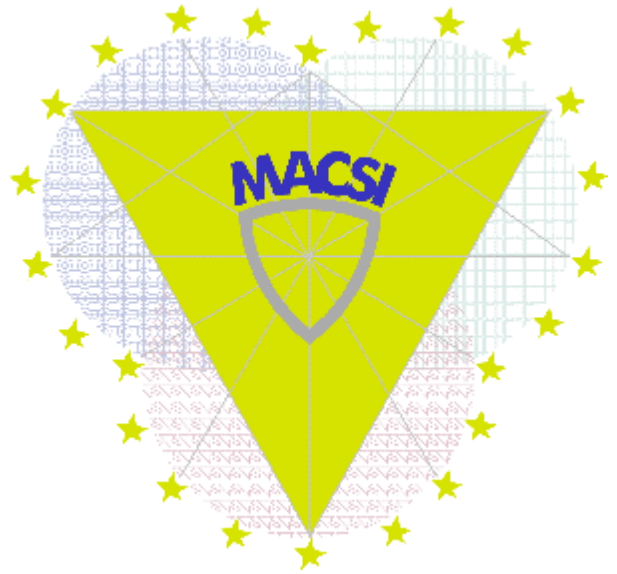


MACSI
Working Group
on



Multidisciplinary Optimization and Inverse Problems

Kickoff Meeting

Industrial Mathematics Institute,
Johannes Kepler Universität
Linz



Erwin Schrödinger Institute,
Vienna, 19-20 November 2001



MACSI Working Group on "MULTIDISCIPLINARY OPTIMIZATION AND INVERSE PROBLEMS"

I. Aims: to investigate, test, evaluate and compare innovative optimization and inverse methods on databases for solving new multi-disciplinary generic problems ; test cases are to be defined from specific problems in the areas of Aeronautics, Transport, Material processes, Telecommunication, Chemistry, Environment, Bio-engineering and Medicine, Energy.

II. Format: the WG is a triangular cluster made of three sub-groups, whose chairmen jointly act as coordinators of the WG:

G1) Inverse Problems (Chairman: H.W. Engl, Kepler Universität Linz, Austria)

G2) Optimization problems (Chairman: J.Periaux, Dassault Aviation)

G3) Software (Chairman: S. Odorizzi, EnginSoft,Italy)

One aim is also to exploit synergies between these areas, also working on a single data-base at the centre of the triangular cluster.

III. Possible Activities

- Workshops with presentations of current problem fields by industry and current methods by academia
- industry proposing and /or running test cases,
- academia running test cases with innovative methods, and
- both academia and industry installing data on a database with html papers describing the optimization/inverse method.

IV. Subjects

The following items apply to both optimization and inverse methods:

S1. TRADITIONAL and DETERMINISTIC METHODS

- Automatic differentiation
- Large scale linear and non-linear programming
- Surrogate models
- Non-smooth problems
- Convex and non-convex objective functions
- Regularization methods

S2. PROBABILISTIC and ADAPTIVE METHODS

- Evolutionary Algorithms

- Neural Networks
- Fuzzy Algorithms
- Multi-objective/Multidisciplinary optimization
- Parameter identification
- Multi Criteria Decision Making

S3. HYBRID METHODS

- coupling deterministic and stochastic methods
- coupling neural networks and stochastic methods

V. Linked European Projects

Representatives of the following ongoing or recent projects focused on optimization and design could contribute to the WG :

- FRONTIER (IT)
- DECISION (IT)
- INGENET (DG12)
- AEROSHAPE (DG12)
- TRA3 (DG12)

VI. Activities:

Meetings (M), Open Industrial Days (OID) and DataBase Workshops (DBW)

- Gather experience of academic and industrial experts in different disciplines in prospective meetings;
- Cross fertilize through Open Industry Days;
- Identify generic test cases from Industry and evaluate performances of new computational tools through yearly Database Workshops.

Meeting organised by

Prof. Heinz W. Engl
Doris Nikolaus
Ralf Uwe Pfau

engl@indmath.uni-linz.ac.at
nikolaus@indmath.uni-linz.ac.at
pfau@indmath.uni-linz.ac.at

Supported by

the European Commission, Information Society Technologies Program (IST)

Program of the Kick-off Meeting

Monday 19.11.01

9:00-9:05	Opening
9:05-10:05	Mohamed Masmoudi <i>"Surrogate models and multidisciplinary optimization"</i>
10:05-11:05	Jacques Periaux <i>"Recent Advances in Evolutionary Algorithms for Multicriteria Design Optimisation in Aeronautics"</i>
11:05-11:30	coffee break
11:30-12:30	Stefano Odorizzi <i>"Frontier: Open System for Collaborative Design Optimisation using Pareto Frontiers"</i>
12:30-14:00	lunch break
14:00-15:00	V. Selmin <i>"Some recent experiences of multidisciplinary design optimisation at Alenia Aeronautica"</i>
15:00-16:00	Domenico Quagliarella <i>"Applications of hybrid multi-objective genetic algorithms to aerodynamic shape design problems"</i>
16:00-16:30	coffee break
16:30-17:30	Oskar von Stryk <i>"High Performance Optimization and Control of Nonlinear Dynamical Systems in Automotive and Process Engineering"</i>
20:00	Wine evening at Heuriger Schüberl-Auer, Nußdorf

Tuesday 20.11.01

9:00-10:00	Klaus Schittkowski <i>"Sequential Quadratic Programming versus Sequential Convex Programming Methods for Nonlinear Optimization and some Industrial Applications"</i>
10:00-11:00	Jaroslav Haslinger <i>"Shape Optimization in contact problems with Coulomb friction"</i>
11:00-11:30	coffee break
11:30-12:30	Robert Anderssen <i>"Is Understanding the Processing Rheology of a Material One of the Keys to Better Interaction with Industry?"</i>
12:30-14:00	lunch break
14:00-15:00	Werner Roemisch <i>"Optimization of electric power production and trading under uncertainty"</i>
15:00-16:00	Discussion <i>"Research needs in optimization and inverse problems for industry, especially within MACSINET"</i>

Abstracts of Lectures

Is Understanding the Processing Rheology of a Material One of the Keys to Better Interaction with Industry?

R. S. Anderssen

*CSIRO Mathematical and Information Sciences
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Even though the answer is a definite “Yes!”, the question is rhetorical. Whether mathematical or non-mathematical, practical model building, and especially industrial, is driven by questions. In particular, the formulation of an industrial inverse problem is a response to a question that must be answered before a decision can be made. In fact, in many industrial applications, it is decision-making that drives the questions that spawn the inverse problems that must be solved, in terms of the available data. The actual model constructed and solved defines how the information, required to answer the question under examination, is related to the available data.

In the efficient and sustainable manufacture of foods, decision-making spawns questions that require knowledge about the changing rheology (flow and deformation properties) of materials as they are processed. However, such information is recoverable only if suitable indirect measurements are performed that capture the appropriate flow and deformational behaviour of the material under investigation. Among other things, this leads naturally to experimental design considerations related to the optimal choice of the indirect measurements.

This point-of-view will be illustrated by examining the measurement of the hardness of wheat and the mixing of wheat-flour dough. Though the underlying questions differ greatly, they all, in one way or another, require, for their resolution, the recovery of information about the stress-strain behaviour of the material under examination. Among other matters, this leads naturally to the modelling of linear viscoelasticity and, thereby, to the inversion of its Boltzmann causal integral equation model. The talk will conclude with an examination of recent research on the recovery of the Boltzmann relaxation modulus from oscillatory shear measurements.

Shape optimization in contact problems with Coulomb friction

J. Haslinger
Charles University, Prague

This contribution deals with shape optimization in discretized Signorini problems involving Coulomb friction on designed surfaces. It is well-known that the state problem leads to a quasivariational type elliptic inequality. First we shall present some basic properties of the respective control-state mapping. We prove that for the coefficient of friction small enough this mapping is Lipschitzian on the set of discrete design variables. This makes possible to use tools of non-smooth analysis to compute the generalized gradients of minimized functions which are needed in nonsmooth optimization methods. Numerical results of model examples will be shown. This is a joint contribution with J. Outrata and M. Kocvara.

Surrogate Models and Multidisciplinary Optimization

Mohamed Masmoudi
CADOE/MIP

A **parameterisation** is an explicit (or very easy to compute) function that gives almost the same result as a complex numerical model (finite elements, finite volumes, finite differences methods, ...) in a given range of design parameters.

Neural networks, Design of experiments (multivariate polynomial interpolation) are popular parameterisation methods.

Higher order derivatives of a complex model is a powerful way to obtain parameterisation. This approach is particularly efficient for oscillating responses (electromagnetism, acoustics, ...).

Higher order derivative method is based on automatic differentiation.

There are at least two applications for surrogate models.

Multidisciplinary optimisation

Multidisciplinary optimisation could be organised in the following way. Some public parameters $p=(p_1, \dots, p_n)$ are to be shared by all the designers. Then a surrogate model is built for each discipline.

For each discipline, the surrogate model is supposed to update automatically private parameters in order to give the best response.

Multidisciplinary optimisation is a compromise between disciplines. The designers could reach a compromise easily if the response of the system is available in real time.

Genetic algorithms

Genetic algorithms provide an interesting field to surrogate models applications. The range of application of genetic algorithms is very large and they have an interesting property: we need only the evaluation of the cost function. No gradient is needed.

In many industrial applications the evaluation of the cost function needs a long computing time. It is possible to replace the cost function by a parameterised model. Thus we can enlarge the application of genetic algorithms to expensive cost functions.

Some industrial applications will illustrate the application of surrogate models.

FRONTIER: OPEN SYSTEM FOR COLLABORATIVE DESIGN OPTIMISATION USING PARETO FRONTIERS

*Stefano Odorizzi
Engin Soft, 38100 Trento, Italy*

It is no surprise that any company in the world is facing to an ever increasingly competitive marketplace with new technologies and processes driving the engineering cycle. From the boardrooms of the CEOs to the offices of the design floor, everyone has to deal with those all too familiar words resounding through the ranks: "Shorten the product development cycle". These demands are placing a squeeze on the design cycle in order to achieve time-to-market reductions. New modes of operation are being implemented and required by engineering departments as they face internal and external pressures. Efficiencies in methods, hardware, software and shared communication/information systems are becoming the standard.

In particular the multi-partnered collaborative design optimisation is the key area for future industrial competitiveness, which requires leading edge capabilities to provide improved design whilst significantly reducing costs and

time to market. But what does "collaborative design optimisation" mean? How is it structured? What resources are required?

In this paper the main issues which support the collaborative design optimisation process are dealt with mainly in the perspective of the computer simulated soft prototyping approach.

Recent Advances in Evolutionary Algorithms for Multicriteria Design Optimisation in Aeronautics

*J. PERIAUX**, *M. SEFRIOUI**, *K. SRINIVAS*** *E. WHITNEY*** and
*J.F. WANG****

* *Dassault Aviation, Direction de la Prospective, St Cloud, France*

** *Univ. of Sydney, Dept of Aerospace Engineering, Sydney, Australia*

*** *Pole Scientifique Dassault-Aviation/UPMC and NUAA, PR of China*

This lecture presents recent developments in Hierarchical Parallel Genetic Algorithms and Game Theory to speed up the optimum design process of aerodynamic shapes. One is the implementation of different models in different layers of a Parallel Genetic Algorithm. The other is the coupling of different game decision strategies with Genetic Algorithms in distributed multicriteria optimization problems. Parallel implementation on clusters of PCs using Asynchronous Hierarchical Evolution Strategy is also considered as a candidate to speed up evolutionary computation through a continuous individual selection process with asynchronous evaluation of fitness.

Results obtained from numerical experiments will be presented to reconstruct transonic nozzles and aerofoil shapes and also to maximize lift of multi-element airfoils systems at landing and take off flow conditions. It is shown from the results that a significant speed up is achieved making these approaches an innovative road map to affordable and robust multidisciplinary design optimization techniques.

Applications of hybrid multi-objective genetic algorithms to aerodynamic shape design problems

Domenico Quagliarella
CIRA, Italy

The talk is focused on the application of Genetic Algorithms to aerodynamic shape design problems. The general features of these algorithms are outlined and their advantages and drawbacks in the application to aerodynamic design are discussed.

A hybrid design procedure is then presented as a possible remedy to the discussed drawbacks. This procedure is based on a multi-objective genetic algorithm coupled with a classical gradient based search technique.

The advantages of this approach are discussed and illustrated with some examples of single and multi-objective aerodynamic optimization problems.

Optimization of electric power production and trading under uncertainty

W. Römisch

Humboldt-Universität Berlin

Institut für Mathematik

D-10099 Berlin, Germany

A dynamic (multi-stage) stochastic programming model for the weekly generation and trading of electric power of a utility owning a hydro-thermal generation system is developed. The underlying stochastic data process consists of the electrical load, electricity (spot) prices and inflows to hydro reservoirs. The model involves a large number of mixed-integer (stochastic) decision variables and constraints linking time periods and operating power units. A stochastic Lagrangian relaxation scheme is designed by assigning (stochastic) multipliers to all constraints coupling power units. The stochastic data process is approximated by a finite number of scenarios in form of a scenario tree. Solving the Lagrangian dual by a proximal bundle (subgradient) method leads to a successive decomposition into stochastic single (thermal or hydro) unit subproblems. These stochastic single unit subproblems are solved by algorithms that exploit the underlying tree structure. A final Lagrangian heuristics provides approximate (primal) decisions starting from the optimal (stochastic) multipliers. Numerical results are presented for realistic data from a German power utility and for numbers of scenarios ranging from 5 to 100. The sizes of the corresponding optimization problems go up to 200.000 binary and 350.000 continuous variables, and more than 500.000 constraints. (The talk reports on joint work with N. Gröwe-Kuska, K.C. Kiwiel, M.P. Nowak and I. Wegner.)

(romisch@mathematik.hu-berlin.de, <http://www-iam.mathematik.hu-berlin.de/~romisch>)

Sequential Quadratic Programming versus Sequential Convex Programming Methods for Nonlinear Optimization and some Industrial Applications

*Klaus Schittkowski
Department of Mathematics,
University of Bayreuth, D-95440 Bayreuth*

The lecture will introduce a class of optimization methods, that have been invented to solve structural design problems arising e.g. in mechanical engineering, and that are in practical use since many years. They are based on a successive convex approximation of the original nonlinear programming problem and are called SCP-methods. It turns out that these methods are very efficient for a certain class of problems, e.g. for problems with stress and displacement constraints, where the weight of a mechanical structure is to be minimized.

The methods are analysed and their theoretical and numerical properties are compared to that of the well-known sequential quadratic programming algorithms (SQP). These algorithms are also widely used in mechanical engineering, but they are general purpose methods in the sense that any model dependent features are not exploited. It is shown that both methods can be treated in the same way when introducing a line search to stabilize the algorithm, i.e. to enforce convergence even from bad initial values.

A couple of industrial applications will be introduced, for example

1. Topology optimization (CAD-FEM)
2. Ship design (Meyer Werft)
3. Horn radiators for satellite communication (Dornier Satellite Systems)
4. Surface acoustic wave filters (Epcos)
5. Optimal control of a cracker (BASF)

Some recent experiences of multidisciplinary design optimisation at Alenia Aeronautica.

*E. Pelizzari, A. Pennavaria and V. Selmin
New Products and Technologies Development
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Corso Marche, 41. I-10146 Torino. Italy
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Multidisciplinary Design Optimisation (MDO) will provide designers a new array of tools and approaches that will take them closer to that elusive goal, an “optimum airplane”. MDO has been defined as “a formal design methodology based on integration of disciplinary analysis and sensitivity, optimisation and artificial intelligence, applicable at all stages of the multidisciplinary design of aerospace systems”. What this really means is that MDO is a way of getting engineers from various disciplines, such as aerodynamics, structures, weights, control systems, propulsion, etc., to work together. Mathematical tools, such as sensitivity analysis, modelling methods and optimisation solvers, provide a mechanism by which working together can be accomplished. The result is a process that can both reduce the design cost and flow-time, and improve the quality of aerospace systems.

The present work reports on recent experiences done in Alenia Aeronautica on multidisciplinary design analysis and in particular on multidisciplinary design optimisation. The reference geometry, illustrated in figure 1, depicts a small jet (under 100 seats) airplane which is used for research purposes and in particular to validate new technologies from grid generation to fluid/structure interaction and multidisciplinary optimisation.

The reference optimisation problem is formulated as follows: find the wing jig shape that allows to minimize a simplified DOC function (weighted combination of aerodynamic drag and structural weight) at cruise conditions maintaining a single curvature upper surface in order to contain manufacturing costs. This means to solve at least a four disciplines problem: aerodynamic, structural sizing, static aeroelasticity and manufacturing costs control, the latter being transformed into constraints on the geometry.

The optimisation system is formed by an optimisation module, an analysis module and an interface module that handles the geometry modifications (figure 2). The interface module is integrated within a multi-model generator which provides the CFD(Computational Fluid Dynamics) system with a discretisation of the wing geometry and the CSM(Computational Structural Mechanics) system with a finite element model of the wing. The optimisation module controls the design variables and modifies them in order to locate the optimum of the objective functions while satisfying the prescribed constraints. Gradient based methods are used and derivatives are computed with respect to the design variables are currently computed by first order forward finite difference, but work is underway to compute them by using automatic differentiation techniques both in forward and reverse modes. Aerodynamic coefficients are computed by using in-house CFD solvers based on the solution of Euler and Navier-Stokes equations on general grids (structured, unstructured or hybrid) while wing mass is estimated through MSC NASTRAN structural optimisation

module. Aeroelastic deformations are provided through the CFD/CSM coupling between aerodynamics and static structural analysis.

The design variables can be any of the wing planform defining parameters or those that govern the modification of selected wing section shapes. The parametrisation technique is based on a shape perturbation method. The aerodynamic grid update due to a new wing surface definition can be carried out both by using remeshing or mesh deformation techniques, the latter seems more versatile and efficient when dealing with very complex configurations and unstructured meshes.

The talk will described in details the overall system and discussed the results of the optimisation exercise. In particular, the strategy to couple the different disciplines in an accurate and efficient way will be soundly analysed.

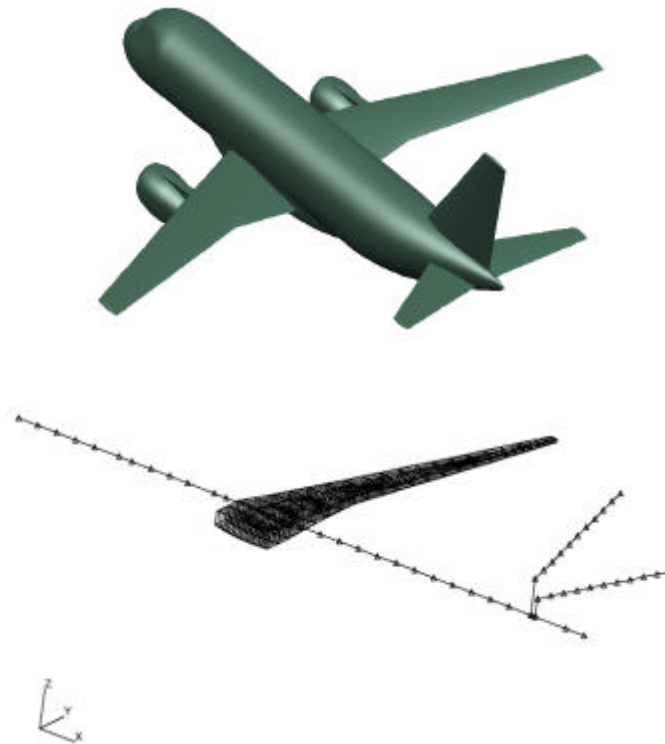


Figure 1: Reference geometry and structural model.

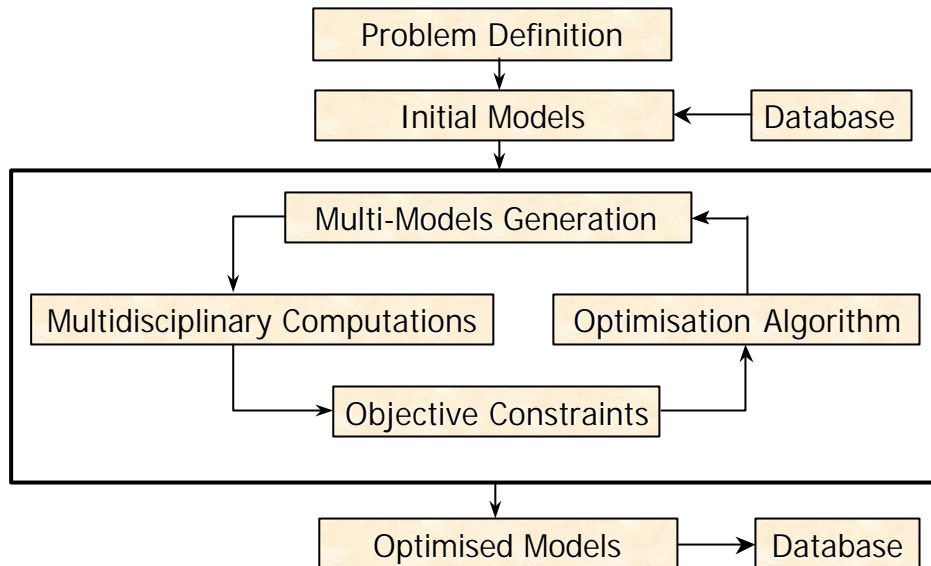


Figure 2: Multidisciplinary Optimisation System

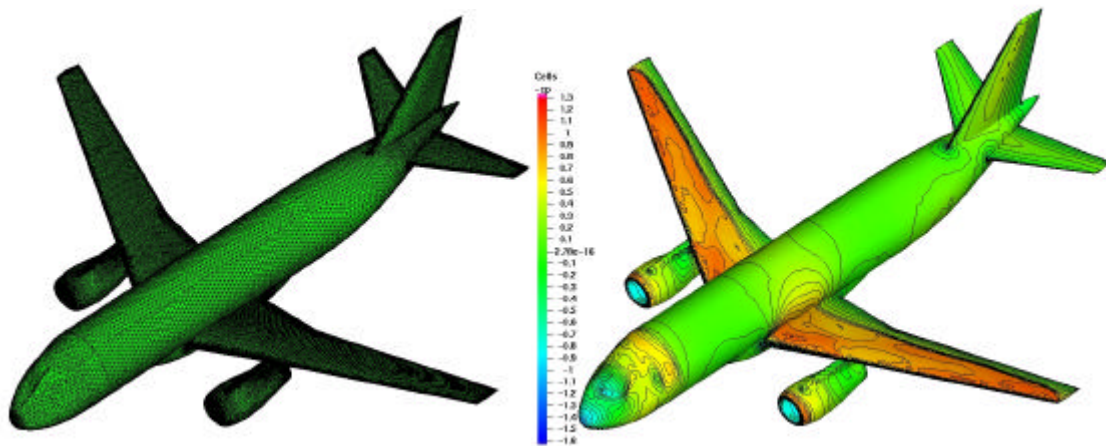


Figure 3: CFD grid and computation.

High Performance Optimization and Control of Nonlinear Dynamical Systems in Automotive and Process Engineering

Oskar von Stryk

FG Simulation und Systemoptimierung,

Technische Universität Darmstadt, D-64 283 Darmstadt

Dynamical properties of chemical process plants as well as of motor vehicles are described mathematically by large-scale systems of ordinary differential equations or differential-algebraic equations, possibly of higher index and incorporating state-dependent switchings. Due to their complexity, the dynamic models are usually derived by computer-aided modeling methods.

Offline and online optimization problems for instationary plant operation result in various optimal control problems. A numerical solution approach for air separation plants will be presented.

Modern motor vehicles contain an increasing number of feedback control loops whose primary purpose is to increase vehicle safety, comfort and performance. An optimization of these subsystems gives rise to various optimal control problems. Several examples will be presented and discussed in the talk.

List of Speakers

Dr. Robert S. Anderssen

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Locations, Maps and Directions

Location of the Hotel

The address of the hotel is

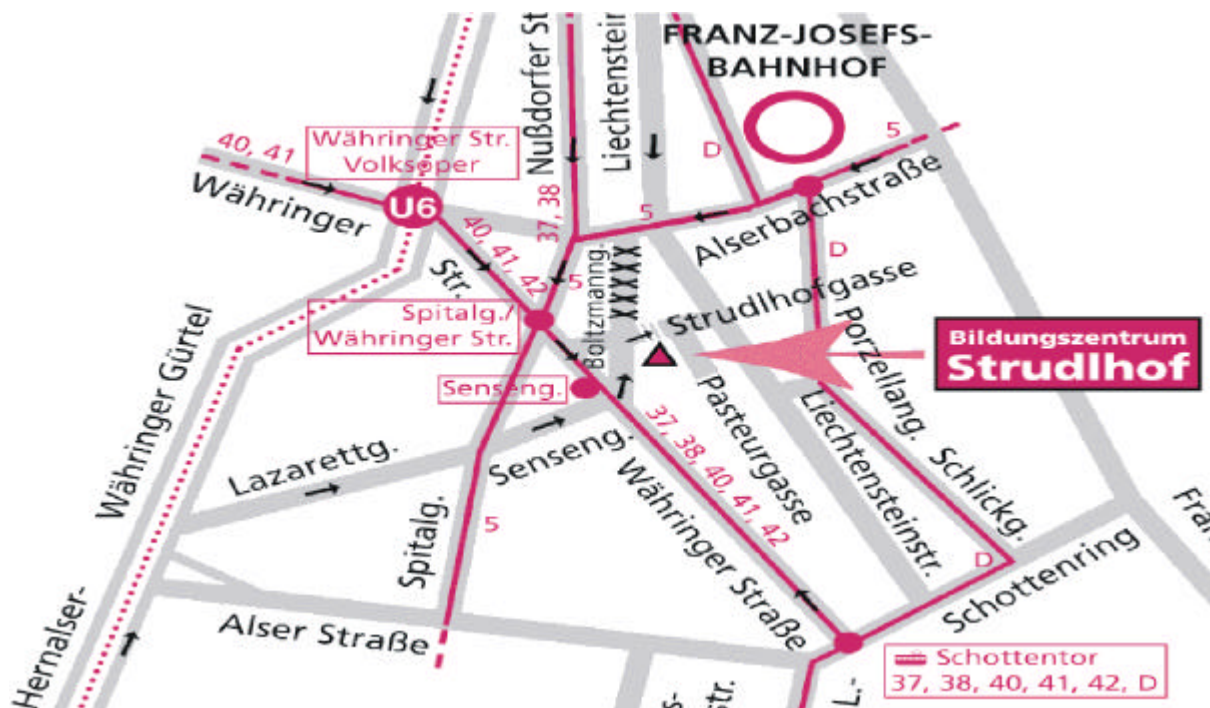
Hotel Strudlhof

Pasteurgasse 1

1090 Vienna

Tel. 01/319 25 22 - 10111

www.strudlhof.at



(map taken from www.strudlhof.at)

Location of the Erwin-Schrödinger-Institute

The address of the Erwin-Schrödinger-Institute is

ESI

Boltzmannngasse 9

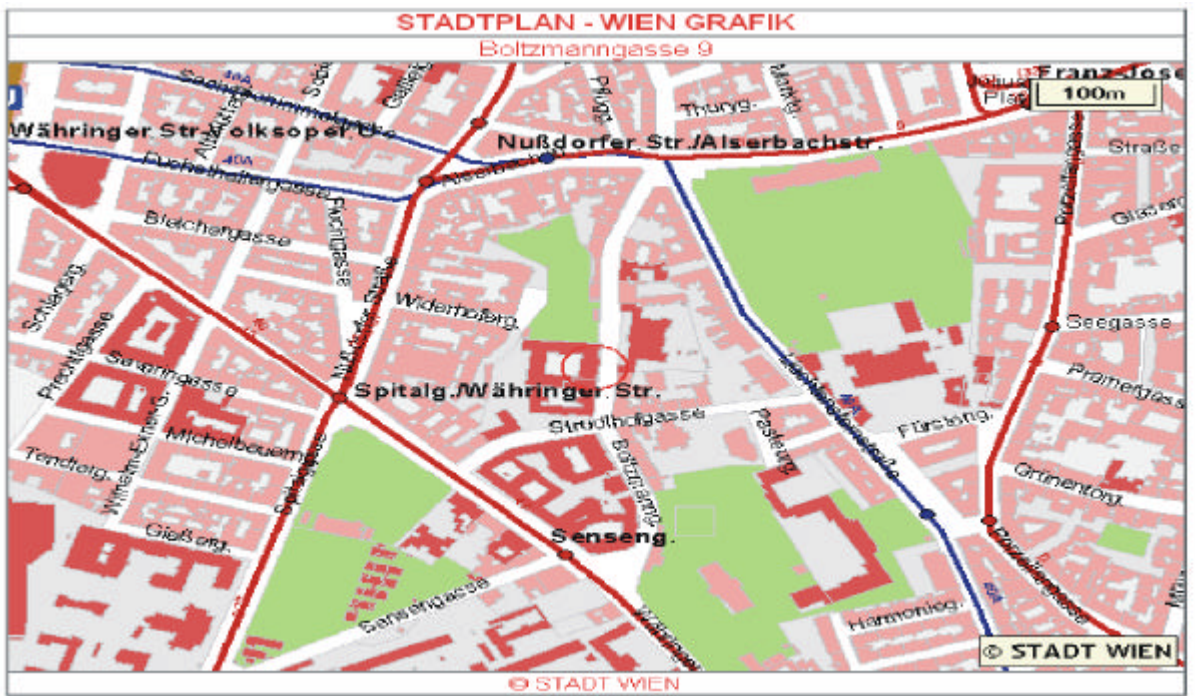
2nd floor,

1090 Vienna

Tel. 01/ 317 20 47

Fax: 01/ 317 20 47 30

www.esi.ac.at

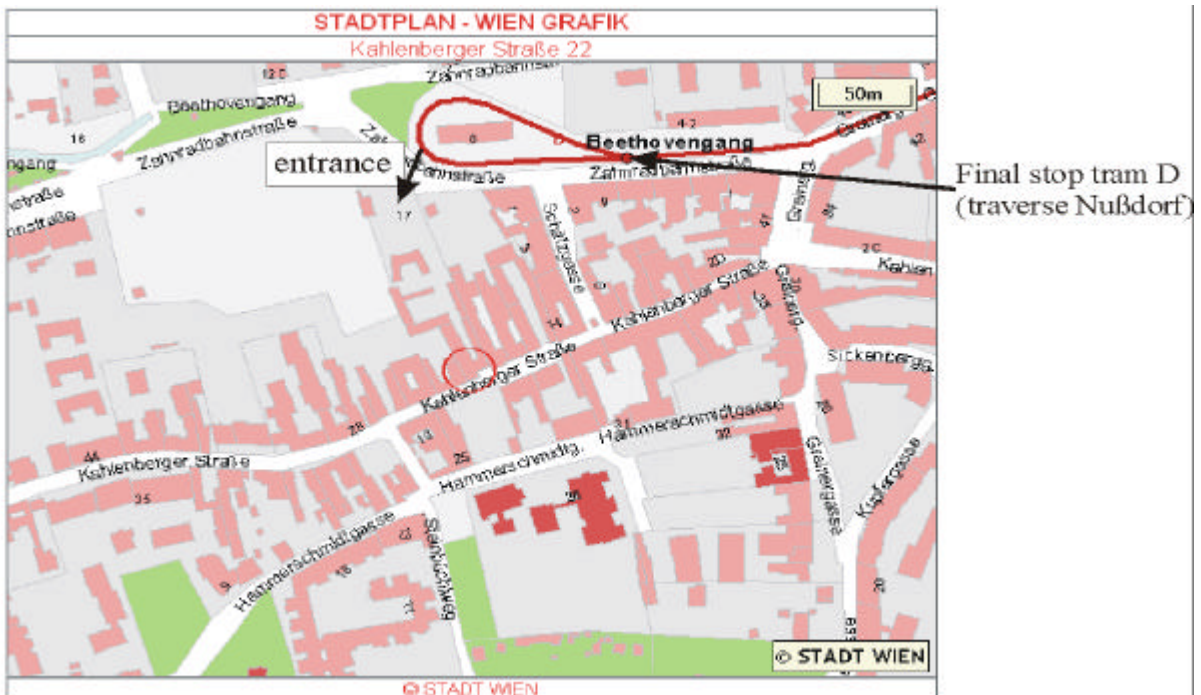


(map taken from www.magwien.gv.at)

Location of the Heuriger

The address for the Heuriger on Monday evening is

Schübel-Auer
 Weinbau und Heurigenbuffet
 Kahlenberger Straße 22
 1190 Vienna-Nußdorf



(map taken from www.magwien.gv.at)

The location is at the end of the tram line D, direction Nußdorf. The price for a single ticket is 19 ATS, if you buy it beforehand, and 22 ATS if you buy it in the tram. Tickets are available, e.g. at newspaper kiosks, and at the hotel reception.

How to go there ...

Starting from the hotel in the *Pasteurgasse*, go via the *Fürstengasse* to the *Porzellangasse*. Turn left into the *Porzellangasse* and go to the stop *Seegasse*. Take line D in direction *Nußdorf* till the final stop. An entrance to the Heuriger is from the *Zahnradbahnstraße*. A special room is reserved under the name "Engl".



tram line D name of different stops, taken from www.wienerlinien.at

... and back to the hotel ...

Going back to the tram stop of line D. Take the next tram and leave at the stop *Seegasse*, go a few meters into the direction of the tram line, than turn right into the *Fürstengasse*, cross the *Lichtensteiner Straße* and go into the *Pasteurgasse*.

Registration and Hotel Reservation

The invited speakers are already registered, rooms are reserved.

Others who want to attend, please fill in the following registration form and **fax** to +43-70-2468-8855

Registration Form

Title: Prof. Prof. Mr. Mrs.

First Name:.....Surname(s).....

Organization:.....

Address:.....

Postcode/City.....Country.....

Phone.....Fax.....

E-Mail.....

Hotel: single/ double

check-in date.....check-out date.....

We will try to get a room at the Strudlhof Hotel, Pasteurgasse 1. The price of ATS 950 for single/ATS 1500 for double per night has to be paid directly to the hotel.

Registration Fee

The registration fee of ATS 1500 (109,01 Euro) has to be paid in cash (Austrian currency, exact change) on Monday morning.

The registration fee includes lunches, coffee breaks and Heuriger.

Please fax this form to +43-70-2468-8855.

E-mail: nikolaus@indmath.uni-linz.ac.at