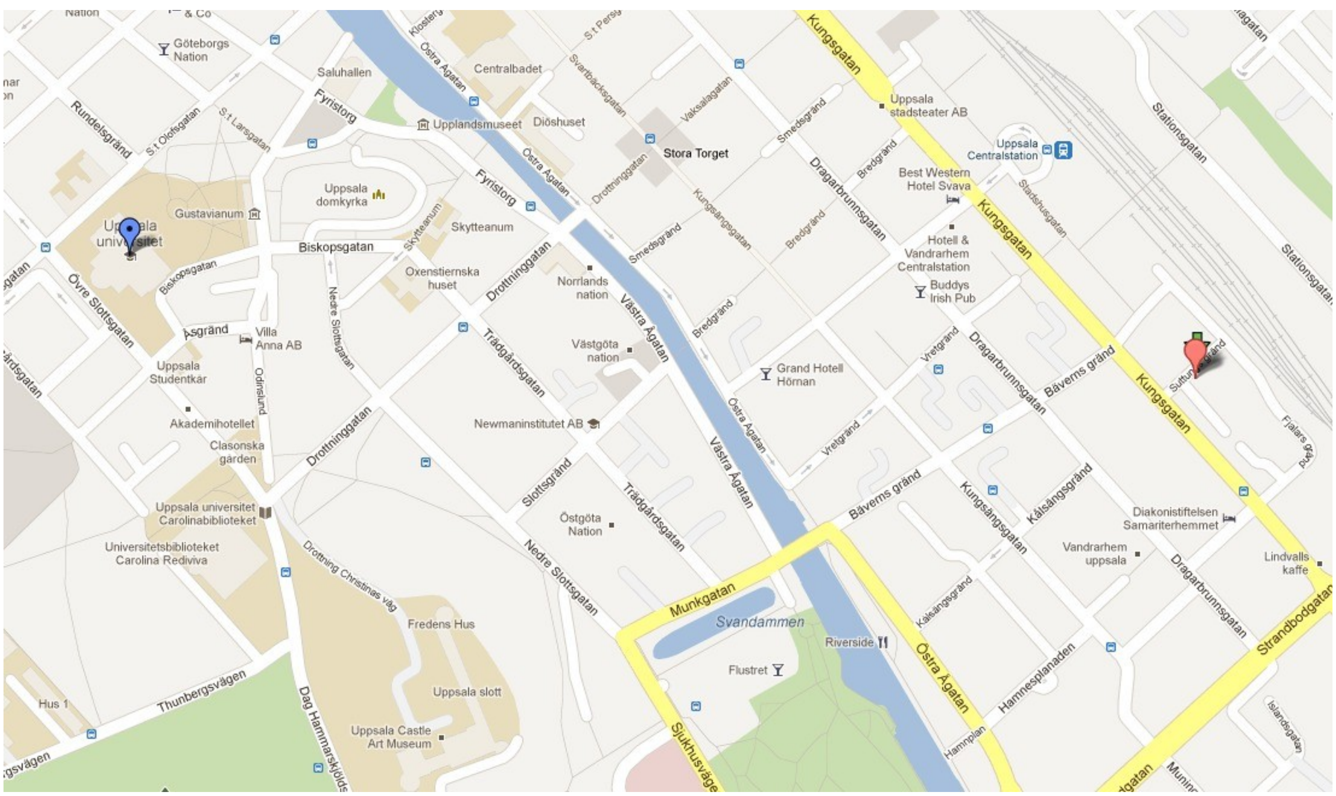
IPA2012 – Schedule with abstracts

Time	Monday	Tuesday	Wednesday
10:00 – 10:45		Fika	Fika
10:45 - 11:30	Fika	Marko Lange	Frederic Messine
11:30 – 12:15	Irina Mitrea	Zbigniew Galias	Denis Arzelier
12:15 – 14:00	Lunch	Lunch	Lunch
14:00 – 14:45	Christian Jansson	Philippe Bonnifait	Alexander Danis
14:45 – 15:30	Nicolas Delanoue	Oliver Junge	Luc Jaulin
15:30 – 16:00	Fika	Fika	Fika
16:00 – 16:45	Gilles Chabert	Didier Henrion	
16:45 – 17:30	Raazesh Sainudiin	Markus Neher	
>= 19:00	Dinner		

Workshop: Uppsala University Main Building, room VIII, first floor (blue mark).

Dinner: Restaurant *Peppar Peppar,* Suttungs gränd 3 (red mark).



Monday

Time: Monday 11:30 -- 12:15
Speaker: Irina Mitrea
Affiliation: Temple University, USA
Title: Validated numerics techniques for singular integrals
Abstract: In this talk I will discuss spectral properties of singular integral operators of layer potential type in the class of curvilinear polygons in two dimensions and illustrate how a combination of Harmonic Analysis techniques and Validated Numerics methods can be successfully implemented for establishing well-posedness results for boundary value problems for second order elliptic partial differential operators with constant coefficients in this geometric setting. This is based on joint work with T. Johnson, K. Ott and W. Tucker.

Time: Monday 14:00 -- 14:45
Speaker: Christian Jansson
Affiliation: TU Hamburg - Harburg, Germany
Title: Verified error bounds in optimization
Abstract: A large variety of applications from areas like system and control theory, combinatorial optimization, signal processing and communications, machine learning, quantum chemistry, and others can be formulated as conic optimization problems. These are problems with a linear objective function and linear constraints where the variables are restricted to a cone. Almost all convex optimization problems can be reformulated as conic problems. Linear programming, quadratically convex programming, second order cone programming and semidefinite programming are special cases. For this class of optimization problems verified forward error bounds for the optimal value as well as verified certificates of feasibility and infeasibility can be computed. In this talk we consider the software package VSDP (Verified Semidefinite Programming) for solving conic problems with guaranteed accuracy, and present some applications and numerical results.

Time: Monday 14:45 -- 15:30
Speaker: Nicolas Delanoue
Affiliation: LISA, Angers, France
Title: Classification of stable maps from a simply connected subset of R^2 to R^2
Abstract: Classification of mappings is an important issue in robotics (motion planning, design and analysis of serial and parallel manipulators). From the theoritical point of view, classification of mappings is related to their singularities. I will recall some results: Thom transversality theorem and its corollaries (Whitney theorem and Morse theory) which give local properties of generic maps. During the second part of the talk, I will present an algorithm based on interval analysis providing a global invariant. Given a map from a compact simply-connected domain of R^2, the method computes a planar graph. Our conjecture is that this graph is strong enough to classify stable smooth maps.

Time: Monday 16:00 -- 16:45
Speaker: Gilles Chabert
Affiliation: Ecole des Mines de Nantes, France
Title: Contractor programming
Abstract: An interval-based algorithm can often be viewed or recast as a "contractor", that is, a function that maps a box to a smaller box. This very simple observation allows to reduce algorithms to simple and pure mathematical objects. We will build, in this setting, various higher-order operators, that is, functions that map contractors to contractors. These operators can be composed together in some (arbitrarily complex) way and yield a top-level function corresponding to a sophisticated program. This is what we call "contractor programming". Contractor programming gives generic ways to calculate with sets implicitly

defined by constraints. Basic examples are the usual set intersection, union and so on. More interesting examples involve logic formulae with quantifiers or combinatorial operators. It also provides a high-level way to finely control the search of solutions for a given constraint. Finally, it makes trivial the collaboration of algorithms of heterogenous nature. For example, a contractor for the solution of algebraic equations or ODEs can interact with a contractor based on signal processing or combinatorial optimization.

Time: Monday 16:45 -- 17:30
Speaker: Raazesh Sainudiin
Affiliation: University of Canterbury, Christchurch, New Zealand
Title: Mapped regular pavings
Abstract: A regular paving is a finite succession of bisections that partition a root box x in R^d into sub-boxes using a binary tree-based data structure. We extend regular pavings to mapped regular pavings which map sub-boxes in a regular paving of x to elements in some set Y. Arithmetic operations defined on Y can be extended point-wise over x and carried out in a computationally efficient manner using Y-mapped regular pavings of x. The efficiency of this arithmetic is due to recursive algorithms on the algebraic structure of finite rooted binary trees that are closed under union operations. Our arithmetic has many applications in function approximation using tree based inclusion algebras and statistical set-processing.

Conference Dinner at restaurant *Peppar Peppar* at 19:00.

Tuesday

Time: Tuesday 10:45 – 11:30
Speaker: Marko Lange
Affiliation: TU Hamburg - Harburg, Germany
Title: Verification methods for ill-conditioned relaxation frameworks of quadratic assignment problems
Abstract: The quadratic assignment problem (QAP) is known to be among the hardest discrete optimization problems. They can be solved via relaxation techniques. By using recently introduced relaxation techniques we can derive strong bounds that can be computed very efficiently. The drawback of these new relaxation frameworks is the bad condition of many relaxation instances, sometimes yielding numerical problems. We show how these techniques improve the relaxation bounds of QAPs, and how different verification approaches can be used to overcome the ill-conditioning of these relaxation frameworks.

Time: Tuesday 11:30 -- 12:15
Speaker: Zbigniew Galias
Affiliation: AGH, Poland
Title: Rigorous analysis of piecewise linear flows
Abstract: The problem of rigorous integration of piecewise linear (PWL) continuous-time dynamical systems is discussed. It is assumed that the flow is defined by a continuous PWL vector field, and that the regions of linearity are separated by the so-called C0-hyperplanes. Rigorous integration of trajectories tangent to C0-hyperplanes poses a problem, since standard methods which work under the assumption that the vector field is smooth are not directly applicable. A method to handle such trajectories is presented. The PWL system is treated as a perturbed linear system. The technique is based on the theory of differential inclusions used to obtain estimates for solutions of perturbed continuous dynamical systems. It is shown that the algorithm provides narrower enclosures of the true trajectories also in the case of transversal intersections. It is also shown how to handle trajectories passing arbitrarily close to an unstable equilibrium. Using the techniques presented, rigorous analysis of the Chua's circuit (a simple three-dimensional

continuous PWL system) is performed. Two cases are considered. In the first case, in simulations one observes a spiral attractor containing trajectories tangent to the C0-hyperplanes. In the second case the double scroll attractor, which contains trajectories tangent to the C0-hyperplanes and trajectories passing arbitrarily close to an unstable equilibrium, is considered. For both cases, it is proved that a certain set is a trapping region for the associated return map. Rigorous bounds of the returns times over the attractor are calculated, and the graph representation of the dynamics is constructed.

Time: Tuesday 14:00 -- 14:45
Speaker: Philippe Bonnifait
Affiliation: University of Technology of Compiègne, France
Title: Using interval analysis in real-time for mobile robot integrity monitoring
Abstract: Real-time positioning is of prime importance in mobile robotics and more specifically for intelligent vehicle applications. When position information is used in a safety-critical context, like autonomous vehicle navigation, an integrity method is needed to check that the positioning error stays within the limits specified for the mission. In aeronautical navigation when using GPS, such an approach is known as Receiver Autonomous Integrity Monitoring. The key idea is to compute "protection levels" which limit the (unknown) position error with a given integrity risk. This talk presents different methods that compute in real-time confidence domains in which the mobile is located with a given integrity risk. The possible presence of outliers is handled by the use of robust set-membership methods. Sensor measurements and model parameters are prone to errors, which are often modeled by their probability distribution. In a set-membership working frame, errors can be represented by intervals, thus making the assumption of bounded errors. When guaranteed error bounds are unknown or too pessimistic, error bounds associated with a risk can be used. The risk taken on measurements is then propagated to the computed confidence domain. The studied methods have been implemented in real-time and tested with real data in urban environments which are particularly difficult for satellite positioning.

Time: Tuesday 14:45 -- 15:30
Speaker: Oliver Junge
Affiliation: Technische Universität München, Germany
Title: Set oriented numerics for optimal control problems
Abstract: We review recent work on a set oriented discretization of Bellman's optimality principle. In particular, we show how to construct feedback controllers for nonlinear systems and how to elegantly handle perturbed, quantized, hybrid and event systems within this unifying framework. The underlying theory will be illustrated by several examples from the engineering sciences.

Time: Tuesday 16:00 -- 16:45
Speaker: Didier Henrion
Affiliation: LAAS-CNRS, University of Toulouse, France
Additional Affiliation: Czech Technical University in Prague, Czech Republic
Title: Convex computation of the region of attraction of polynomial control systems
Abstract: We address the problem of computing the region of attraction (ROA) of a target set (typically a neighborhood of an equilibrium point) of a controlled nonlinear system with polynomial dynamics and semialgebraic state and input constraints. We show that the ROA can be computed by solving a convex linear programming (LP) problem over the cone of nonnegative measures. In turn, this problem can be solved approximately via a converging hierarchy of convex finite-dimensional linear matrix inequalities (LMIs). The dual LP on nonnegative continuous functions (approximated by polynomial sum-of-squares) allows us to generate a hierarchy of guaranteed semialgebraic outer approximations converging almost uniformly to the ROA. This is joint work with Milan Korda, Ecole Polytechnique Federale de Lausanne, Switzerland.

Time: Tuesday 16:45 -- 17:30
Speaker: Markus Neher
Affiliation: Karlsruhe Institute of Technology, Germany
Title: Verified Integration of ODEs with Taylor Models
Abstract: Verified integration methods for ODEs are methods that compute rigorous bounds for some specific solution or for the flow of some initial set of a given ODE. For almost fifty years, interval arithmetic has been used for calculating bounds for solutions of initial value problems. The origin of these methods dates back to Moore [5]. The most well-known interval method is the QR method due to Lohner [2], implemented in the AWA software package. Unfortunately, interval methods sometimes suffer from overestimation. This can be caused by the dependency problem, that is the lack of interval arithmetic to identify different occurrences of the same variable, and by the wrapping effect, which occurs when intermediate results of a calculation are enclosed into intervals. Overestimation is a particular concern in the verified solution of initial value problems for ODEs. While it may sometimes be possible to reduce dependency by skillful reformulation of the given equations or by evaluating all function expressions by centered forms, the wrapping effect is more difficult to prevent. Interval methods usually compute enclosures of the flow at intermediate time steps of the interval of integration. When the flow is a nonconvex set, which is bounded by some convex interval, overestimation is inevitable. In verified integration, overestimation may degrade the computed enclosure of the flow, enforce miniscule step sizes, or even bring about premature abortion of an integration. To reduce overestimation, Taylor models have been developed as a combination of symbolic and interval computations by Berz and his group since the 1990s. In Taylor model methods, the basic data type is not a single interval, but a Taylor model U := pn + i consisting of a multivariate polynomial pn of order n and some remainder interval i. In computations that involve U, the polynomial part is propagated by symbolic calculations where possible, and is thus hardly affected by the dependency problem or the wrapping effect. Only the interval remainder term and polynomial terms of order higher than n, which are usually small, are bounded using interval arithmetic. For the verified integration of IVPs, Taylor models also benefit from their capability of representing non-convex sets, which is especially advantageous for enclosing the flows of nonlinear ODEs [1, 3, 4, 6]. Whenever richness in available enclosure sets and reduction of the dependency problem is an advantage, Taylor models are better suited for integrating ODEs than interval methods. This is usually the case for IVPs for nonlinear ODEs, especially in combination with large initial sets or with large integration domains. For nonlinear ODEs, this increased flexibility in admissible boundary curves for the flow is an intrinsic advantage over traditional interval methods. In our talk, we analyze Taylor model methods for the verified integration of ODEs and compare these methods with interval methods.
References:
[1] M. Berz and K. Makino. Suppression of the wrapping effect by Taylor model-based verified integrators: Long-term stabilization by shrink wrapping. Int. J. Diff. Eq. Appl., 10:385–403, 2005.
[2] R. Lohner. Enclosing the solutions of ordinary initial- and boundary-value problems. In E. Kaucher, U. Kulisch, and Ch. Ullrich, editors, Computerarithmetic: Scientific Computation and Programming Languages, pages 255–286. Teubner, Stuttgart, 1987.
[3] K. Makino and M. Berz. Suppression of the wrapping effect by Taylor model-based verified integrators: Long-term stabilization by preconditioning. Int. J. Diff. Eq. Appl., 10:353–384, 2005.
[4] K. Makino and M. Berz. Suppression of the wrapping effect by Taylor model-based verified integrators: The single step. Int. J. Pure Appl. Math., 36:175–197, 2006.
[5] R. E. Moore. Interval Analysis. Prentice Hall, Englewood Cliffs, N.J., 1966.
[6] M. Neher, K. R. Jackson, and N. S. Nedialkov. On Taylor model based integration of ODEs. SIAM J. Numer. Anal., 45:236–262, 2007.

Wednesday

Time: Wednesday 10:45 -- 11:30
Speaker: Frederick Messine
Affiliation: ENSEEIHT-IRIT, Toulouse, France
Title: Use of affine relaxations in interval based global optimization algorithms.
Abstract: Interval Branch and Bound based methods are well known to provide a global minimum of a non-linear and non-convex problem. Moreover, they are rigorous in a numerical sense: no numerical error due to floating point computations can yield wrong results and the accuracy on the solution is previously fixed by the users. Affine arithmetic was introduced by Comba, Stolfy, Andrade, De Figueiredo in 1992, and it was extended by considering new forms by Messine in 2002. An automatic method based on affine forms for constructing linear relaxations of a continuous constrained optimization problem was recently introduced. The linear programs so-generated has exactly the same numbers of variables and of inequality constraints; each of the equality constraints is replaced by two inequality ones. Therefore, this new procedure for computing reliable bounds and certificates of infeasibility, is inserted inside a classical interval Branch and Bound algorithm. Its efficiency is shown by solving, in a reliable way, several difficult numerical examples of continuous constrained global optimization problems from the COCONUT website.

Time: Wednesday 11:30 -- 12:15
Speaker: Denis Arzelier
Affiliation: LAAS-CNRS, Toulouse, France
Title: Linearized fuel-optimal space rendezvous: Some theoretical and numerical aspects
Abstract: The optimal fuel impulsive time-fixed rendezvous problem is shortly reviewed. In a linear setting, it may be reformulated as a non convex polynomial optimization problem for a pre-specified fixed number of velocity increments. Some theoretical results are first recalled and two different algorithms are presented. In particular, when addressing the problem of a free number of maneuvers, one has to resort to a mixed iterative algorithm involving the solution of a system of polynomial equation at each step. Different numerical issues are finally pointed out.

Time: Wednesday 14:00 -- 14:45
Speaker: Alexander Danis
Affiliation: Uppsala University, Sweden
Title: Inconsistency formulations for existence verification by constraint propagation
Abstract: We present a constraint propagation point of view on the problem of verifying the existence of solutions to nonlinear systems of equations in finite dimensional euclidean spaces.

Time: Wednesday 14:45 -- 15:30
Speaker: Luc Jaulin
Affiliation: ENSTA-Bretagne, France
Title: An interval approach for stability analysis of nonlinear systems
Abstract: This talk proposes a new interval-based method for robust stability analysis of nonlinear systems. The principle of the approach is to represent uncertain systems by differential inclusions and then to perform a Lyapunov analysis in order to transform the stability problem within a set-inversion framework. With this approach, we can show that for all feasible perturbations, (i) there exists a safe subset A of the state space the system cannot escape as soon as it enters in it and (ii) if the system is outside A, it cannot stay outside A forever. In a second step, the methodology is used to build reliable robust controllers. An illustration related to the line following problem of sailboat robots is then provided. A experimental validation that took place on January 2012 will then be presented. On this experiment, the autonomous sailboat robot Vaimos, has gone from Brest to Douarnenez (more than 100 km). more details can be found at http://www.ensta-bretagne.fr/jaulin/vaimosdouarn.html.