved frequent interactions between Martin, Baccelli (INRIA) and Mairesse (LIAFA). The work by Martin on the asymptotics of large queueing systems composed of blocking queues in series was presented at the ALAPEDES convention held in Delft in October, 1999.

The work of by Baccelli (INRIA), Mairesse (LIAFA) and Borovkov [4] studies the links between products of infinite-dimensional random $(\max, +)$-matrices and more general random longest path problems, on one side, and interacting particle systems and percolation on the other side. Typical examples are tandem queues or totally asymmetric exclusion processes with general statistics.

Martin (INRIA) is now investigating other and more general structures. In [60], these results are extended to apply to situations where the queues have finite capacity and so various types of "blocking" can occur. The models correspond to $(\max, +)$-recursions, of simple form but in infinitely many dimensions. Topics treated include: laws of large numbers for the speed of customers progressing through the system; stationary behaviour for systems with external arrival processes; functional laws of large numbers, describing the behaviour of the "front of the wave" progressing through a system which starts empty; and stochastic orderings for waiting times of customers at successive queues.

Work in progress also involves the extension of these models to include more general task graphs with tandem-like properties, in particular to determine which systems behave like "infinite capacity" queueing systems, and which behave like systems with blocking, and to analyse the asymptotic behaviour and conditions for stability in each case.

The infinite-dimensional $(\max, +)$-systems referred to above, correspond to problems of finding paths of maximum weight through a two-dimensional lattice with random weights at the vertices: "directed last-passage percolation". Current work involves the analysis of "asymptotic shape" for such systems and for their generalisations into higher dimensions. Some very hard problems exist (concerning the strict concavity and the smoothness of the shape), which have remained unsolved in analogous undirected models for some time, and which seem similarly difficult in the directed case. More approachable problems concern the asymptotics of the shape at the boundary (which exists only in the directed case), and the dependence of the shape on the distribution of the weights at the vertices.

The "greedy lattice animals" model was introduced by Gandolfi, Kesten and others, and in one sense is a generalisation of the "last-passage percolation" models described above. In [61], slightly improved conditions for linear growth in these models are given, using arguments which are considerably more straightforward than in previous work. These yield stability conditions for the tandem queueing models, and conditions for the existence of the asymptotic shape in the last-passage percolation models. Other applications include a variety of models in statistical mechanics.

Work in progress by Martin involves the construction of non-Markovian versions of traditional interacting particle systems such as the simple exclusion process and the zero range process. These models correspond to versions of the tandem queueing networks mentioned above, but in which the set of queues is infinite in both directions. The aim is to establish a duality with the problem of finding "geodesics" in the associated percolation models.

Work in progress involves the extension of traditional "first-passage" percolation models to systems which are continuous both in time and in space, to model the transmission of information by radio broadcast among a rather dense collection of transmitters. Questions of interest involve again the asymptotic shape of the "covered region", and the distribution of the length (number of hops) of the time-minimising path between two points in the space.

In [62, 63], Martin continued the study of Markovian queueing networks with load-balancing. The first paper concerns the convergence of point processes of arrivals and departures at individual queues as the networks become large. The second paper establishes stochastic bounds for the transient behaviour of such networks in the case where some nodes are overloaded, and so no equilibrium exists.

Collaboration between Mairesse (LIAFA) and Prabhakar (Stanford University), has also continued on the subject of fixed point existence for a single server station.

Cochet-Terrasson and Gaubert (INRIA) pursued the theoretical, algorithmic, and implementation work on policy iteration algorithms, which are fast algorithms well adapted to large size problems. They showed that in the special case of deterministic optimal stopping, policy iteration takes a strongly polynomial time [23]. Additionally, policy iteration gives a new strongly polynomial algorithm to find a circuit of positive weight in a digraph. They included the algorithm in the $(\max, +)$-library of Scilab, and performed numerical experiments. The efforts described here bear strong relationships with other subprojects: see §§ 1.1.3 and 1.1.10.

Burbanks and Sparrow (HP), in collaboration with Nussbaum (Rutgers) have made progress in understanding the conditions under which order-preserving maps of the cone extend continuously to the boundary of the cone. In particular their work shows that topical maps always extend continuously, and so answers, in the negative, the question of whether existence of a cycle time vector is connected with extendibility.

A publication within Alapedes which is relevant to this part of the subproject is [22].

1.1.6 A-1

A study of a simple traffic system has been studied by Lotito, Mancinelli (INRIA), Malyshev and the $(\max, +)$-working group (Cohen, Gaubert and Quadrat). The problem consists in studying a circular traffic road in which N cars can move at two possible speeds changing randomly with time (successive values are independent and the desired speeds of two different cars are also independent at any time). The two possible speeds w and v have given probabilities. They want to compute the average speed of cars on such a road.

In the case where overtaking is forbidden, the system is a linear stochastic system, the Lyapounov exponent of which provides the average speed. This system is simple enough and the stationary regime is completely understood. A simple recurrent and explicit formula yields the average speed. It is a rare case when we are able to compute the Lyapounov exponent explicitly. The formula obtained can be adapted to give at least a very good approximation of the average speed in more general cases when overtaking is allowed.

Generalizations to more general distributions of the speed of cars, or to systems with inputs and outputs of cars and more general traffic network architectures, are possible. A connection with the Boltzmann equations for traffic has been made. An internal report [57] is available.

Another investigation by Pablo Lotito and Elina Mancinelli is starting with the aim of designing a toolbox for Scilab dedicated to traffic problems (see also § 1.1.10). Indeed, there exists mainly commercial software in this area, but it is difficult to find something open (not black-boxed) that researchers can adapt to more global modelling problems, as for example the mutual interactions between land use and traffic supply. One important part of the traffic modelling process is the computation of Wardrop equilibria which has a lot to do with $(\max, +)$-algebra: this is one issue they hope to investigate.

The group at KUL is currently working on modelling and control of highway traffic. Also here, two types of traffic models are studied in the scope of traffic control: microscopic and macroscopic models.

In order to simulate traffic in a reliable way, one need traffic measurements to fit the mathematical models. The traffic sensors are installed along the highway, and the acquired data need to be transported or manually collected. The KUL members studied the different steps to be undertaken in order to collect and preprocess the data and eventually use it in a simulation. The last step in this process is the estimation of origin-destination (OD) matrices. These OD-matrices contain the (time-dependent) traffic flows from every possible origin in the network to every possible destination. An estimation of OD-matrices for the E 17 motorway Gent–Antwerpen was conducted by Bellemans, De Schutter and Egido Arteaga.

Publications within ALAPEDES which are relevant to this part of the subproject are [11, 10].

Some research on macroscopic models and on ramp metering has been conducted by Egido Arteaga, in cooperation with Bellemans and De Schutter. Based on the highway model they studied the possible improvements that can be obtained by using optimal ramp metering. They are looking into adaptive controllers for a ramp metering set-up, hereby taking constraints into account, such as a limited queue length in order to prevent lock-up at the intersections at the on-ramp.

Publications within ALAPEDES which are relevant to this part of the subproject are [26, 9].

Soto y Koelemeijer (TUD) was involved in a project with the Netherlands air carrier KLM, which resulted in a delay propagation model for static networks; this model has been presented during the 5^{th} Trail Congress. Unfortunately, the initial collaboration did not lead to a follow-up.

A publication within ALAPEDES which is relevant to this part of the subproject is [72].

Van Zuylen (Civil Engineering, TUD) presented a paper by Van Egmond, Olsder and himself about the optimization of network traffic control using $(\max, +)$-algebra, in a new environment — the 78^{th} TBR meeting in Washington DC.

A publication within ALAPEDES which is relevant to this part of the subproject is [35].

De Kort, employed with the Dutch Railinfrabeheer, works temporarily at TUD for one day per week on his doctoral thesis under the supervision of Olsder. He hopes to obtain his doctoral degree in the course of 2001. The central theme of the thesis is formed by various approaches to the capacity assessment of railway networks. He also still works together with the former ALAPEDES postdoc Heidergott.

Publications within ALAPEDES which are relevant to this part of the subproject are [54, 50, 55].

Van Egmond (TUD) worked on the optimisation of buffer times in transportation networks and on the heaps of pieces approach within a continuous setting. Unfortunately, Van Egmond decided to leave the university without having finished his doctoral research. The M-matrix, as introduced by Van Egmond (the $(i,j)^{\text{th}}$ entry of the M-matrix denoting the maximum time delay possible at node j whose propagation just does not reach node i), finds applications in other works.

Publications within ALAPEDES which are relevant to this part of the subproject are [33, 34].

1.1.7 A-2

The efforts in the direction of applications have been somewhat shifted from manufacturing systems to transportation problems in the last year. It appears difficult to have access to interesting information about production systems which are of strategic importance for private companies. On the other hand, traffic problems are not well solved nowadays and public research efforts are welcome at this moment.

Nevertheless, an example of application of $(\max, +)$-system theory to production is now available in the demos of the $(\max, +)$-SCILAB-toolbox (see § 1.1.10). The performance evaluation of flowshops can be easily achieved. The resource optimization routine is still missing but we will provide one by the end of the ALAPEDES project.

1.1.8 A-3

Substantial progress was made this year in connection with performance analysis of telecommunications protocols using combinatorial methods. In close contact with Dornstetter (head of Nortel Networks' research and development departement) and Thibon (Université de Marne-la-Vallée), Krob (LIAFA) discovered a purely combinatorial method for solving a complicated performance analysis problem arising in the domain of mobile communications protocol. This solution is now implemented as one of the main routines of software used by Nortel.

Regnie (France Telecom) has started a doctoral thesis entitled *Mathematical modelling of differentiated services to be offered on the IP network*. The thesis is co-directed by Roberts (France Telecom Recherche et Developpement) and Mairesse (LIAFA).

Publications within ALAPEDES which are relevant to this part of the subproject are [30, 31].

In [8] Baccelli and Hong (INRIA) gave a representation of the packet-level dynamical behaviour of the Reno and Tahoe variants of the TCP comunication protocol over a single end-to-end connection using the $(\max, +)$-algebra. This representation allows one to consider the case when the connection involves a network made of several, possibly heterogeneous, deterministic or random routers in series.

It is shown that the key features of the protocol and of the network can be expressed via a linear dynamical system in the so called $(\max, +)$-algebra. This opens new ways of both analytical evaluation and fast simulation based on products of matrices in this algebra. This also leads to closed form formulæ for the throughput allowed by TCP under natural assumptions on the behaviour of the routers and on the detection of losses and timeouts; these new formulas are shown to refine those obtained from earlier models which either assume that the network could be reduced to a single bottleneck router and/or approximate the packets by a fluid.

1.1.9 S-1

The subproject S-1 (investigation and critical analysis of existing software) was completed during the first year of the network.

1.1.10 S-2

The $(\max, +)$-toolbox, started by M^{c} Gettrick and Cohen (ARMINES / ENPC), continued with Gaubert and Quadrat (INRIA), is now available through Internet as a contribution to SCILAB at the following address: `http://www-rocq.inria.fr/scilab/`. For the time being, it includes the $(\max, +)$-arithmetic, $(\max, +)$-linear systems and eigenvalue / eigenvector computation, state space manipulation of dynamical $(\max, +)$-linear systems, stochastic control problems, nonlinear flow problems, and some production system applications. It is available for Linux, Unix and Windows platforms. The integration in SCILAB is complete in the sense that this toolbox adds new internal types to SCILAB.

Adding facilites for transportation systems in the $(\max, +)$-toolbox is the next ongoing development by Lotito and Mancinelli (INRIA). For the time being, a microscopic traffic simulator of a circular road is available. Investigations after Wardrop equilibrium computation have been started. A first implementation of the simplest algorithms will be provided soon. The algorithms to compute the Wardrop equilibrium (optimal traffic assignment in a network) are based on computation of paths of maximal length in a graph.

The $(\max, +)$-toolbox has been presented at WODES (Gent, August 2000), and the application to transportation has been demonstrated at two French workshops dedicated to that category of problems in Paris: GICC ("Gestion et impact du changement climatique", June 2000) and PREDIT ("Modélisation des flux de transport", October 2000).

Work has been started for integration of the SEMIGROUPE software of Pin (LIAFA) in SCILAB. It is still in progress.

The efforts around the program SEMIGROUPE, developed by Pin (LIAFA) have continued. Its specificity is, to be able to deal with semigroups of relations, semigroups of matrices, et cetera. In particular, one can deal with matrices over commutative semirings such as the Boolean semiring, $\mathbb{N}_{\max}$, $\mathbb{N}_{\min}$ and $(\mathbb{N}, +, \times)$.

A (userfriendly) software tool (named PETER) is being developed by Iounoussov (scientific programmer from Ufa, Russia), under the supervision of Van Egmond and Soto y Koelemeijer, at TUD, in collaboration with the Faculty of Civil Engineering and members of the Dutch railways. This software tool must enable non-expert railway employees to judge delays and bottlenecks in railway systems and, amongst others to come up with online solutions, for instance to downplay delays. As yet, the software is too slow.

This collaboration resulted in a few papers [71, 42, 41].

1.1.11 Milestones

After the successful spring school on $(\max, +)$-algebra, held in Noirmoutier, in May, 1998 (and reported in the second annual progress report, Appendix G), the editors of the scientific journal *Theoretical Computer Science* (TCS) suggested to prepare a special issue of TCS on $(\max, +)$-algebras. The co-editors for this special issue are Gaubert (INRIA), Loiseau (Ircyn, Nantes), Mairesse (LIAFA) and Pin (LIAFA).

The 17 papers submitted were covering a large spectrum of the field (ranging from formal languages and control to applications). The selection process for this special issue is now completed; 11 papers have been accepted, and the issue is to appear soon. Several ALAPEDES members are authors of selected papers: Gunawardena (HP), Klimann (LIAFA), Subiono and van der Woude (TUD). A survey to be included in the special issue is being prepared by Gaubert.

A list of the papers which were accepted for publication may be found in Appendix G.

SCILAB, a scientific software environment, being developed is France, has been extended with a $(\max, +)$-toolbox. It is used for solving problems in transportation networks. In the same vein, PETER is being developed as a userfriendly dedicated software tool for railway applications.

Olsder has been invited as plenary speaker on a $(\max, +)$-like subject at the large IFORS congress to be held in Edinburgh, July 8–12, 2002.

The notion of M-matrix as created by R.J. van Egmond. This M-matrix is for instance used in the software (being) developed by Iounoussov for a userfriendly use of $(\max, +)$-calculations for time table issues. This software already functions, be it as yet too slow for practical implementation.

Blondel (UCL) obtained a research grant of his university. The research topic is "Complexity of dynamical systems".

1.2 Scientific highlights

Two trends are visible. The first one is about scientific progress in various directions (the notion of a separation theorem in the $(\max, +)$-setting, model predictive control, spectral theory of homogeneous maps, decidability results, proofs and counterexamples to various

conjectures, to mention a few). The second one is that the applications concentrate on traffic control (as evidenced by results from INRIA, KUL and TUD), and on characterisation of packet flows on networks (INRIA).

1.3 Networking and coordination

1.3.1 General coordination

E-mail Day-to-day contact between ALAPEDES members within different partners is established by electronic mail. The medium is used evenly for scientific purposes (spreading knowledge and tools) and for coordination (preparation of meetings, reporting, information exchange).

Vacancies Vacancies are less a point of concern than before, though there are still some reasons why it turns out to be difficult to find, within a reasonable amount of time, qualified candidates for all positions available. Administrative issues (such as changes in the contract with the European Commission — see below) frequently interfere. The partners seemingly are less hampered by eligibility restrictions in their quest for candidates. UCL reports to have had the choice between several candidates, and could offer several postdocs to work for the network.

The coordinator played little rôle in the search for postdocs to fill in the positions available in the network. In most cases the network partners advertised their own positions specifically. The issue of coordination in the quest for suitable candidates for vacant positions for ALAPEDES researchers is treated in § 1.4.1.

Unfortunately — from the network point of view — quite a few ALAPEDES postdocs stay a relatively short period within the network, because they are offered tenured (academic) positions. The planned exchange of postdocs between the partners is therefore difficult to realize. As a second consequence, the frequency with which the network has to sollicit fresh ALAPEDES researchers is substantially larger than foreseen. Thirdly, the gaps between the contract periods for subsequent ALAPEDES researchers at any partner are not negligible.

All these reasons contribute — to a certain extent — to falling short in the number of deliverable manmonths. Because of the rates of salaries to pay (higher than foreseen and planned), the budget for wages is expected to be insufficient for all remaining manmonths. By using the networking and consumables budgets this problem will effectively be eliminated.

Formal contacts The main reason for formal contacts with the European Commission had to do with changes to the contract, because of two scientists-in-charge having found a new employer. As a consequence, both ARMINES and ULG found obliged to leave the network, because they felt to lack the competence to continue to participate at the anticipated level. They are replaced by ENPC and UCL, respectively, the new employers of the aforesaid scientists-in-charge. Though no net change in the scientific organization and input resulted, the responsibilities had to be changed, and the financial support by the European Commission had to be fairly distributed.

The latter was being left to the partners involved, with consent by the contractor, the former gave rise to two rounds of signatures — at first by all partners in the network, and later on by the partners involved, the contractor, and the European Commission. The changes as such are effective since September 1, 1999, but the contract matter was not finished before August, 2000. The delay, mainly caused by the involved procedure, but also resulting from lack of attention by the ALAPEDES partners themselves, had an adverse effect on the agility and alertness of the network as a whole.

Contacts with the European Commission also resulted from ambiguities between the previous annual progress report and the cost statements. Also, the financial support for an

ALAPEDES researcher, paid as part of the first, withheld from the second, and expected again for the third installment, is still wanting, which has lead to questions to the financial offices of the European Commission. The continuous absence of this third installment meant a further reason for contacts, in which it proved very difficult to obtain the required information.

Furthermore, via the project officer in Brussels, several questions were posed to the European Commission. They had to do with possibilities to redistribute budgets between the partners and between the cost categories, about eligibility of a candidate from outside the European Union, and about the final meeting, in 2001.

As it took a relative long time to get all contract issues settled, both the research group that moved from ARMINES to ENPC, and the research group that moved from ULG to UCL underwent a transitional year, during which they were not in the position to hire new postdocs. Formally, as the change to the contracts became in force as per September 1, 1999, the report at hand concerns work and achievements by the new partners ENPC and UCL, respectively. Retroactively, as became clear much lateron, also during the previous reporting period, the last month formally concerned the new partners in stead of the former ones.

1.3.2 Management committee

The management committee met twice: on October 1, 1999 in Delft, and on July 7, 2000 in Hamburg. Minutes of such meetings are available for internal use.

In both meetings, and like always, the progress within the subprojects, vacancies for ALAPEDES researchers and plans for the period to come were being discussed.

In Delft those present learned about the positive attitude by the European Commission towards the activities in the network, that resulted from the mid-term review meeting om March 31, 1999 in Paris. They were pleased by the extension of the contract with a fifth year, which greatly enhanced the capacity of the ALAPEDES network to fulfill its obligations. The management committee unanimously supported the replacement of two partners by the new employers of the scientists-in-charge for those partners.

In Hamburg the management committee discussed the long absence of the third installment by the European Commission, and estimated remaining obligations and budgets, computed pending expenses for the fourth year, contemplated on ways to redistribute tasks and budgets in order to fulfill — as closely as possible — the deliverables within the available budgets, and concluded that most obligations might be fulfilled if only the possibility were open to reuse the budgets for networking and consumables for personnel costs, as these were still far from exhausted, as a result of prudential network management. Furthermore, plans have been developed for a final meeting, in 2001.

1.3.3 Plenary meeting

During the reporting year two plenary meetings (conventions) have taken place. The first one was held in Delft on October 1 and 2, 1999, and the second one in Hamburg on July 7 and 8, 2000. In both cases many ALAPEDES members were present, and sporadically even a guest from outside the network. Fruitful discussions took place, and valuable contacts between members were laid or tightened.

The (scientific) programmes of both conventions can be found in Appendices D and F, respectively. See also § 3.3.

1.3.4 Subproject meetings

Many meetings have taken place. An overview of most of them can be found in Appendix C, while details on some specific ones have been included in further appendices. In the sequel a

few others are summarized. Beyond those, several other opportunities for the teams to meet each other were being exploited.

ENPC and INRIA - Rocquencourt Cohen visited INRIA - Rocquencourt once a week, the whole year long for interaction with Gaubert, Quadrat, Lotito and Mancinelli.

Maddes workshop Gaujal, Gaubert and Altman have organised a workshop (Maddes) on "Discrete Event Systems and Dynamic Programming" that will be help in INRIA - Sophia Antipolis, on October 28 and 29, 1999. This workshop will bring together researchers coming from the fields of discrete event systems, Markovians decision processes and game theory in the hope to share their insights on common problems arising in the different domains.

Invitation of Blondel to LIAFA Again, this time from end-March to mid-April, 2000, Blondel acted as invited professor at LIAFA. During his stay he worked closely together with Mairesse and Mantaci, and had several meetings with other members of the ALAPEDES network. Mantaci also, in December, 1999, visited Blondel at the UCL.

Meetings at HP HP reports two meetings to have taken place there. The first one was between Burbanks (HP), Katirtzoglou (TUD), Sabot, Metz, Gunawardena (HP) and Walsh (HP).

On 19 July Burbanks, Kolokoltsov, Gaubert (INRIA), Akian (INRIA), Gunawardena and Walsh met, and continued working together in an effort to generalize the policy iteration algorithm (see also § 1.1.1).

HP-Microsoft Workshop In September, 2000 an HP-Microsoft Workshop on Random Matrices, Percolation and Queues was being organized, that brought together many researchers with the network: Gunawardena, Walsh, Gaubert, Baccelli, Haar, Hong, Lotito, Mairesse, Mancinelli, Martin, Quadrat and Sparrow. See also § 1.3.5.

1.3.5 Further networking

Internet At the address `http://www.cs.rug.nl/~rein/alapedes/alapedes.html`, the ALAPEDES network presents itself on Internet. The pages contain the research objectives, approach and work plan, schedules and milestones, a list of participants, an overview of meetings and an advertisement for postdocs and postgraduates. Furthermore, the body of the previous annual progress reports is available there. A brochure aiming at a general public is included as well.

The function of the ALAPEDES pages is to provide factual data on the ALAPEDES network. It is not meant to attract otherwise not interested visitors, and is held sobre. There have been some complaints about the ALAPEDES web page. It is our intention to improve the information regarding our project and Smedinga (RUG) is willing to add and to update. It is not our intention, however, to improve the layout in the sense of a flashy layout with bright colours, etcetera, due to lack of time.

Conferences ALAPEDES members meet each other frequently at conferences outside the network.

Blondel served as a member of the scientific and organizing committee of the WODES (Workshop on Discrete Event Systems), that was being held in Gent during August, 2000.

Also, Cohen and Lotito attended the WODES in Gent. Cohen was one of the panel members during the round table discussion which closed the workshop and he was also a member of the jury for the best student paper prize of this workshop. Lotito gave a talk in the "tools"

session at which he demonstrated the $(\max,+)$-SCILAB toolbox. At the same session, Jean-Marie also demonstrated his toolbox ERS on discrete event systems, and discussions about how to interface both toolboxes have taken place.

It should also be mentioned that a third demonstration at this session was given by researchers of the LISIA (ISTIA, Angers, France) about C^{++} programs to manipulate polynomials and power series in the framework of $\mathrm{M}_{\mathrm{in}}^{\mathrm{ax}}[\![\gamma,\delta]\!]$ (this algebra provides a synthesis of the $(\min,+)$-counter and of the $(\max,+)$-dater approaches of timed event graphs). Those C^{++} programs were activated through SCILAB, and further cooperation between the LISIA team (which is not a member of ALAPEDES) and the $(\max,+)$-working group of INRIA is considered to strengthen the connections between their respective software tools. See also in § 1.1.10.

In the HP-Microsoft conference in Bristol, half a day has been dedicated to $(\max,+)$-algebra. Two surveys have been given, one on basic $(\max,+)$-linear algebra by Gaubert and another one giving a $(\max,+)$-point of view of the main results obtained in large deviation theory by Akian. Lotito also gave a talk on the explicit computation of the average speed of cars on a circular road. See also in § 1.1.6.

In June, 2000, Baccelli (INRIA) gave a course on the $(\max,+)$-modelling of flow control algorithms during the "Conference and Workshop on Stochastic Networks, 2000", that took place at the University of Wisconsin in Madison. At `http://www.cms.wisc.edu/~stochnet/` more details can be found.

Likewise, information on the "Second workshop on the modelling of flow and congestion control mechanisms", begin September, 2000 in Paris, co-organized by Baccelli, is available at `http://www.ens.fr/~mistral/tcp2.html`; two of the lectures were given by Baccelli and Hong (INRIA).

Theses Several instances of co-supervised theses foster networking within ALAPEDES. During the reporting period, Subiono successfully defended his doctoral thesis, entitled "On classes of $(\min,\max,+)$-systems and their applications" [73], at TUD on June 29, 2000. Supervisors were Olsder and Van der Woude.

1.4 Researchers

1.4.1 Publication of vacant positions

Vacancies related to the ALAPEDES project have been published or made known via several webpages, including `http://www.cs.rug.nl/~rein/alapedes/alapedes.html` (those of the network), CORDIS, the ABG website, the NA Digest and the ESAT vacancy webpage at `http://www.esat.kuleuven.ac.be/vacancies/index.en.shtml`, and via the use of electronic letters: the E-LETTER on Systems, Control, and Signal Processing , the Intelligent Transportation Systems Council Newsletter at `http://www.ewh.ieee.org/tc/its`, the Vehicular Technology Society's newsletter at `http://www.vtsociety.org/` and the Interuniversity Pole of Attraction (IUAP) newsletter are mentioned here.

Furthermore informal networks and accidental contacts are being used to sollicit potential candidates on an individual basis.

During the year reported on several ALAPEDES researchers (all of whom fall in the postdoc category) left the network. This effect was counterbalanced, however, because a comparable number of new postdocs entered the network. Even though the number of ALAPEDES researchers is up to the level that was planned originally, and the total research effort by this category raised substantially since the mid-term review, the deliverables in terms of manmonths will only be approached from below.

See § 1.4.3 for an overview of ALAPEDES researchers.

1.4.2 Dissemination of applications

Applications were sollicited specifically for vacancies the partners in the network have. Information on relevant candidates for open positions within other associated contractors was communicated throughout the network.

The network has the intention to reallocate postdocs at least once during the duration of the network (thus after one or two years) over the ALAPEDES partners. Because of difficulties in solliciting (see § 1.6) and in tying postdocs with a temporary position to the network this intention hardly can be concretized.

Stefan Haar has, from November 1, 1999, joined INRIA-ENS, but stayed within INRIA (see also § 1.4.3). Not only he, also several of the former postdocs stay in close contact with ALAPEDES.

1.4.3 Researchers paid from the network

A list of ALAPEDES researchers can be found in § 2.3 and in Appendix A, where also a table of all other researchers involved in ALAPEDES can be found.

Integration ALAPEDES researchers partly enter the network with a background that differs from the ALAPEDES theme. Integration in the network is quite successful. This is partly due to the local scientific environment, where they can usually participate in projects that the institutes where they are employed are involved in, but a good part also by the cooperation between the partners, of which Appendix C gives a good impression, and by meetings such as that in Delft and Hamburg (see § 1.3.3 and Appendices D and F).

Eleni Katirtzoglou During the period from March 1, 2000 until August 22, 2000 Eleni Katirtzoglou worked on functions on the cone of nonnegative vectors in $\mathbb{R}^n$, that are homogeneous and order preserving. Such maps, which she calls HOPe functions, are nonexpansive (with respect to Hilbert's projective metric) and continuous.

She gave an asymptotic characterization of the (cone) spectral radius (see also § 1.1.2). As an immediate conclusion she got that the maximum component of the cycle time vector , whenever it exists, of such maps is equal to their spectral radius. The latter is consistent with earlier results concerning the cycle time vector of specific HOPe functions.

Furthemore she studied the question of existence of eigenvectors in the interior of the cone, a question that so far has a satisfactory answer only for certain classes of HOPe functions.

vacancy ENPC At the beginning of the last year, Cohen moved from École des Mines / ARMINES to ENPC. It took some time to go through all the administrative steps, required to transfer the ALAPEDES contract from the former to the latter employer. It seems that this process is now completed and plans are made to make use of the money still available for personnel costs.

In particular, Pablo Lotito, presently with INRIA - Rocquencourt, is expected to relocate to ENPC at the beginning of next year, to stay there up to the end of the ALAPEDES contract period, that is, for 8 or 9 months. He will continue his work on theoretical and software aspects of interest for ALAPEDES, especially around transportation problems and a related toolbox within the $(\max, +)$-SCILAB developments. However, even if this is realized as anticipated, some money will still be left and this could be used to welcome doctoral students from other partners in the network for a few months (such an operation was considered last year with a planned visit of Van Egmond from Delft to Fontainebleau; unfortunately, due to the move of Cohen from ARMINES to ENPC, this could not take place at that time and, later on, Van Egmond left the network).

James Martin James Martin worked in the ALAPEDES network from November, 1998 to October, 2000, based in the INRIA group located at École Normale Superieure in Paris.

A major part of his research has centred around themes connected with the analysis of infinite dimensional stochastic $(\max, +)$-systems. This extends in many directions, for example: tandem queueing networks and related interacting particle systems, various "percolation" models, both on the lattice and in continuous space (applications include various models of radio broadcasting), and other stochastic graphical models such as the "greedy lattice animals" model, with various applications in statistical mechanics.

He has cooperated closely with other researchers such as Baccelli (INRIA) and Mairesse (LIAFA) during the course of this work.

He has also continued previous work on the analysis of large Markovian queueing networks, especially those with load-balancing or dynamic routing. Here one addresses questions such as: is it possible to improve significantly the performance of a large network by allowing a small amount of routing flexibility at certain points? The general approach combines tools from queueing network theory with "mean-field" techniques from statistical physics.

Stefan Haar Stefan Haar has joined the INRIA Sophia Antipolis team of ALAPEDES on February 1, 1999. He has been located at INRIA Nancy until October 31, 1999, and has since been with ENS Paris, where he will stay until the end of his contract in January 2001. His background is in stochastic processes, in particular stochastic differential equations and stochastic dynamical systems, Petri nets, partial and cyclic order theory, and temporal logics.

Within ALAPEDES, Stefan Haar has been working with Gaujal and Baccelli at INRIA. Haar and Gaujal investigated non-ambiguous behaviour in timed Petri nets. In [40] and Stefan Haar's talk at the Delft ALAPEDES convention, they identified policies of resolving non-deterministic conflicts for suitable well-behaved net classes such that their behaviour is determined unambiguously by timing, routing, and priorities. In a paper presented at WODES 2000 [38], they have shown that the limit policy (immediate transitions are seen as timed transitions with a timing interval going to 0) provides such a non-ambiguous policy, provided the net is bounded and does not contain uncontrolled cycles of immediate transitions.

In another approach to analyse the behaviour of concurrent systems, *unfoldings* of the Petri net modelling the system into an*occurrence net* have been used in particular to verify *logical* properties. Stefan Haar has been investigating the *structure* of occurrence nets as well as the *semantics* they provide. The aim is to study performance and statistical properties of concurrent behaviour, which is very hard to grasp by sequential techniques, in an adequate framework of branching concurrent processes. To this end, he has introduced variants of the unfolding semantics and studied the structural properties of occurrence nets. A by-product of this was the introduction of new classes of partial order logics of high expressivity [44], presented at the *CS & P* Warsaw in September, 1999. Moreover, occurrence nets show how the *confusion* (indirect influence by concurrent events) can be structurally characterized in terms of net clusters; at the same time, clusters provide a new partial order semantics respecting performance [43], which will be presented at the *CS & P* in Berlin during October, 2000.

Along with this, Stefan Haar is currently working on probabilistic semantics for occurrence net processes. In two different cooperations, one with the Humboldt Universität zu Berlin, and the other with IRISA at Rennes, he is working on the probabilistic investigation of logical and quantitative properties in concurrent processes. He presented first results of this approach at the ALAPEDES convention in Hamburg in July, 2000.

In cooperation with Françoise Simonot-Lion and Laurent Kaiser of INRIA Nancy, Stefan Haar obtained new results on timed discrete event systems. In [47], they showed, through an explicit translation, the equivalence between a natural subclass of timed automata (*Timed*

State Machines) and a set of bounded timed Petri nets without multiple simultaneous firings. Several new connections with other timed models (a presently very active field) have come in sight during this work, and Stefan Haar has begun a cooperation with LAAS in Toulouse, to further investigate these issues.

Baccelli (INRIA) and Haar are jointly working on evolution equations for competition based networks. The main results obtained so far are monotonicity results. The main motivation is the study of multiclass networks.

The emphasis of Stefan Haar's work is in subproject T-1 (see § 1.1.1), with some connections to T-5 (see § 1.1.5).

Santiago Egido Arteaga Santiago Egido Arteaga obtained his doctoral degree in applied mathematics at the University of Maryland, College Park for work on nonlinear and parallel algorithms for finite element discretizations of the incompressible Navier-Stokes equations. He is also interested in some areas of discrete mathematics, including integer factorization and the $3n+1$ problem. Per July 1, 1999, he joined KUL, attracted by the problem of traffic simulation and control. His contract originally lasted till December 31, 1999, but has been extended. He left KUL on June 30, 2000.

Cormac Walsh Cormac Walsh is working on two problems. The setting for both is topical maps on finite-dimensional cones. These generalize the concept of a topical map on the positive cone.

The first problem is the investigation of the topical isomorphisms, which are objective maps between two cones that are topical in both directions. He conjectures that these maps are exactly the linear isomorphisms between the cones. So far he has managed to prove these for strictly convex cones and for the positive cone. Since topical maps are nonexpansive in the Hilbert projective metric and the Thompson part metric associated with the cone, it is also relevent to investigate the isometries of these spaces. In the Hilbert case, partial results were obtained in literature. He is hoping to use the Finsler structure of these to spaces to prove the general result.

The second problem is the behaviour of iterates of topical maps. In a symmetric cone the associated Jordan algebra gives a way of defining the cycle time of a map. I have recently shown that this cycle time exists for all topical maps if the cone is strictly convex. The proof uses the techniques of Kohlberg and Neyman who proved the analogue of the result for non-expansive maps in strictly convex normed spaces. He thinks to have a paper on the subject written up shortly.

Ioannis Michos Ioannis Michos has joined the LIAFA team of the ALAPEDES network on July 2, 1999. His contract has been extended and concluded on August 31, 2000. His scientific background is in algebra and combinatorics: free Lie algebras and representation theory (integral and modular) of finite groups, free monoids, formal (rational and algebraic) power series and free partially commutative structures.

Ioannis Michos has been working, with Mairesse and Krob at LIAFA, on the problem of the height of traces. In the visualization of traces using heaps of pieces (à la Viennot), the height corresponds precisely to the height of the heap. Also, in the language of task resource models (see previous reports), the height is equal to the *makespan* or execution time of the schedule, associated with the trace.

They proved that the bivariate commutative series of the height and the length, over the trace monoid, is rational, and they get a triple recognizing it. As a by-product, the asymptotic average height of the traces of a given length is proven rational and explicitly computable.

Then the attention is focused on two families of trace monoids whose dependence graphs are respectively C_n (the cycle with n nodes) and $L(K_n)$ (the line graph of the complete graph

with n nodes). They provide recurrence formulæ (on n) for the bivariate series in the case of $L(K_n)$.

Ioannis Michos has presented his work at the ALAPEDES convention at Delft in October, 1999, and at the *8mes Journées Montoises d'Informatique Théorique*, Université de Marne-la-Vallée, march 2000. He has also attended the ALAPEDES convention in Hamburg in July, 2000, and the *Formal Power Series and Algebraic Combinatorics Conference* in Moscow in June, 2000.

The emphasis of his work lies in subprojects T-5, and A-2 (see § 1.1.5 and § 1.1.7, respectively). An extended abstract within ALAPEDES and relevant to this work is [65].

Ahmed Al-Falou In the period from September 16, 1999 till October 1, 2000 Ahmed Al-Falou worked at RUG. After his contract was finished he departed to Austria.

Primarily, he was working in the field of supervisory control of large automata and control of hybrid systems, in collaboration with Smedinga.

As a newcomer to this field he spent the first three months with a literature survey and other preparatory work. Towards the end of 1999, a collaboration has set up Van Schuppen (CWI, Amsterdam), who had been working in the same field. They agreed to meet in regular intervalls of about two weeks and the subsequent research has all been done in close collaboration (who is also listed as author on the resulting publication).

Their research revolves around the supervisory control of automata like production plants and networks, which in practice are very large. They try to reduce the complex task of controller design by reducing the large system into smaller units. To do so, they aggregated states in blocks. As the aggregation process is iterated, a hierachy of decompositions is obtained. Of course, this idea is not new to our research, however, it has been an open question as how to obtain a hierachy of decompositions by efficient algorithms. Proposals as are found in the literature (see Caines et al.) are unsuited for large systems in practical applications.

They designed an efficient algorithm for the reduction of a large system. The results are to be published in a journal [1]. Most of the content of this paper was presented at the ALAPEDES convention in Hamburg (see Appendix F). Further open problems in this field will be the subject of a subsequent second paper. Eventually, it is hoped to apply some of the techniques to the question of hybrid control where the underlying continuous dynamics are aggregated into blocks turning the system into a discrete event system.

In relation to this work, Ahmed Al-Falou went to the WODES conference in Gent as well as to Wien, where people are interested in some of the research results from a perspective of system identification. Possibly, the results can be extended to suit their problems in system identification.

Pablo Lotito Pablo Lotito entered INRIA - Rocquencourt, and hence the ALAPEDES network, on December 13, 1999, and will stay there till February, 2001. After that he is planning to relocate to ENPC. He works on the transportation part of the $(\max,+)$-SCILAB-toolbox and its applications. See also § 1.1.6 and § 1.1.10.

In a technical report, a stochastic $(\max,+)$-model of the traffic on a circular road without overtaking is given. It is shown that the average speed is a $(\max,+)$-Lyapounov exponent. A complete characterization of the stationary regime is provided. Based on this characterization, an explicit formula for the average speed and a very simple asymptotic result when the number of cars grows to infinity are obtained. Numerical simulations of the evolution of the system using the $(\max,+)$-SCILAB-toolbox are shown and they confirm the theoretical results.

The contribution of Pablo Lotito to the $(\max,+)$-toolbox consists in writing the simulator of this system and in implementing algorithms in SCILAB to compute Wardrop equilibria.

Four presentations of his work have been given in seminars and conferences: the GICC seminar, the PREDIT workshop, the HP-Microsoft conference and the WODES. See also in § 1.3.5 and in § 3.3.

Vincent Canterini At the UCL, Vincent Canterini started on September 17, 2000 as an ALAPEDES postdoc; he will stay for 11 months. He graduated from the Université de Marseille. He is working on complexity aspects of problems for discrete event systems. He is likely to interact with Mairesse on the recent counter-example (by Mairesse and Bousch) of the finiteness conjecture (see § 1.1.8).

1.5 Interactions with industry

HP, as industry, is one of the associated contractors within the network. The HP group involved is theoretically inclined.

The TUD group within ALAPEDES works closely together with Trail and the DIOC SMM (Seamless Multimodal Mobility); both are interdepartmental organisations within TUD with a clear rôle for the Faculty of Civil Engineering.

Also, concrete contacts exist with the Dutch Railinfrabeheer, Utrecht, through the work of their employee De Kort.

It is a pity that the initial contacts with KLM did not find a continuation.

Many contacts and collaborations (especially through two doctoral theses) continue to be made with the research and development department of Nortel Networks (see also § 1.1.8). The main direction of research presently followed is performance analysis of equalization related protocols.

Two joint articles [30, 31] with Dornstetter (Nortel Matra) have been written.

1.6 Difficulties encountered

We are glad that the "Kanta-issue" has been solved satisfactorily (see the previous annual report). We do not understand why "Brussels" did not yet give free (at least did not transfer) the corresponding amount of money.

It was not clear how the moves of two of our teamleaders to new employers should have been handled efficiently with the European Commission. We did not get clear rules from "Brussels", which caused delays and extra paperwork.

2 Factual information

2.1 Scientific speciality

All ALAPEDES partners are involved via a mathematics department; most of them have an information sciences department as well. Consequently, most mathematical subjects and many information sciences subjects are covered.

The following table presents the specialities of the partners that are most relevant for the ALAPEDES network expressed in the discipline classification codes for the mathematics, information and engineering sciences, issued and utilized by the European Union offices. As the list contains only a few broad subject categories the table does however not convey much detail. The disciplines which are referred to in the forthcoming tables are summarized in a second part.

partner	discipline codes		
TUD	M-99	M-53	I-22
ENPC	M-53	M-99	M-51
INRIA	M-41	M-53	I-26
KUL	M-53	M-49	I-22
HP	M-43	M-54	I-26
LIAFA	M-46	M-48	M-41
RUG	M-48	M-51	M-53
UCL	M-53	M-48	

code	*description*
	mathematics and information sciences
M-41	Statistics and Probability
M-42	Algebra and Number Theory
M-43	Geometry and Topology
M-45	Applied Mathematics and Mathematical Physics
M-46	Discrete Mathematics and Computational Mathematics
M-48	Algorithms and Complexity
M-49	Signals, Speech and Image Processing
M-51	Information Systems, Software Development and Databases
M-53	Systems Control, Modelling and Neural Networks
M-54	Parallel and Distributed Computing, Computer Architecture
M-99	Other Mathematics and Information Sciences
	engineering sciences
I-22	Transport Engineering
I-26	Telecommunications

Table 1: Specialities by partner.

2.2 Research staff

A list of all researchers within the ALAPEDES context can be found in Appendix A. It contains the teamleaders (scientists-in-charge) and further permanent research staff, ALAPEDES researchers, postgraduates employed with ALAPEDES partners, who study a subject in connection with the ALAPEDES field, undergraduates having contributed to the research within ALAPEDES and administrative staff involved. The table is not supposed to be exhaustive.

The research effort (in manmonths) spent to ALAPEDES by the different partners is estimated[1] below; it is sorted out according to the source of payment (from ALAPEDES funds or not, respectively), and gives figures per partner.

partner	manmonths			*total*
TUD	11	40	0	51
ENPC	0	6	0	6
INRIA	33	62	0	95
KUL	9	7	0	16
HP	11	12	0	23
LIAFA	12	14	0	26
RUG	12	1	0	13
UCL	0	6	0	6
ALAPEDES	88	148	+ 0	236

Legend: in the table the first column indicates the partner, the second column gives the number of manmonths paid by the European Commission, the third column the same, but invested by the partners themselves, the fourth column applies to undergraduate students, and the fifth column gives totals (leaving out undergraduate students).

Table 2: Research effort by partner and by category.

During the period from October 1, 1999 through September 30, 2000, Codrin Nichitiu worked as a postdoc at UCL. He got his doctoral degree from the École Nationale Supérieure in Lyon. He left the network for a permanent position as Maître de Conférence at the Université de St. Étienne.

2.3 Researchers financed

In table 3 all ALAPEDES researchers have been listed; their nationality, date of birth, begin and prognosed end of their (present or past) appointment, the partner they are working at, and the specialities are given. See also Appendix A. For the meaning of the codes used for the specialities the reader is referred to the information in § 2.1. All ALAPEDES researchers fall in the postdoc category.

Note that end dates of appointments are unsure as they are subject to: 1) internal regulations within the partners (the contract may initially not extend beyond one year of duration), 2) the possibility that further funding (outside ALAPEDES, however) may be found, 3) the possibility that ALAPEDES researchers may want to leave earlier to fulfill a permanent position (this has occurred several times), 4) the reallocation between partners that is strived at (ALAPEDES researchers are encouraged to change their "homebase" within the network), and 5) uncertainty on the financial situation.

2.4 Publications

2.4.1 Publications by ALAPEDES researchers

Publications by ALAPEDES researchers are listed in table 4. The table refers to the list of publications in Appendix B.

[1] as not all partners contributed recent figures, table 2 has to be handled with some care; yet, the numbers given are believed to give a good impression of the involvement by the partners

name	nationality	*birth*	appointment	*partner*	*specialities*
Remco de Vries	NL	640328	961101 – 980831	KUL	M-53, M-41
Stéphane Perennes	F	681206	961115 – 970930	TUD	M-99
Matthias Kanta	D	571004	961115 – 971115	LIAFA	M-43, M-42
Eleni Katirtzoglou	GR	651016	961125 – 981125	HP	M-99
Eleni Katirtzoglou	GR	651016	990222 – 000822	TUD	M-99
Michael Mc Gettrick	IRL	641103	970101 – 980531	ARMINES	M-51
Bernd Heidergott	D	630430	970401 – 990731	TUD	M-41
Sam Lifshes	ISR	630411	970801 – 990401	RUG	M-47, M-53, M-99
Natacha Portier	F	711009	981101 – 990901	ULG	M-47
James Martin	GB	730124	981101 – 001031	INRIA	M-53
Sabrina Mantaci	I	680323	990108 – 991001	LIAFA	M-47, M-99
Stefan Haar	D	650814	990201 – 010201	INRIA	M-41, M-53
Santiago Egido Arteaga	E	670518	990701 – 000630	KUL	M-45, M-54, M-44
Cormac Walsh	IRL	730628	990701 – 010630	HP	M-41, M-99
Ioannis Michos	GR	690331	990621 – 000930	LIAFA	M-42
Ahmed Al-Falou	D	680119	990916 – 001001	RUG	M-46, M-53, M-99
Pablo Lotito	I	691112	991213 – 010228	INRIA	M-45
Vincent Canterini	F	720422	000918 – 010817	UCL	M-53, M-48

Table 3: Researchers financed within ALAPEDES.

2.4.2 Publications by other ALAPEDES members

Publications by other members of the network are incorporated in Appendix B. Joint publications are summarized in § 3.1.

2.5 Secondments

Within ALAPEDES there has been one secondment in which expertise between institutes was mediated by a detachment lasting for a period longer than two weeks: Blondel (ULG) stayed from March 26 to April 16, 2000, at LIAFA. There he worked together with Mantaci and Mairesse (LIAFA). See also § 1.3.4.

Remco de Vries	[142, 271, 144, 143, 220, 273, 272]
Stéphane Perennes	[176, 178, 221, 243, 245, 244, 246]
Matthias Kanta	[]
Eleni Katirtzoglou	[53, 52] [223, 224]
Michael Mc Gettrick	[124, 248, 249]
Bernd Heidergott	[70, 50, 55] [208, 206, 207, 205, 214, 217, 216, 215, 212, 211, 209, 213, 220, 210, 218, 219] [168, 169, 170, 228]
Sam Lifshes	[230]
Natacha Portier	[251, 253, 252, 254, 256, 255]
James Martin	[61, 60, 64, 62, 63]
Sabrina Mantaci	[59]
Stefan Haar	[38, 44, 43, 45, 46, 47, 49, 48] [40]
Santiago Egido Arteaga	[]
Cormac Walsh	[]
Ioannis Michos	[65] [237]
Ahmed Al-Falou	[1]
Pablo Lotito	[57]
Vincent Canterini	[]

Remark: publications that were mentioned in a previous ALAPEDES annual progress report are type-set in a smaller typeface on separate lines.

Table 4: Publications by researchers financed within ALAPEDES.

3 Joint work

3.1 Joint publications

Joint papers — defined as publications in which authors from at least two ALAPEDES partners have contributed — are [4, 9, 11, 10, 14, 24, 26, 36, 57, 59].

Publications in this category, that were mentioned in the previous ALAPEDES annual progress reports are: [92, 90, 125, 130, 131, 137, 135, 142, 184, 183, 187, 191, 199, 232, 233, 274, 260, 259, 261, 126, 124, 134, 133, 140, 141, 144, 143, 185, 189, 220, 242, 241, 249, 91, 106, 136, 132, 129, 190, 188, 192, 194, 203, 275].

They have been included in the publication list of Appendix B.

3.2 Collaboration

Many mutual visits have been paid by ALAPEDES members. In Appendix C an overview of such visits is attempted, that probably stayed incomplete. Furthermore, in § 1.3.4 some extra information has been included on some of these contacts.

3.3 Conference visits by ALAPEDES-members

3.3.1 Delft convention

The plenary meeting on 1 and 2 October, 1999, in Delft brought together most ALAPEDES members. Many of them presented (part) of their achievements since the convention in Paris, in a relaxed setting. Appendix D contains the programme. More information on the presentations is available upon request.

3.3.2 Hamburg convention

On 7 and 8 July, 2000 in Hamburg again a plenary meeting was being organized. Many ALAPEDES members presented new achievements. Appendix F contains the programme. More information on the presentations is available upon request.

3.3.3 Other conferences and workshops

Appendix C contains an overview of visits by ALAPEDES members to other conferences, workshops and courses, that are related to ALAPEDES. Probably the overview is incomplete.

Quite a few ALAPEDES members were present at the 2000 version of the WODES (Workshop on Discrete Event Systems), that was being held in Gent during August, 2000.

Another important event was the HP-Microsoft workshop, held September, 2000, in Bristol.

3.3.4 External collaboration by ALAPEDES-members

Stimulated by a course at her university, Mancinelli from the Universidad de Rosario came during the previous reporting period to INRIA - Rocquencourt for work on a postdoc position at INRIA on applications of $(\max, +)$ to transportation systems. She gave an account of her initial work during the Delft convention (see Appendix D).

In April, Cohen gave a two-week course entitled "Discrete Event Systems Analysis and Control: from Timed Petri Nets to Algebra" at the Instituto Beppo Levi of the Universidad de Rosario. This was the third of a series of courses on discrete event systems. A next one is being prepared for next year; recall that last year, the course was given by Quadrat and the course notes, translated in Spanish, appeared as volume 28 of the "Cuadernos" of the Instituto Beppo Levi [66]; this should also happen with the course of Cohen.

One expected outcome of these series of courses is a closer cooperation with that university in Argentina and a flow of doctoral students or post-docs from that country (recall that

Mancinelli and Lotito — presently at INRIA - Rocquencourt — originate from Rosario).

Al-Falou (RUG) regularly met Van Schuppen (CWI, Amsterdam) for a fruitful bilateral collaboration. See § 1.4.3 for more information.

Blondel (UCL) collaborates intensively with Tsitsiklis (MIT, USA), Koiran (ENS, Lyon), Moore (Santa Fe Institute, USA) and Cassaigne (IRM, Marseille — see § 1.1.3), as the bibliography (see Appendix B) witnesses [12, 13, 17, 14, 18].

Cohen (ENPC) attended the defence on October 5, 1999 of the thesis of Cottenceau in Angers. The thesis ([25]) has as a subject the control of discrete event systems in relation with timed event graphs on dioids.

A Research effort

The next tables give the research effort by ALAPEDES researchers, and the same for other ALAPEDES members, arranged into the categories "teamleaders", "permanent staff", "postdocs", "postgraduates", "undergraduates" and "administrative staff".

The share column contains percentages that apply to the intersection with the period reported on. Involvement planned in remaining years may be incomplete.

In the second table several estimations had to be reverted to. In some cases,the second table includes an involvement by ALAPEDES members that left one of the partners in the network.

name	*nationality*	*period concerned*	*share*	*partner*
ALAPEDES **researchers**				
Remco de Vries	NL	961101 – 980831		KUL
Stéphane Perennes	F	961115 – 970930		TUD
Matthias Kanta	D	961115 – 971115		LIAFA
Eleni Katirtzoglou	GR	961125 – 990131		HP
Eleni Katirtzoglou	GR	990222 – 000822	100 %	TUD
Michael Mc Gettrick	IRL	970101 – 980531		ARMINES
Bernd Heidergott	D	970401 – 990731		TUD
Shmuel Lifsches	ISR	970801 – 990401		RUG
Natacha Portier	F	981101 – 990831		ULG
James Martin	GB	981101 – 010001	100 %	INRIA - SA
Sabrina Mantaci	I	990108 – 991001		LIAFA
Stefan Haar	D	990201 – 010301	100 %	INRIA - SA
Santiago Egido Arteaga	E	990701 – 000630	100 %	KUL
Cormac Walsh	IRL	990701 – 010630	90 %	HP
Ioannis Michos	GR	990702 – 000831	100 %	LIAFA
Ahmed Al-Falou	D	990916 – 001001	100 %	RUG
Pablo Lotito	I	991213 – 010228	100 %	INRIA - Rocq
Vincent Canterini	F	000918 – 010817	100 %	UCL

Table 5: Research effort by ALAPEDES researchers.

name	*period involved*	*share*	*partner*
scientific teamleaders			
Geert Jan Olsder	961001 –	10 %	TUD
Guy Cohen	961001 –	50 %	ENPC
François Baccelli	961001 –	50 %	INRIA - SA
Jean-Pierre Quadrat	961001 –	50 %	INRIA-Rocq
Bart de Moor	961001 –	5 %	KUL
Jeremy Gunawardena	961001 –	10 %	HP
Daniel Krob	961001 –	15 %	LIAFA
Jean Mairesse	961001 –	50 %	LIAFA
Rein Smedinga	961001 –	5 %	RUG
Vincent Blondel	961001 –	10 %	UCL
permanent research staff			
Jacob van der Woude	961001 –	25 %	TUD
Alain Jean-Marie	961001 –	35 %	INRIA - SA
Bruno Gaujal	961001 –	35 %	INRIA - SA
Stéphane Gaubert	961001 –	100 %	INRIA-Rocq
Marianne Akian	961001 –	75 %	INRIA-Rocq
Edmundo Rofman	–	10 %	INRIA-Rocq
Bart De Schutter	981001 –	5 %	KUL
Colin Sparrow	961001 –	10 %	HP
P. Gastin	961001 –	10 %	LIAFA
Jean Éric Pin	961001 –	10 %	LIAFA
C. Choffrut	961001 –	10 %	LIAFA
M. Morvan	961001 –	10 %	LIAFA
P. Weil	961001 –	10 %	LIAFA
postdocs			
Andrew Burbanks	980701 –	80 %	HP
Elina Mancinelli	990301 –	100 %	INRIA-Rocq
Codrin Nichitiu	991101 – 000731	60 %	UCL
postgraduates			
Subiono	961001 – 000629	100 %	TUD
Robert Jan van Egmond	970901 – 000701	100 %	TUD
Gerardo Soto y Koelemeijer	980515 –	100 %	TUD
Antoine de Kort	000101 –	20 %	TUD
Andrei Iounoussov	000101 –	50 %	TUD
Hong Dohy	–	25 %	INRIA - SA
Emmanuel Hyon	–	40 %	INRIA - SA
Jean Cochet-Terrasson	961001 –	20 %	INRIA-Rocq
Tom Bellemans	980801 –	50 %	KUL
Laurent Vuillon	970801 –	10 %	LIAFA
Ines Klimann	970801 –	5 %	LIAFA
administrative staff			
Niek Tholen	961001 –	25 %	TUD
Bart Motmans	961001 – 000915	5 %	KUL

Table 6: Research effort by other ALAPEDES members.

B Publications

Remark: All entries beyond [77] were already given in (a) previous annual report(s), but are repeated here for completeness' sake.

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C Contacts

The next table gives a summary of mutual visits by ALAPEDES members. Only such contacts are mentioned that did not take place at one in the meetings in § 1.3 (see there). The reader is referred to the information that was already given in § 1.3.4.

name			*from*	*till*	*destination*	*objective*
1999						
management committee	***	M	01–10	02–10	Delft	formal meeting
several members		OAI	01–10	02–10	Delft	convention
Sabrina Mantaci	T-2	OI	07–12	09–12	UCL	consultation
2000						
Vincent Blondel	T-2	COI	26–03	16–04	LIAFA	invited professor
management committee	***	M	07–07	07–07	Hamburg	formal meeting
several members	***	OAI	07–07	08–07	Hamburg	convention
Marianne Akian	T-1	C	16–07	23–07	Bristol	collaboration
Stéphane Gaubert	T-1	C	16–07	23–07	Bristol	collaboration

Legend: in the tables in this appendix the following codes are used:

*** in the subproject column signal the whole project;
in the third column activities undertaken are signalled:
N = network presentation, S = subproject presentation, O = own work presentation, M = meeting, C = consultation, I = informal contact, A = attend, F = formal function.

Remark: this table is not expected to be complete.

The next table gives some information about visitors from outside to partners of the ALAPEDES network, having a strong relation with its subject. The information is bound to be incomplete.

name			*from*	*till*	*destination*	*origin*
1999						
Glolubkov		SC	01–09	31–10	LIAFA	Moskwa
Sabrina Mantaci	T-3	C	08–12	12–12	UCL	LIAFA
V. Giakoumakis		SC	02–12	11–12	LIAFA	Athinai
2000						
Bas Lemmens		C	17–03	25–03	Cambridge	VU, Amsterdam
Julien Cassaigne		C	23–04	14–05	UCL	IRM, Marseille
Leonid Gurvits		C	14–05	21–05	UCL	Inst. AS, Princeton
C. Meinel		SC	31–05	06–06	LIAFA	Trier

The next table gives some information about visits to scientists outside the network by partners of ALAPEDES, bearing a strong relation with its subject. The information is only given schematically, and hence is incomplete. More information can be obtained from the visiting scientists.

name			*from*	*till*	*destination*	*objective*
1999						
Tom Bellemans	A-1	OI	25–09	10–12	Boston	MIT
Guy Cohen		F	05–10	05–10	Angers	thesis jury
Cormac Walsh	T-2	I	08–12	10–12	Cambridge	
2000						
Cormac Walsh	T-2	I	13–01	29–01	Dublin	DIAS
Andy Burbanks	T-2	C	02–04	04–04	Amsterdam	Vrije Univ.
Colin Sparrow	T-2	C	02–04	04–04	Amsterdam	Vrije Univ.
Guy Cohen	***	N	08–04	21–04	Rosario	course

The next table gives a summary of visits by ALAPEDES members to conferences, workshops and courses. More information on meetings of the working group on tropical algebra can be found in § 1.3.4, and in Appendix E (on Internet at `http://amadeus.inria.fr/TROPICAL/`), and for conferences the reader is referred to § 1.3.5.

More details on presentations by ALAPEDES members are available upon request.

name			*from*	*till*	*destination*	*objective*
1999						
Vincent Blondel	T-3	A	27–10	29–10	Lyon	Cellular Automata
Daniel Krob		OI	13–10	19–10	Mons	
several members	***	A	15–12	15–12	Paris	Algèbres tropicales
Gerardo Soto y Koelemeijer	A-1	O	–12	–12	Scheveningen	5th Trail Congress
2000						
Daniel Krob		OI	23–02	28–02	Trier	
Tom Bellemans	A-1	O	01–03	03–03	Mierlo	Benelux Meeting
James Martin	T-5	O	–03	–03	Atlanta	SE Prob. Days
Jean Mairesse		O	20–03	23–03	Hamburg	Stochastik-Tage
Daniel Krob		OI	06–04	11–04	Mons	
Tom Bellemans	A-1	OA	11–04	11–04	Birmingham	Telemat. Automotive
Stefan Haar	T-1	OI	20–04	24–04	Hamburg	Stochastik-Tage
Eleni Katirtzoglou	T-1	O	–05	–05	Leiden	Analysis Seminar
Christian Choffrut		OI	24–05	10–06	Milano	Workshop on traces
Jean Mairesse		OI	31–05	07–06	Milano	Workshop on traces
Anca Muscholl		OI	01–06	04–06	Milano	Workshop on traces
Tom Bellemans	A-1	OA	13–06	15–06	Braunschweig	Transportation
Hong Dohy	A-3	O	–06	–06	Sverige	Sigcomm 2000
Vincent Blondel	T-3	A	18–06	23–06	Perpignan	MTNS
Pablo Lotito?	A-1,S-2	S	–06	–06	Paris	GICC
James Martin	T-5	O	26–06	30–06	Madison	Stochastic Networks
François Baccelli	T-5	NOI	26–06	30–06	Madison	Stochastic Networks
Ioannis Michos		A	25–06	02–07	Moskwa	FPSAC '00
James Martin	T-5	O	–08	–08	Cambridge	Stat. Mech. 2000
James Martin	T-5	O	–08	–08	Novisibirsk	Applied Probability
several members	***	OAF	20–08	24–08	Gent	WODES
Sabrina Mantaci		O	28–08	03–09	Bratislava	MFCS '00
several members	***	NOAF	11–09	15–09	Bristol	HP-Microsoft conf.
Hong Dohy	A-3	O	04–09	06–09	Paris	Congestion control
François Baccelli	A-3	FO	04–09	06–09	Paris	Congestion control
Gerardo Soto y Koelemeijer	A-1	O	–09	–09	Bologna	COMPRAIL
Jacob van der Woude	T-2	O	14–09	14–09	Grenoble	Petri Net group

Legend: in the destination column the acronym of the network partner, and name and place of conference etc. participated in is mentioned;
*** in the subproject column signal the whole project.

D Delft convention

SCHEDULE

Friday 1 October 1999

9:50	Wellcome; opening remarks
10:00	**"Non-ambiguous Petri Nets"** Bruno Gaujal and *Stefan Haar, INRIA
10:30	**"Expansions for Joint Characteristics of Stationary Waiting Times in (max, +)- Linear with Poisson Input"** *Hayriye Ayhan, Georgia Institute of Technology and François Baccelli, INRIA
11:00	Coffee break
11:30	**"On Traffic Light Control"** G. Cohen, S. Gaubert, *Elina Mancinelli, J.P. Quadrat, and E. Rofman
12:00	**"Optimal Ramp Metering on Highways"** T. Bellemans, B. De Schutter, *Santiago Egido Arteaga and B. de Moor, KUL
12:30	Lunch
14:00	**"Worst Case Traffic from Regulated Sources"** Cormac Walsh, HP
14:30	**"Optimal Heaps in Tetris Models"** Colin Sparrow, Cambridge-HP
15:00	Coffee break
15:30	**"Large Tandem Queueing Systems"** James Martin, INRIA
16:00	**"On the Design of Robust Timetables"** Robert-Jan van Egmond, TUD
16:30	Break
17:00–18:30	Management committee and postdoc meetings
20:00	Dinner

Saturday 2 October 1999

10:00 **"An Upper Bound for the Coupling Time of (max, +)- Linear Systems, part I"**
*Bernd Heidergott and G. Soto y Koelemeijer

10:30 **"An Upper Bound for the Coupling Time of (max, +)- Linear Systems, part II"**
Bernd Heidergott and *G. Soto y Koelemeijer

11:00 Coffee break

11:30 **"Eigenvalues of Interconnected Bipartite (min, max, +)-Systems"**
Subiono, TUD

12:00 **"A Characterization of the Eigenvalue of a General irreducible (min, max, +) System"**
Jacob van der Woude

12:30 TBA

13:00 Close of the Workshop

E Tropical algebra seminar

A one-day seminar on "Algèbres tropicales" has been organized by Gaubert in Paris on December 15, 1999. The programme was:

- Georges Hansel

  Séries rationnelles positives et probabilités

- Lorenzo Farina

  Nonnegative realizations

- Jean-Claude Hennet

  l'Approche par invariance positive en commande de systèmes dynamiques

- Laurent Truffet

  Vers l'analyse de problèmes transitoires sur de grands modèles Markoviens

F Hamburg convention

ALAPEDES convention Hamburg

PROGRAMME

Friday, 7th July, 2000

Opening TUD

08:45 – 09:15 welcome, coffee, installation

09:15 – 09:30 Geert Jan Olsder, Niek Tholen
Opening, announcements

Representation problems KUL

09:30 – 10:15 T–1 Guy Cohen, Stéphane Gaubert, Jean-Pierre Quadrat
Orthogonal projections in complete idempotent semimodules and the Hahn-Banach theorem

10:15 – 10:45 coffee break

10:45 – 11:30 T–1 Andrew Burbanks (with Colin Sparrow and Roger Nussbaum)
Extension of homogeneous order-preserving maps on a cone

11:30 – 12:15 T–1 Cormac Walsh, Jeremy Gunawardena
Some conjectures concerning topical operators on cones

12:30 – 13:45 lunch break

14:00 – 14:45 T–1 Stéphane Gaubert (with Jeremy Gunawardena)
A topical view of irreducibility[a]

[a] also related to T–2: **Stability problems** TUD

Control of automata LIAFA

14:45 – 15:30 T–4 Ahmed Al-Falou
Aggregation in hierarchical supervisory control

15:30 – 16:00 tea / coffee break

Representation problems KUL

16:00 – 16:45 T–1 François Baccelli (with Hong Dohy)
TCP is $(\max, +)$*-linear*

17:00 – 19:00 meeting of management committee [delegates only]

Saturday, 8th July, 2000

Optimisation problems INRIA

09:30 – 10:15 T–3 Stefan Haar (with H. Voelzer)
Probabilistic branching non-sequential processes

10:15 – 10:45 coffee break

10:45 – 11:30 T–3 Bernd Heidergott
The maximal coupling approach to stochastic $(\max, +)$*-linear systems*

Large systems problems INRIA

11:30 – 12:15 T–5 Pablo Lotito, Elina Mancinelli, Vadim Malyshev and Max Plus
Explicit computation of a $(\max, +)$*-Lyapunov exponent giving the average speed on a circular traffic line without overtaking*

12:30 – 13:45 lunch break

14:00 – 14:45 T–5 James Martin
Shape theorems for directed percolation models

14:45 – 15:30 T–5 Emmanuel Hyon
Optimal routing policy for two deterministic queues

15:30 – 16:00 tea / coffee break

Transportation systems TUD

16:00 – 16:45 A–1 Tom Bellemans
Estimation of origin-destination matrices for highways: a case study

16:45 – 17:30 A–1 Antoine F. de Kort
Capacity assessment for the high speed line Amsterdam – Paris: a real-life application of $(\max, +)$*-algebra*

Closure TUD

17:30 – 17:45 Geert Jan Olsder
Closure, announcements

G Special issue of Theoretical Computer Science

Here is a list of the papers which were accepted for publication in the special issue of the Journal of Theoretical Computer Science, that is based on the spring school on $(\max, +)$-algebra in Noirmoutier in May, 1998.

- L. Aceto, Z. Esik, and A. Ingolfsdottir

  The Max-Sum Algebra of the Natural Numbers has no Finite Equational Basis

- F. d'Alessandro, J. Sakarovitch

  The finite power property in free group

- P. Bernhard

  Minimax, or feared value, L_1, L_∞ control

- P. Butkovic, R. Cuninghame-Green

  The equation $Ax = By$ over $(\mathbb{R}, \max, +)$

- J.-P. Comet

  Application of Max-Plus algebra to biological sequence comparisons

- B. Ducourthial, S. Tixeuil

  Self-stabilization with Path Algebra

- J. Gunawardena

  From max-plus algebra to nonexpansive mappings: a nonlinear theory for discrete event systems

- I. Klimann

  A solution to the problem of (A, B)-invariance for series

- N. Kobayashi

  Some Properties of Recognizable Z-subsets

- Subiono, J. van der Woude

  Conditions for the structural existence of an eigenvalue of a bipartite $(\min, \max, +)$-system

- K. Zimmermann

  Disjunctive optimization, Max-Separable Problems, Extremal Algebras