



# MTA SZTAKI

HUNGARIAN ACADEMY OF SCIENCES  
COMPUTER AND AUTOMATION  
RESEARCH INSTITUTE



**EU Centre of Excellence**  
in Information Technology and Automation



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## The Mission

The fundamental task of the Institute is to perform basic and application oriented research in an interdisciplinary setting in the field of computer science, intelligent systems, process control, wide-area networking and multimedia. The application tasks are performed on the basis of contracts with the aim of transferring the research results into the industry and state administration. The application activity is concentrated mainly on complex systems, the turn-key tasks from system planning to realization, furthermore the training of the personnel in cases when the complex interdisciplinary knowledge, possibility of organizing specialized teams, the good infrastructure and financial stability of the Institute mean competitive advantages compared with small- and medium size enterprises. The Institute's mission includes the transfer of up-to-date results and research technology to university students. The Institute is very active in graduate and postgraduate education, cooperating with most of technical universities in Hungary and operating common chairs, post-graduate programmes with them. More than 40 colleagues conduct regularly lectures on graduate and post-graduate levels, and senior researchers hold part-time position as university professors. About 50 Ph.D. students and 30–40 graduate students participate in the work of the Institute.

## The Operating Strategy

All units at the Institute are operating as individual profit centers, the basic research activity is financed from budget subsidy and from a part of contract work's profit. Colleagues who are willing to deal with basic research in the next period may apply for grants of maximum 3-years. The laboratories for basic research ensure:

- the internal and international goodwill of the Institute as a high-tech organization of high level,
- the new results, methods, technologies which provide competitive advantages for us in the field of consulting, system planning and integration,
- highly qualified young researchers through personal contacts with best students during university years.

The R & D departments live from revenues deriving from contract works and subsidies of R & D competitive funds. The basic research laboratories too may participate in contract work forming specialized teams with R & D units. The profit from contract work can be used for additional benefits for the researchers and the improvement of the infrastructure.

## The Institute as a high-tech company

Contract-based target research, development, training and expert support for domestic and foreign industrial, governmental and other partners have been some of the key activities of the Institute.

The Institute's research and development activity aims primarily at creating customdesigned computer-based applications, implementing the related software and providing turn-key systems. Our scientists and engineers have the necessary fieldspecific expertise (theoretical, technological and methodological experience) by which they can complete – in close co-operation with potential users – the functional plan of the system to be implemented, followed by software design and system development. The Institute undertakes the teaching in and training of users, system installation and supervision in the starting phase of operation, as well as the followup of its software products.

### **The main fields of applied research and development are as follows:**

- artificial intelligence methods in medical diagnostics, process control, mechanical engineering and in the field of financial mathematics,
- expert- and knowledge-based systems in medicine and process supervisory systems,
- design and application of analogic CNN algorithms for high-speed image detection, e.g. for evaluation of mammograms, echo-cardiograms in the field of medicine, video compression techniques, cryptographic procedures,
- robust control, simultaneous identification and control, signal processing methods and their application in diagnostics and control of industrial processes and in integrated vehicle control system,
- computer integrated manufacturing systems,
- distributed information management,
- decision support systems,
- new technologies for local and wide area networks, WWW-based and multimedia tools, computerized libraries,
- specification of telecommunication protocols, development of protocol engineering tools and conformance testing,
- software quality assurance.

Quality management is an important issue at the Institute: we have an ISO 9002 certificate issued by TÜV Rheinland Euroqua and a BOOTSTRAP quality assurance system for SW-development.

### **External relationships of the Institute**

The Institute has wide external relationships in its R & D profile. ERCIM (European Research Consortium of Informatics and Mathematics) granted full membership to the Institute in 1994. Members of the Consortium are national informatics research centers of EU and EFTA countries (one from a country) who aim at co-operating in projects of European scale and in joint education of young scientists. The Institute is a member of the W3 Consortium led by the MIT, of the European Software Institute and of other international organizations.

Upon getting the award of numerous EU-grants, researchers of SZTAKI contribute extensively to European scientific co-operation projects. The Institute was the first in our region to obtain an ESPRIT Basic Research Grant. Our international educational contacts include participation in the TEMPUS programme. Some research programs are supported by US Agencies, including NSF, ARO and ONR.

Recent years have delivered us promising development in our contacts with Western- European, North-American and Far-Eastern universities and research centers. Our senior researchers are also very active in the management and in the working committees of various international scientific organizations. Many researchers are members of editorial boards of leading international scientific periodicals.

## Staff

The present staff consists of about 320 employees, out of which about 200 are university graduates, 60 people have intermediate education, and an assistant staff of about 60 is also available. Graduate employees are highly qualified engineers and mathematicians with ample expertise and practice in advanced information sciences (computers, communication and control) as well as in information technology. All of them speak foreign languages (most of them speak English), about half of them speak two or more languages (the second foreign language is mostly German or Russian). An average researcher has about 8–10 years of working experience and the Institute's team of software engineers offers an impressive development capacity. A significant part of the researchers have scientific degrees – practically all researchers older than 30:

- members of Academy of Sciences 8
- Doctor of Academy of Sciences (Dr.Ac.) 15
- Ph.D. 57
- Dr. tech. 20

The Institute employs many young specialists. At present 60–65 full-time researchers are under 35 and 40–50 post-graduate, 20–30 graduate students are employed in part time. They complete their diploma-work or dissertation under the supervision of Institute's researchers.

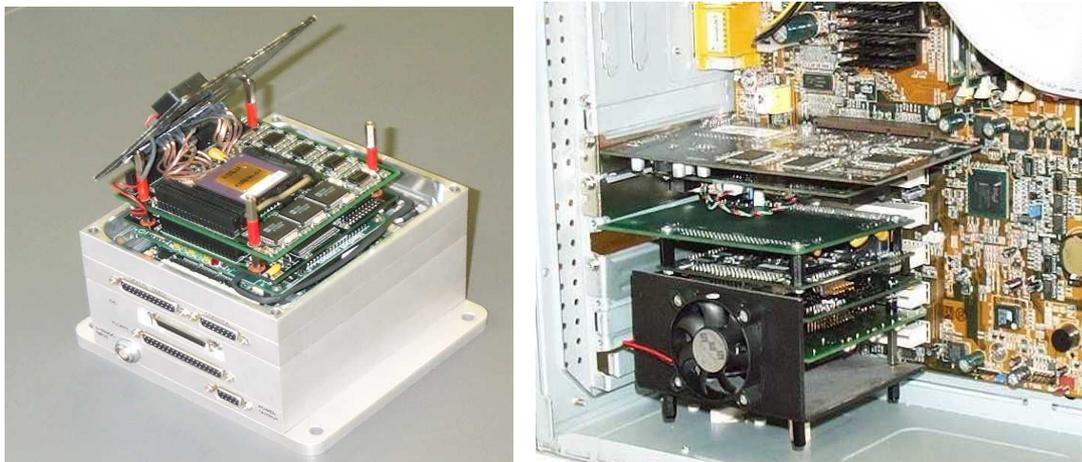


-----> **ANALOGIC CELLULAR COMPUTERS –  
TOPOGRAPHIC/VISUAL MICROPROCESSORS**

Analogic Computers combine analog spatio-temporal dynamics and logic. After the introduction of the CNN paradigm (CNN: Cellular Neural/nonlinear Network), CNN Technology got a boost when the analogic cellular computer architecture, the CNN Universal Machine (CNN-UM) had been invented. The most successful chips embedded in a computational infrastructure provided the framework for analogic cellular software development. Now the industrial applications rely on the available ALADDIN system. References: <http://lab.analogic.sztaki.hu>

**The Analogic CNN Engine (ACE)**

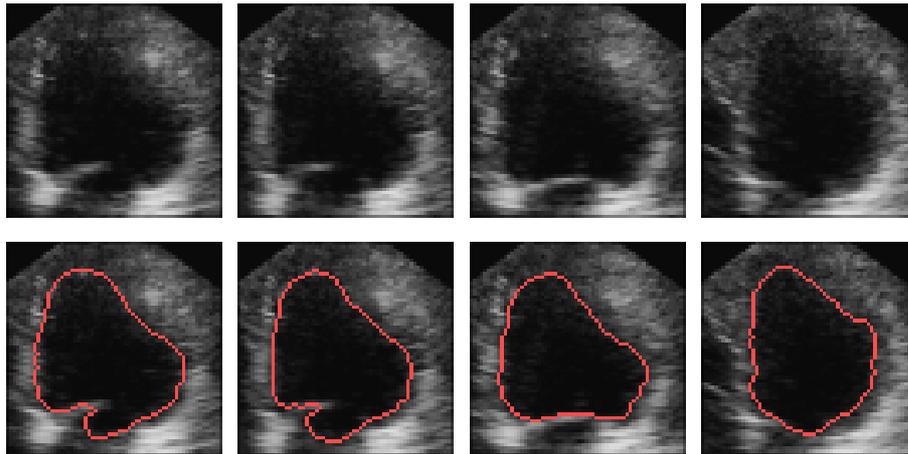
The CNN paradigm related research resulted in the development of a number of analogic array processor chips. Currently, the most advanced one is the ACE 4k constructed of an array of 64x64 pixel analog processor cells. The 4096 cells work parallel. The overall computational performance of the chip provides the possibility of processing 64x64 pixel-sized images up to 10,000 frame/second including I/O. Each cell in the array processor corresponds to one pixel in an image. Images larger than 64x64 can be processed tile-by-tile and then merged together again. Stored programmability with a wide operation set is the most important feature of the analog-and-logic (analogic) processor array. The operation set contains dynamic analog array operations, and local logic operations for gray-scale or binary images. The chip can store eight 64x64-pixel images. Its input-output speed meets the minimal requirements of video processing. The operation and I/O accuracy of the chip is of 7-8 bits, appropriate for many applications (note that this is not equivalent to the digital accuracy, here there is no iteration in time!). The above advantages of the ACE 4k chip encouraged us to build the ALADDIN Visual Computer (see the figure), being the first high-performance industrial quality image processing device utilising cellular neural networks.



*The industrial (left) and the desktop versions (right) of the ALADDIN Visual Computer*

## Applications

An extremely wide set of problems can be addressed by CNN Technology. Two snapshots of an echocardiogram video flow are shown in the figure, before and after image flow processing. The inner boundary of a left ventricle is determined. A complex analogic cellular algorithm consisting of nonlinear wave actions and local logic operations implemented on the ACE 4k chip solves the task.



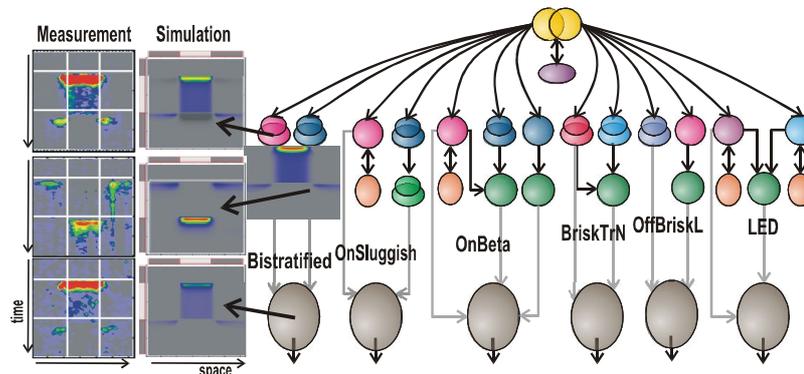
*Determination of the inner boundary of the left ventricle.  
 A snapshot of an echocardiogram video flow.*

The Visual Computer can be applied in two modes, firstly when a high-speed external camera is connected to the system via a PCI frame grabber. In this mode, ultra high frame rate (up to 10,000) can be attained with low resolution (64×64 – 256×256) images. This way the system can be applied as a visual trigger or a high-speed visual event detector. Moreover, it can manage extremely high-speed events, such as flashes of a spark-plug, or can make the shape analysis of a rapidly moving object, such as a pill, or a grain.

In the second application mode, the system processes video image flows, coming from a single or a number of different cameras, in real-time. Due to its high computational power, whole frames can be processed, unlike in the case of digital image processing systems. This feature makes surface quality control possible even in complex surface patterns. Multi-modal image fusion that can be used in a number of security or traffic safety applications is another typical application in this mode.

## Biology relevance

Many sensory processing parts of the nervous system have been modelled. Very recently, after the discovery of the parallel channels in a mammalian retina, we have developed a multi-layer CNN model for reproducing some simple effects, as well as a simulation framework which is accessible from the internet. The model is illustrated below.



*The structure of a mammalian retina model*

Some parallel channels of the mammalian retinal processing are shown schematically on the left-hand side. The first column contains the measured space-time pattern of one channel in the rabbit retina and the second column the corresponding simulated outputs. These are the spike frequency (last row), excitatory current (first row) and inhibitory current (middle row) representations of the flashed square in a given channel. Time changes on the vertical axes downward, and space is projected onto the horizontal axes. White bars indicate the time and space marked regions of the stimulus. The model qualitatively reproduces the patterns measured in rabbit retina.

The different model structures of the mammalian retina channel are shown on the right-hand side. The different neuron types in the retina are organised into two-dimensional strata, each represented by spheres, modelled with CNN layers. A neuron in a given layer effects another neuron in another layer through synapses while the arrows represent the connections. The layers have different time and space constants and the synapses operate by non-linear transfer functions. The general neuro-biological names of the channels are given and the positions of the terms indicate the morphological depths of the parallel representations.

<http://lab.analogic.sztaki.hu>

-----> **MODELLING MULTI-AGENT SYSTEMS**

Our aim is to develop sophisticated formal language theoretic frameworks, for modelling multi-agent architectures and study their applicability in computer science. The main objective is to get a better understanding of the nature of the intrinsic behaviour of systems of (autonomous) agents and to offer convenient and efficient tools for computing based on multi-agent technology. Basis of research: Grammar Systems, a recent field of formal language theory modelling distributed complex systems. By using this framework, unconventional, nature-motivated computational paradigms such as models for molecular computing are developed, as well.

Main directions of investigations:

- grammatical paradigms for distributed and decentralised AI,
- language theoretic models of ecosystems,
- networks of language processors,
- distributed architectures in molecular computing,
- applications of grammar systems theory in natural language processing.

Research is carried out in co-operation with a growing group of researchers from about a dozen of countries in Europe, Canada, Japan and India. Their activity is supported by national and international grants.

<http://www.sztaki.hu/mms>

-----> **SYSTEMS AND CONTROL**

Over the past years the Systems and Control Laboratory has grown to be a national center of the field with international reputation and also of the related industrial applications, furthermore, served as a graduate and post-graduate center for teaching modern and postmodern signals-, systems- and control theory. Activity includes fields traditionally related to successful R&D at the SZTAKI, extended with some of the newly emerging theoretical approaches and applications, inspired by the progress in information technology and smart instrumentations.

Specific focus is on: System theory, system identification and robust control

Advanced signal processing

Fault tolerant and dependable systems

### **Systems Theory, Identification and Robust Control**

Significant results are achieved by introducing new paradigms such as approximate identification and related robust and adaptive control design schemes by using non-standard bases.

Novel methods are proposed in the generic two-degree-of-freedom robust servo control design. These control structures are based on a special, K–B parametrisation, and the interaction between the controller and the model is also taken into account.

Iterative methods developed: modelling and control performances, and robustness are also considered. Results are applied in several case-studies and industrial projects.

### **Advanced Signal Processing**

Efforts in this field are concentrated on research and development of delicate methods for acquiring high-level – accurate and reliable – information on the structure and the behaviour of the systems. Beyond the general directions of signal processing, we concentrate on methods by utilising a priori knowledge (e.g. structural information) available on the systems to attain high sensitivity and robustness.

Typical specific themes: measurement and data acquisition procedures and methods, sensors and sensor systems, signal analysis theory, principles and methods of signal synthesis, detection of changes and failures, system design for signal processing, applications e.g., in automotive technology and nuclear power plants.

### **Fault Tolerant and Dependable Systems**

In the form of engineering consulting and transfer of technology to the industry, the results are applied in problems related to the theory and implementation of dependable systems including fault detection and isolation, fault accommodation and system reconfiguration, moreover, active redundancy management.

## Intelligent and Autonomous Vehicle Systems

With the pressing experience of a large number of road accidents occurring due to lapses in drivers' attention, in co-operation with Knorr Bremse Ltd, an automatic visual detection system to prevent unintended lane-departures was developed.

The vehicle is equipped with digital cameras for monitoring lane geometry in real-time and detecting eventual obstacles. The motion is predicted by using velocity and steering angle signals from on-board sensors. Both the detected lane geometry and the predicted motion of the vehicle are considered in decisions. A warning speech signal is sounded to the driver together with a message sent to the supervisor system. The supervisor can intervene in the vehicle's motion by using the drive stability control system (DSC) if there is no driver's activity (steering, accelerating or braking) and the duration of the lane departure is less than the reaction time of the driver. The intervention itself is done by using the brake system.



## Safety Critical Systems

The basic objective of the Reactor Protection System Refurbishment Project (RRP) at the Nuclear Power Plant Paks, Hungary, is to replace the old safety instrumentation, prone to failures due to its age, with a new state-of-the-art computerised Instrumentation and Control system, improving this way the safety level of the plant and extending the life cycle of the reactors.

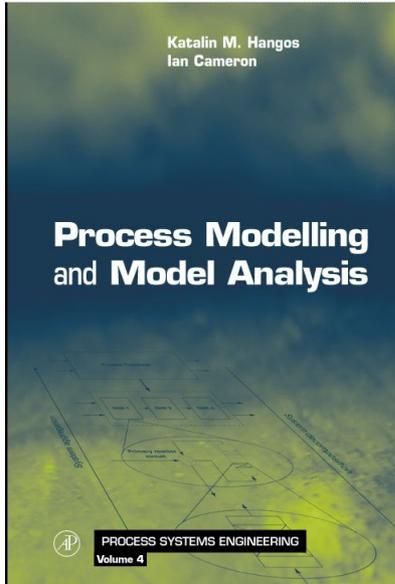
The Reactor Protection System has to be tested periodically just like the actuators during each start-up. A unified test environment and a test description language (ETEL) was developed, including the periodic test, start-up tests, RC autonomous tests and the Factory Acceptance Tests (FAT).

<http://www.sztaki.hu/sci>



-----> **PROCESS CONTROL**

A synergetic grey-box approach is applied to solve research problems in process control integrating process systems engineering with systems and control theory.



The basis of the approach is **process modelling and model analysis** using first engineering principles. Formal methods of computer science and artificial intelligence are applied to construct, verify, analyse and simplify process models in a rigorous and automated way. These methods are implemented in intelligent computer-aided modelling tools to support the modeller in process model building and analysis.

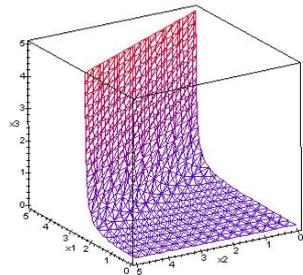
Our interest also includes the investigation of the effect of algebraic, model building and model simplification transformations on the computational and dynamic properties of process models.

Work in this area, a joint effort with Prof. Ian Cameron, CAPE Centre, Dept. of Chemical Engineering, The University of Queensland, Brisbane (Australia), resulted in a joint book published by Academic Press, London, in 2001.

Nonlinear system theory, nonlinear control and diagnosis belong to the most challenging and developing areas in post-modern systems and control theory. Process systems are known to be highly nonlinear and are governed by the basic laws of thermodynamics. Therefore, the grey-box modelling and control of these systems are based on the joint understanding of modern nonlinear system analysis and control methods and the fundamentals of process systems engineering.

Our interest in **nonlinear process systems** includes:

- nonlinear reachability and stability analysis
- Hamiltonian process systems
- passivation and loop-shaping controllers
- nonlinear controller selection based on the analysis of input-output behaviour



Simple but industrially important process systems, such as heat exchangers and fermentation processes are used as case-studies.

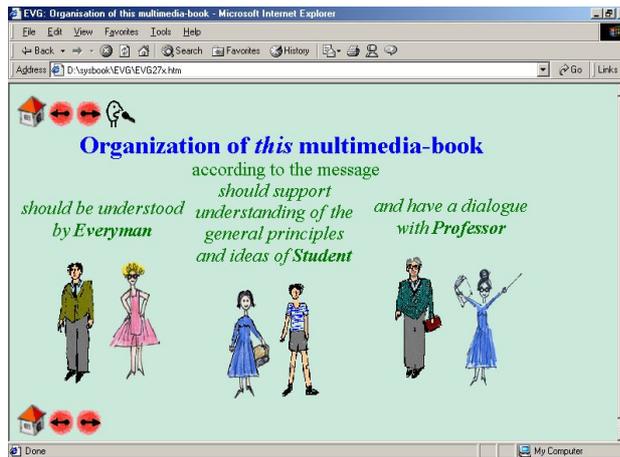
**Intelligent discrete process control and diagnosis** methods apply discrete event system models. Based on our experience in coloured Petri net models, the aim is to find efficient methods and algorithms for automatic generation, verification and hierarchical decomposition of operating (control), safety, diagnostic and maintenance scheduling procedures for process systems. The underlying engineering knowledge is expressed in terms of discrete event dynamic process models.

<http://www.sztaki.hu/sci>

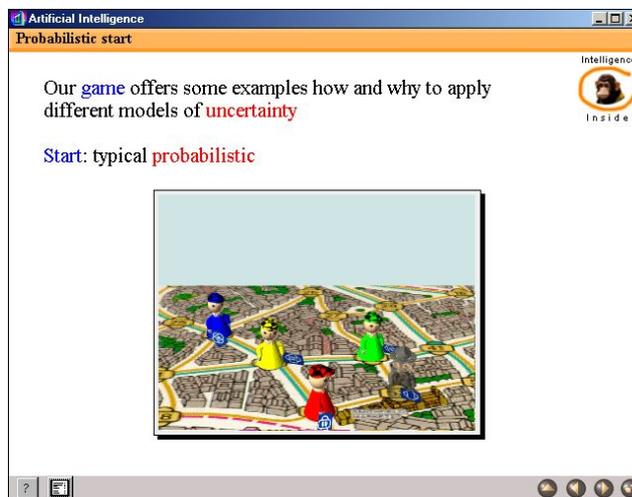


-----> **ARTIFICIAL INTELLIGENCE**

The ongoing project, in cooperation with the Systems and Control Laboratory, endeavours the ambitious objective of creating a new scope of system science. Basic philosophical- mathematical and practical engineering aspects are represented on three levels, the same for scientists, students and for everyman. A resulting multimedia CD is under development; the first demonstration was in 1996, San Francisco, and a full plenary demonstration in 1999, Beijing.



The system science multimedia is, in some respect, based on the experience gained through a CD course on Artificial Intelligence. The CD in question explains all the basic ideas and methods of Artificial Intelligence by the Scotland Yard logical game



As a special subject in Artificial Intelligence, data mining with fuzzy signature has emerged. Signature is a string of fuzzy estimates, each local value has a semantic meaning as a part of situation, diagnosis description. Several brute force clustering methods were elaborated for data mining in large-scale diagnostic databases. The first successful experiments were done on the 300 Mbyte database of the group's earlier expert system efforts. The database contains a quarter of a century diagnostic data on a method developed by Prof. Ferenc Katona (Paediatric Institute of Svábhegy) for early diagnosis and habilitation of babies born with some defects of the central neural system.



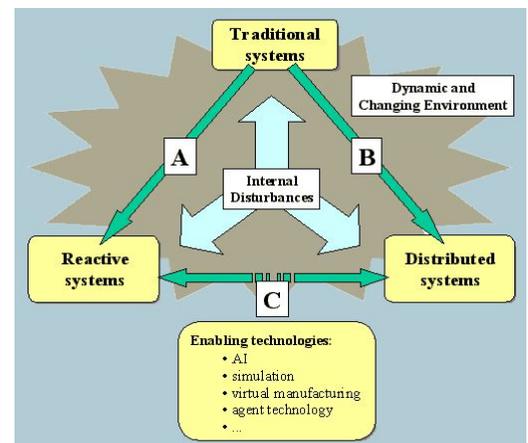
## -----> ENGINEERING AND MANAGEMENT INTELLIGENCE

**Goal:** Research and elaboration of techniques applicable for handling *complex* production and business systems working in *uncertain, changing* environments, with special emphasis on *artificial intelligence* and *machine learning* approaches. Simultaneously: development of models for intelligent behaviour and problem solving in different application fields.

Selected projects in the field of intelligent manufacturing and business processes

**Constraint-based computer-aided manufacturing process planning (CAPP):** Manufacturing process planning is modelled as being a large-scale *constrained optimisation problem*. The model captures several kinds of constraints relevant in manufacturing. The planner that has been built on the top of a general-purpose constraint programming system can cope with conditional and antagonistic constraints as well.

**Modelling, control, simulation and optimisation of processes and process chains:** Significant results were achieved in modelling, control and monitoring of manufacturing processes by using *ANN, fuzzy, and hybrid AI* approaches. A block-oriented framework for modelling and optimising process chains was also introduced, and its applicability was shown by the optimisation results of cutting processes. It was demonstrated how the framework can support the simulation-based optimisation of whole production plants.



**Multi-agent order processing and scheduling:** A multi-agent model was developed for solving integrated order processing and dynamic production scheduling problems. The model is based on the economic rationality of individual agents, though, by the application of a special incentive mechanism, reconciles autonomous and co-operative behaviour, paving the way toward so-called *holonic manufacturing systems*. Also the adaptive behaviour of holons (agents) are investigated within a simulation framework for distributed manufacturing. An integrated order selection and resource allocation model was developed where production-balancing is solved by a reinforcement learning mechanism. Efforts are made to extend the approaches to *environmental benign production* and to the level of *production networks*.

**Fraud detection and analysis:** In response to an initiative of a number of major banks in Hungary, problems of *detecting and subduing bankcard fraud* were investigated. While protecting the secrecy of business and personal data, the proposed methods integrate reasoning efforts over distinct data sources and adapt to changing behavioural patterns. The concept of software agents provided practical guidelines for designing a fraud watch system.

For the list of recent publications and further information on the above and other projects, mostly run in the frame of national and international consortia, visit:

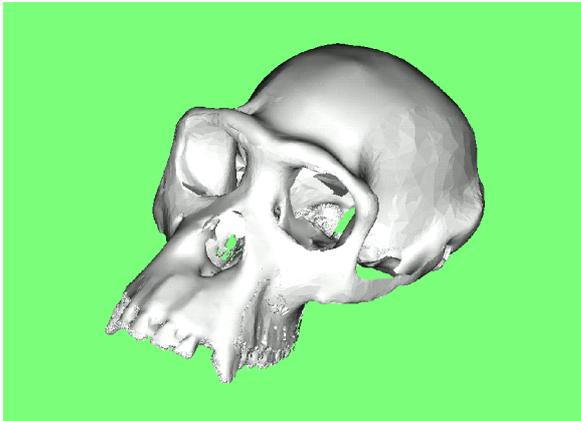
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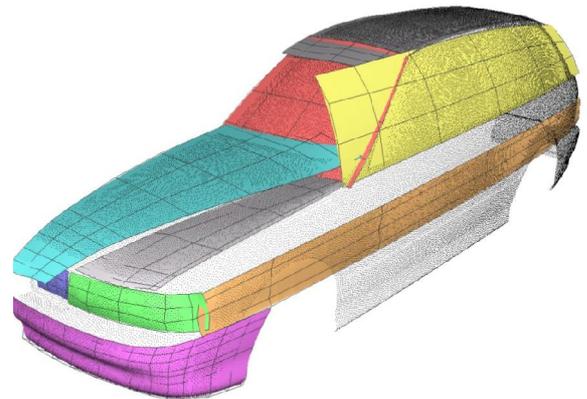
-----> **GEOMETRIC MODELLING**

The problems of *Computer Aided Geometric Design* of complex surfaces and solid objects have been investigated for more than two decades. The research and development activity of Geometric Modelling Laboratory includes various projects concerning styling, computer representations, geometric algorithms, graphic visualisation and several industrial applications. Research is highlighted by a large number of publications and many Ph.D. theses; as to international reputation: visit [www.sztaki.hu/gml](http://www.sztaki.hu/gml). General motivation, besides research, is to utilise theoretical results in industry. Successful applications: our algorithms were integrated into commercial CAD/CAM systems both in Europe and the United States; visit the web-page of GML's spin-off company Cadmus Consulting and Development Ltd.: [www.cadmus.hu](http://www.cadmus.hu).



Past five years' research: focused on *Reverse Engineering shapes*. There are many areas of engineering, medical sciences or art where an appropriate computer representation of existing objects needs to be created from huge sets of measured data points. Typical applications include reproducing parts, when no original drawings or documentation are available, but analysis and modifications are required to construct new improved products. Another important area is to generate personalised fits to human surfaces for custom parts such as helmets, or prostheses.

Important results are achieved in reverse engineering including data capture, merging multiple point clouds, creating and decimating triangular meshes, segmenting point clouds, fitting surfaces, building and "beautifying" boundary representation models. The most significant: the segmentation of point clouds, i.e., separating subsets of points from each other according to their fundamental geometric or functional properties. Two new segmentation paradigms - *functional decomposition* and *direct segmentation* - have been developed to handle free-form and conventional engineering objects, respectively, together with important algorithms for the efficient approximation of free-form surfaces, blends and swept feature surfaces. A new concept *constrained fitting* was elaborated to fit a set of surfaces simultaneously, while several geometric constraints, such as tangency, parallelism, orthogonality, concentricity are also satisfied.



[www.sztaki.hu/gml](http://www.sztaki.hu/gml)



-----> **COMPUTER INTEGRATED MANUFACTURING**

Long-standing R&D co-operation has evolved with Hungarian (e.g. Technical University of Budapest and Miskolc University) and foreign universities and research institutes (as in Korea, Japan, Mexico, Italy, Germany). This wide international co-operation directed us towards joint European research projects with prestigious academic and industrial partners. Fields: keeping the “traditional” design and control tasks of manufacturing automation, and turning towards intelligent manufacturing applications, virtual/extended enterprises and www network applications. Focus: handling the management, design and operation of manufacturing systems together in an integrated way. Results are verified at industrial sites, are then published in journals and at conferences of important international organisations, as IFAC, IFIP, IEEE, etc. Research is designing, simulation, scheduling, real-time control, evaluation and quality control of flexible manufacturing cells (FMC) and systems (FMS). Some projects are completed successfully (e.g. WHALES) and some national (Film-saver, Digital factory) and international projects (e.g. BIDMED, REDEST, XPERTS and Akita) have started recently.

Some basic, joint characteristics of our R&D projects:

- Object-oriented design methodologies and software reuse were applied in CORBA environment for the modelling and simulation system and in the CNC control system for the OSACA EU project. Virtual enterprises are typical in our EU projects with the acronyms: PLENT, FLUENT and WHALES. In the EU 5<sup>th</sup> Framework project of WHALES, the goal is the web-based management of complex, high-volume, expensive projects of big, powerful, distributed, complex enterprises. The REDEST project deals with management of requirement gathering and analysis, while the BIDMED project solves the computer assisted management of co-operative bidding in the medical sector. By joining the XPERTS running EU project we have a chance to deal with intelligent/knowledge based machine tool design.
- Being members in the EU networks of ICIMS-NOE, AMETMAS-NOE, SIM-SERV and NEURON, we cooperate with 35-40 research and industrial firms in robotics, simulation and virtual/real enterprises on their design and management issues.
- In the project with Paks Nuclear Power Plant (Hungary) the knowledge server technology was used to assist the substation operators and engineers by designing and implementing a multi-function Decision Support System.



-----> **COMPUTER SCIENCE**

The widespread use of high performance electronic computers has led to several new research directions on the common frontiers of mathematics and theoretical computer science: the study of the algorithmic aspects of mathematical structures and theories. The results have a wide range of applications from symbolic computation to general data processing tasks. Our activities reflect this diversity. The main research themes are as follows:

- Development of symbolic computational tools to explore the structure of algebras (associative and Lie), group representations and related objects, which have theoretical performance guarantees and, at the same time, can be implemented efficiently on a symbolic computational platform. Some of our methods are already available as GAP functions.
- The study of the applications of algebraic methods to various problems in discrete mathematics, a highlight being the construction of norm graphs, which exhibit advantageous properties related to certain extremal combinatorial questions.
- In nonparametric statistics, investigations pertaining to theoretical and practical problems related to the universal prediction paradigm. Recent past results include methods for the piecewise linear estimations of density functions and the strongly consistent nonparametric estimations of smooth regression functions.
- Study of the relational database model and its extensions with the aim of easily understandable and theoretically well-founded data models. This endeavour includes investigations of relational dependencies, and possible extensions of the traditional relational model. The model underlines that certain problems related to dependencies can be studied quite independently of the attributes we adjoin to the scheme. It leaves for further study the problem of selecting a "good" collection of attributes.
- Research into the data mining aspects of the Internet, one of the principal objectives being an analysis of the link structure of the .hu domain. This may provide the foundational work for a good search engine of the Hungarian web pages.
- Study of edge augmentation, a class of network design problems where one wants to improve various connectivity properties of a network by adding the minimum number of edges (i.e. links, connections, etc.). Recently, a new algorithm for undirected edge connectivity augmentation has been developed.
- Problems of discrete and computational geometry pertaining to visualization of (scientific and engineering) information. Various extremal problems in the area, including illumination systems for families of convex bodies, protecting polygons and Newton numbers for overlapping circular discs have been studied.

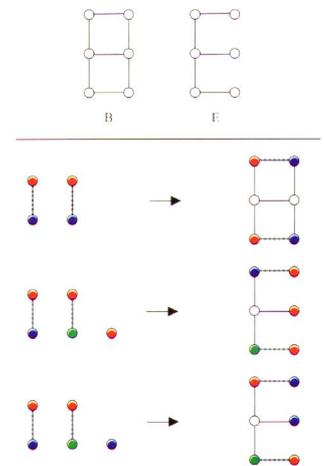
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## -----> DISCRETE STRUCTURES

The research areas cover a wide range of theoretical and applied combinatorial problems. We continue the traditional directions of the Hungarian School (such as Ramsey Theory, Graph Coloring, Extremal Theory of Graphs and Hypergraphs, Combinatorial Information Theory) initiated by Erdős and Rényi. The motivations of many problems come from Communication Networks, Optimal Code constructions, Searching, On-line algorithms.

Most important long-term cooperations: with University of Memphis and with Carnegie Mellon University. Joint papers: with prominent scientists, e.g., N. Alon, R. Ahlswede, A. Frieze, R. Faudree, Z. Füredi, D. Kleitman and legendary late Paul Erdős who often visited us.



[www.sztaki.hu/sztaki/ake/applmath/discrete](http://www.sztaki.hu/sztaki/ake/applmath/discrete)

## -----> COMBINATORIAL COMPUTER SCIENCE

Aim: achievement of research results in various fields by combining methods of combinatorics, computer science and other areas. Though the goal is to do theoretical research, many of the questions studied are motivated by practical problems.

Wide range of published results: in graph theory (vertex and edge coloring, perfect graphs, independent sets, decompositions, clique cover, Ramsey theory, graph domination, maximum cuts, random graphs, tournaments, edge labelings), communication networks (routing, diameter, path systems), hypergraph theory (extremal problems, packing and covering, Helly property, Steiner systems, mixed hypergraphs), theoretical computer science (complexity of algorithms, Boolean functions, formal languages, approximation algorithms), operations research (scheduling, bin packing, on-line algorithms), algebra (polynomial identities over matrix rings), algebraic logic (representations, axiomatizability), process control (control structure selection, model simplification), and theoretical biology (formal models of cell division).

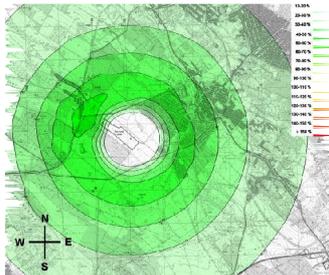
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-----> **OPERATIONS RESEARCH AND DECISION SYSTEMS**

**Operations Research** activity comprises optimisation theory, specifically in global-, linear and quadratic-, smooth optimisation; analysis of stochastic, furthermore, deterministic systems, and resulted in almost 50, real-life applications, through our projects, during the past 10 years.

**Decision systems:** multi-attribute group decision making, applications of operations research and mathematical physics.

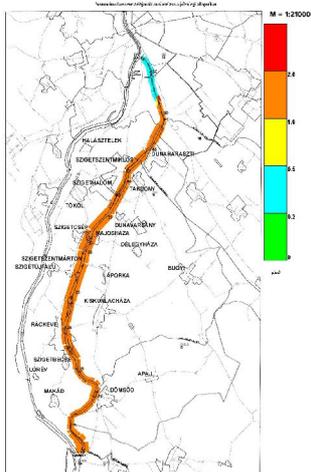


**WINGDSS - Windows based Group Decision Support System - a new methodology and a software product**

WINGDSS - with visualisation tools - supports multi-attribute decision making, providing flexibility for setting up the problems: the determination of the attributes, statement of the alternatives and the decision makers, then for solving the decision model through the built up attribute tree, assigning the voting powers to the decision makers, weighting the attributes and evaluating the alternatives with respect to the attributes by the decision makers, and for aggregating

the results of the individual decision phase into a group decision. A powerful sensitivity analysis accomplishes the job.

WINGDSS served as a reliable software tool in tender evaluations for several companies and governmental institutions, e.g., the Prime Minister's Office and the Ministry of Economic Affairs, in environmental impact assessments and in evaluating the strategies for environmental and regional planning.



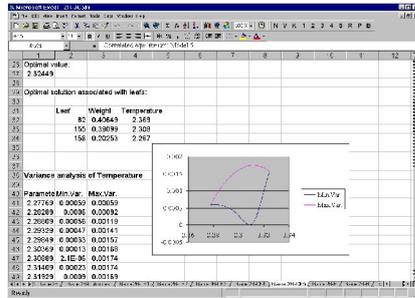
**Environmental Modelling**

Main objective is modelling the transmission of pollutants in the **air** (based on the Hungarian Standards), in the **surface** and **ground water**. Effects, emission by point-sources (stacks), linear and surface sources - even several of them - in the air are examined by our software, APT. *Calculations* are done for continuous and instantaneous emissions - short and long averaging times; regarding environmental mishaps causing many sorts of pollutants (e.g. cyanide) in the surface and ground water. Digital maps take the relief into account. The results are provided numerically and visualised by image files and mappings.

*Some references:* General Electric Ltd., MOM Park, Dunamenti Power Station, a waste battery recycling firm and a composting plant.

Although the recent technologies are extremely safe, one should not disregard possible malfunctions. The damage of the water-proofing system may cause environmental mishaps: pollutants may penetrate into the soil and ground water. For managing the unexpected events, the consequences must be forecasted. *Some references:* Regional waste-material depositories in Gyál and Szigetszentmiklós, Ráckeve-Soroksár river branch of the Danube, a sewage sludge composting plant at Dunaharaszti, an active aluminium dross depository of a foundry, etc.

**SIADCERO – Strategic Integrated Assessment of Dynamic Carbon Emission Reduction Policies - an EU project**



The main goal of *SIADCERO* is to analyse the strategic interests and policy options of the EU in international negotiations on climate change. In co-operation with the Budapest University of Economic Sciences and Public Administration and research institutes from Europe - among other models - dynamic-sequential ones of game

theory have been established. An Excel add-in for the computation with the appropriate game theoretic models, tree-correlated equilibrium, the Nash bargaining and the Kalai-Smorodinsky models was developed.

<http://www.oplab.sztaki.hu/>

-----> **STOCHASTIC SYSTEMS AND FINANCIAL MATHEMATICS**

The focus in research is on the analysis of options on discrete-time financial markets with transaction costs. A new technique has been developed by which the seller of the option can decide whether an initial endowment is sufficient to hedge against the given contingent claim. Extension to quintile hedging, (i.e. the replication of the claim is required with, say 95%) is under progress.

The daily returns of some of the most liquid shares traded on the Budapest Stock Exchange are analyzed by using heavy-tailed distributions, such as NIG (normal inverse Gauss), particularly suitable for modelling the tick by tick dynamics of the process.

Hidden Markov-models (HMM) is a flexible and rich class of stochastic systems and is a hot area in communication, control and finance. Considerable progress has been made in transferring the technology of linear stochastic systems. We are active in developing computational methods for Hidden-Markov models by using Markov Monte-Carlo techniques. The analysis of widely accepted stochastic volatility models is our current interest. Emerging research area: modelling the behaviour of market players.

<http://www.sztaki.hu/sztaki/ake/applmath/stoch/>



## -----> **NONLINEAR SYSTEMS**

Research is conducted in the area of nonlinear phenomena. The models arise from diverse fields of applications such as heat transfer, combustion, reaction chemistry, flow through porous media, plasma physics, soil-moisture physics, population genetics, neurology, to name but a few.

- In general, the models consist of nonlinear evolution equations and systems of equations like there. Main issues: Self-similar solutions and their intermediate asymptotic character.
- Travelling wave solutions and stability of general processes.
- Study of the arising free boundaries (fronts, interfaces) which separate domains with different properties.

Past and present collaboration with different universities and research institutes, in particular of Rome, Madrid, Tel Aviv, Bath, Amiens, Orsay, Moscow and Leiden.



<http://www.sztaki.hu/scl/members/kersner.htm>

## -----> **CLUSTER AND GRID COMPUTING**

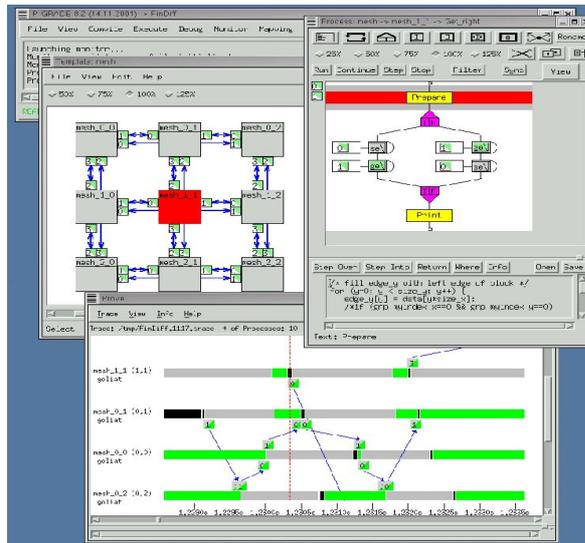
Research in distributed computing aimed at realising a visual environment for parallel programs, P-GRADE that supports the entire software life-cycle by graphical tools.

- visual tools may help researchers not especially familiar with parallel programming (e.g. physicists, chemists, biologists, meteorologists) but demanding computationally intensive applications.
- GRAPNEL hierarchical graphical programming language supports C/C++ and hides the details related to parallel execution and communication.
- GRED graphical editor fully supports the features of GRAPNEL with all the functions usually found in graphical environments.
- DIWIDE debugger for the systematic debugging of parallel programs at instruction, graphical block and macro step level.
- PROVE performance analyser for monitoring and visualising execution.
- P-GRADE supports the most common environments, e.g., SGI MIPS/IRIX, Sun UltraSparc/Solaris, Intel/Linux, Cray T3E/UNICOS, Hitachi SR2201/HI-UX/MPP.



P-GRADE is installed on clusters and supercomputers in numerous countries world-wide and helped, e.g., with the parallelisation of a meteorological application.

- Future development of P-GRADE includes the introduction of automatic checkpointing, task migration, load balancing and fault tolerance.



The grid is a new paradigm. It is a geographically distributed hardware and software infrastructure that allows large-scale resource sharing and thus, supports novel applications, as well as solving computationally intensive problems. Main research themes include:

- Grid monitoring for supporting a new generation of scientific research by providing a shared access to extremely large databases of size from a few hundred Terabytes to the magnitude of Petabytes (DataGrid project of the EU).
- Development of monitoring and information services for the Grid Application Toolkit in the framework of GridLab project aiming at the simultaneous development of the infrastructure and the applications for real large-scale scientific computations in interdisciplinary fields.
- Automatic performance analysis both for supercomputers and grids (APART-2: Automatic Performance Analysis: Real Tools sponsored by the European Union).
- Integration of the heterogeneous systems of eight Hungarian universities and research institutes and creation of a metacomputing environment on the top of this platform - realisation of a virtual supercomputer and the demonstration of its power by solving real scientific problems.

<http://www.lpds.sztaki.hu>

-----> **DISTRIBUTED SYSTEMS**

Primary aim: R&D of distributed computer applications including World Wide Web information services, groupware and digital library systems. Other activities: scientific and technical visualizations, digital art.

We are a major partner in developments of Hungarian E-governmental services. Building and maintaining World Wide Web services for the Prime Minister's Office and the web site of the Hungarian Government. Several groupware software solutions and services such as voting, rating, web-based group discussion and communication software, workflow, groupcalendar, project management tools are developed.

Distributed Systems Department involved in EU supported international projects:

- Web4Groups (TAP RE 1010): Transfer of Knowledge between Research, Education, Business and Public Administration through the World Wide Web
- DELOS (ESPRIT LTR No. 21057): Digital Library project
- SELECT (TAP RE 4008): Rating and Filtering of Scientific, Technical and other Network Documents.
- KNIXMAS (INCO): Knowledge Shared XPS-based Research Network Using Multi-Agent Systems
- DELOS Network of Excellence on Digital Libraries (IST-1999-12262)
- EUTIST-AMI (IST-2000-28221) European Take-Up of Essential Information Society Technologies - Agents and Middleware
- GeneSys (IST-2001-34162) Generic Systems Supervision
- StreamOnTheFly (IST-2001-32226) Personalised Community Radio Program with Collaborative Filtering Agents and Bandwidth Sensitive Streaming
- PublicVoiceXML (IST-2001-34546) VoiceXML Trial for an Open Source Reference Implementation
- CORES (IST-2001-35273) A Forum on Shared Metadata Vocabularies

Future projects: target the problems of group-cooperation and communication between the civil sphere and the public authorities.

Several, publicly available and free web services are provided by Distributed Systems e.g. SZTAKI voting ([www.sztaki.hu/voting](http://www.sztaki.hu/voting)) and rating services ([www.sztaki.hu/SELECT](http://www.sztaki.hu/SELECT)), on-line vocabularies for different languages ([szotar.sztaki.hu](http://szotar.sztaki.hu)).



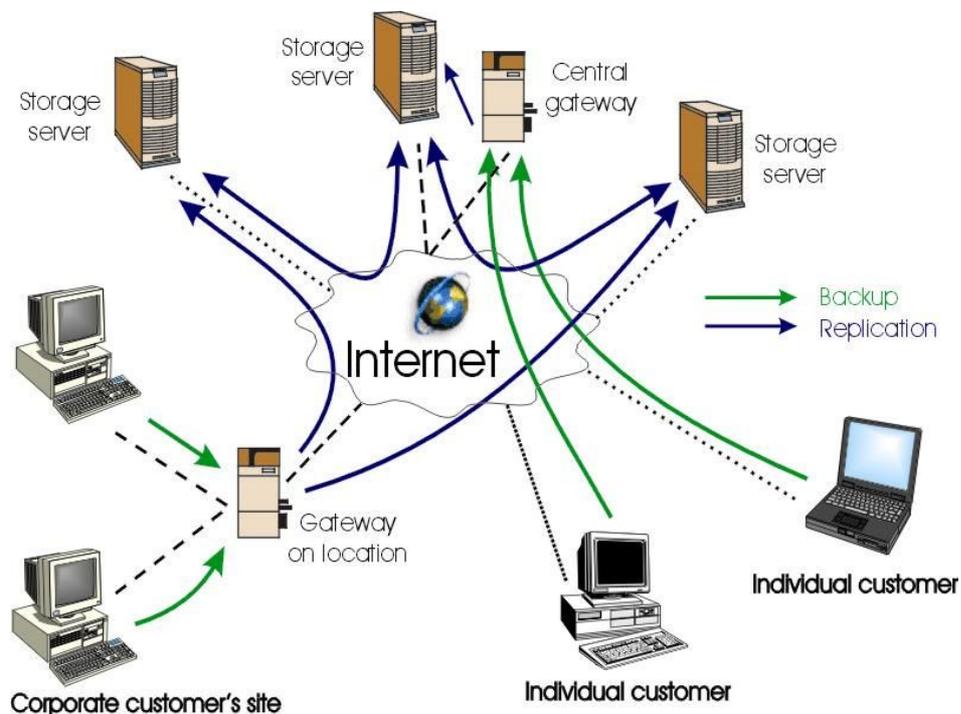
<http://www.sztaki.hu/dsd>

-----> **DATA STORAGE AND PROTECTION**

Resulting from the widespread use of information technology, information stored on computers is of considerable value. Unfortunately, not even modern hardware is exempt from faulty operation, and consequent data loss, but in addition, malicious attacks and environmental disasters threaten valuable data. Regular and frequent backup of stored data is a must. While storing and protecting data against physical losses, some other aspects have to be considered as well:

- unauthorized access to the data must be prevented during network transfers, as well as during storage in the service provider's system;
- the data must be unambiguously associated with the customer, time of delivery etc., to have the proof of these parameters in case of an argument or legal action;
- the security of data must be ensured even in case of a natural/technical disaster or human failure at the service provider.

Experts from the SZTAKI develop a service that solves the problem outlined above. There are some new technical, administrative and legal features that support this endeavour, such as the use of electronic signature. The system regularly forwards the files to be protected via a wide area computer network (usually the Internet), to be physically stored at more than one geographic location. The data validity and security are guaranteed during the whole process. The reliability of the system can be so high that the service provider should be able to offer financial responsibility on the stored data.



<http://www.sztaki.hu/ikk>



-----> **ADVANCED NETWORKING TECHNOLOGY AND APPLICATIONS**

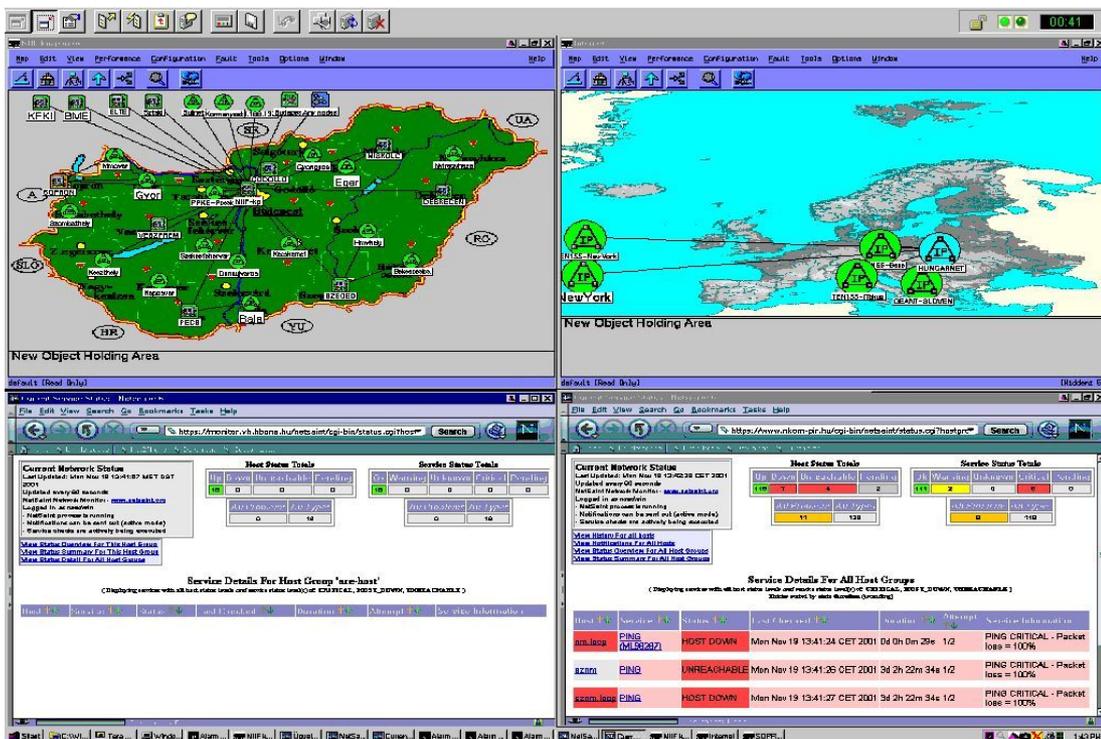
Infrastructure deployment is regarded the key area of our development, either as part of consultancy or as participation in international projects such as PHARE, Europanet, TEN-34, Quantum or GEANT, and in the development of the first generation of high-speed research network in 1999.

Recent activity concentrates on the introduction of advanced network technologies in the high-speed research network. In 2000 the research network was upgraded and multiprotocol label switching (MPLS) was introduced first in a test environment, later as a production service. In 2001 MPLS based virtual private networks were introduced at a large-scale. A novel environment was created for managing virtual networks, including a virtual network management service, comprising trouble ticketing, performance measurements, reporting, deployment and related fields.

The introduction of IP based multicast service in the MPLS environment is a recent development. In December 2001 the nation-wide gigabit network was established with leading edge technologies.

Key development in 2002: the new access network is a challenge to maximize the access capacity in rural areas. In the long run the project leads to the integration of the research backbone and school networks.

Another technology area to be addressed is Internet Telephony. A nation-wide voice service is planned, in co-operation with NIIF (National Information Infrastructure Development Programme) (Voice liberalisation started in December 2001).



The network operator's view of the managed systems

-----> **INTERNET TECHNOLOGIES AND APPLICATIONS**

The main departmental ambition is to find real life applications for the most up-to-date networking and web technologies.

On-line information services

Co-operation with OpenText Co.: a special **on-line information service** technology was developed, which is based on a professional textual database management system, **BRS/SEARCH**, and its extension for the World Wide Web, **NetAnswer**. The technology is especially suitable for handling large databases containing primarily textual information. It is used for the **National Information Infrastructure Development Programme**, serving several hundreds of institutions and hundreds of thousand end-users all over Hungary. Visit: <http://www.iif.hu/db/>

The same technology was applied for the WEB-site, called **Hungarian Information House** <http://infohaz.euroweb.hu/> a joint venture with EuroWeb Rt.

- **Cégjegyzék Online** (English terminology: The Hungarian Firms Registry) database contains the most important data of the approximately 600,000 firms registered in Hungary. A unique service, **Bankruptcy Watch Online**, was also developed.
- The **Idegenforgalmi Kalauz** (in English: The Hungarian Tourists' Guide) is a rich source of information about accommodation facilities in Hungary, hotels, guest-houses, camping sites, catering sites, Hungarian travel agencies and other tourism-related services such as banks, filling stations, theatres etc. Visit: <http://infohaz.euroweb.hu/compalm/compalma.htm>

Book trade on the Internet

"Könyvkereső" (in English: Bookfinder) is an extremely useful tool for those chasing for a particular book, as the database contains information about more than 65.000 books in Hungarian, and more than 5000 Hungarian publishing companies, wholesale dealers and bookstores.

Visit: Könyvkereső at <http://www.bookfinder.hu/>

On line gambling

Charged by the Hungarian state owned company, Szerencsejáték Rt. (in English: National Gambling Company), we have designed and developed the official Web site of the company: [www.szerencsejatek.hu](http://www.szerencsejatek.hu). The site makes betting possible on the most popular games organised by the company, such as toto, lotto, tippmix, etc.

Distance education

This application was developed in charge of the Ministry of Education. It is a large collection of rearrangement problems and solutions in elementary geometry targeted especially for high-school students. Visit: <http://www.sulinet.hu/tananyag/97407/on/GEOM/>

Market Research

Design and development: (co-operation with a Seattle based E-business company (Global Market Insite), a huge software application to support Web based market research.

Visit: <http://www.gmi-mr.com/>

-----> **COMMERCIAL VEHICLE FLEET MANAGEMENT SYSTEM**

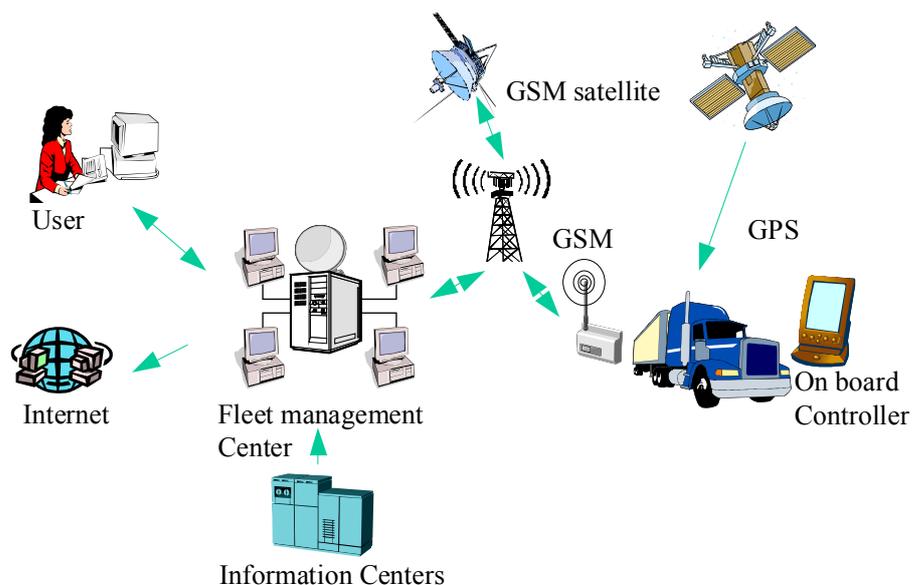
The main objectives of the project are the elaboration of

- the theory and methods of intelligent supervision, control and communication systems installed on vehicles,
- an associated information service system for fleet management.

The development of the information service as part of the fleet management system that collects, analyses and evaluates data sent by individual vehicles, extends the utility of the installed vehicle systems and represents a significant added value to its application.

This system integrates the capabilities of recent mobile telecommunication and the sensory and data measurement systems on the vehicle into a unified framework and has the feature of maintaining a permanent communication among the data acquisition and control modules allocated on the vehicles of transportation companies. It can also supervise and control the transportation processes, assist the driver in decision making, support the co-ordination of transport activities, and provides an information database for all participants possessing the particular unit on the vehicle. An illustration of the system to be developed is shown in the figure.

**Members of the consortium:** MTA SZTAKI, KNORR-BREMSE Research and Development Center, the following Departments of the Budapest University of Technology and Economics (BME): Traffic Automation; Transport Technology; Automobile Engineering; Photogrammetry and Geoinformatics; Highway and Railway Engineering, furthermore, the General Directorate for Public Security, Hungarian National Police. The project co-ordinator is Prof. József Bokor, Academician, Scientific Deputy Director (MTA SZTAKI).





## -----> DIGITAL TECHNIQUES FOR THE RESTORATION OF MOVIE-FILMS

The subject of the project is to design and implement a system and a work-station for restoring motion pictures, suitable for total, high resolution digital restoration. The system will be able to restore the images and volume of sound, especially of distorted nitro-celluloid films, onto available safe films, preserving them this way for archives. Our elaboration is based on a complex, intelligent, self-learning-based mechanism, combined analogue-digital, perception-calculation-estimation-correction process.

*Basic research:* elaboration of new, predictive methods for evaluating the images on frames succeeding each other; elaboration of appropriate statistical means; and an adaptive method for remaking or replacing missing frames or parts.

*Applied research:* elimination of noise and scratches; correction of non-linear and linear deformations; correction of the continuity of contours; continuous evaluation of the contrast and colour parameters of a series of frames; emphasizing individual filtering of colours; correction of colours, setting their brightness.

*Expected result:* development of an intelligent and highly powerful work-station with dedicated periphery, capable to restore archive films in real time, damaged both in their physical condition and informational content, and to save them on film material. Mathematical methods, image processing algorithms that can be useful in other, e.g., medical, biological, chemical, military, etc. fields, will also be considered as significant results.

**Members of the consortium:** MTA SZTAKI, Hungarian National Film Archive, University of Veszprém (VE), Cortex Technical R&D Ltd. The project co-ordinator is Prof. György Kovács (MTA SZTAKI).





-----> **DIGITAL ENTERPRISES, PRODUCTION NETWORKS**



Production systems operate in *changing, uncertain* environments. *Increasing complexity* is the other characteristics, which is manifested in production processes, systems and enterprise structures.

The concept of the *digital enterprise*, i.e., the mapping of all the important elements of the enterprise processes by means of IT provides a unique way for managing these problems. The project partners form a well-balanced industry-academia consortium where a large manufacturing and a small-medium information technology enterprise, as well as the research community of two universities and the Academy are all represented. They want to make progress in the following - partly overlapping - directions:

- management and scheduling of large-scale projects,
- tele-presence and interactive multimedia,
- monitoring of complex production structures.

The main goal of the project is to make all the important production-related information available and manageable in a controlled, user-dependent way by the efficient application of information and communication technologies. The development and application of intelligent decision support systems will help enterprises to cope with the problems of uncertainty and complexity, increase their efficiency, join in production networks and to improve the scope and quality of their customer relationship management.

**Members of the consortium:** MTA SZTAKI, the Budapest University of Technology and Economics, (BME), University of Miskolc, (ME), GE Hungary, MT System Ltd. The project co-ordinator is Prof. László Monostori, Deputy Director, Research (MTA SZTAKI).



-----> **SENSING COMPUTERS AND TELEPRESENCE**

The program - in a new wave of information technology - is based on Hungarian, multi-disciplinary research results successful and significant internationally. The program aims at establishing the basis of new products and services generally important for the society. It is defined to be on the new frontiers of electronics, computer science and telecommunication, partially in the field of artificial and biological information processing.

The scientific and technological fundamentals of the program are analogical spatio-temporal sensory computers (a revolutionarily new computer concept), programmable sensor arrays sensing in different modalities (visual, tactile, auditory, olfactory, etc.), multi-modal sensing, complex event detection in visual, auditory and tactile scenes, mobile and combined telecommunication networks and services, and diagnostics in echocardiology.

One of the sample application areas is the ultrasound-based heart diagnosis where a system with on-line 3D reconstruction, real-time 2D morphological and motion tracking capabilities will be designed. With the envisioned innovations the planning in heart surgery and also the efficiency of routine heart examinations will be significantly enhanced.

The engineering result of the other key area will be a multi-modal sensing computer that, in different modular configurations, could be used as a system for in- and outdoor security/surveillance, industrial quality control or biometrics based recognition combined with telepresence capabilities. Typical products in these areas could be: blind helper *bionic eyeglasses* identifying certain objects and movements, and home *watcher-tackers* with seeing, sniffing, hearing and mobile communication capabilities.

**Members of the consortium:** MTA SZTAKI, Jedlik Laboratory of Péter Pázmány Catholic University, Research Institute for Technical Physics and Materials Science of HAS, Neurobiology Research Unit at Semmelweis Medical University, Research Institute of Psychology of HAS, Saint Francis Hospital, György Gottsegen Hungarian Institute of Cardiology, Center for Paediatric Cardiology, AnaLogic Computers Ltd., IT Consult Pro Inc., GE Medicor Inc. The project co-ordinator is Dr. Csaba Rekeczky (MTA SZTAKI).



-----> **KNOWLEDGE-INTENSIVE INFORMATION TECHNOLOGY  
FOR THE SAFE AND OPTIMAL OPERATION OF  
COMPLEX INDUSTRIAL SYSTEMS**

The three-year R&D project will result in a novel information technology applicable in large and complex industrial systems for process parameter monitoring, early detection and diagnosis of equipment and technology faults, as well as for the fast detection of malfunction roots. Operation support related to the optimal operation of process devices is offered. The system provides user-friendly and efficient interactive tools for storing technology-related knowledge, on-line modelling of process phenomena, visualisation of diagnostics information and for the on-line displaying of advisory documentation.

In its final form the knowledge-intensive information technology will constitute a general-purpose, open architecture software shell. Through the application of the system, significant improvement is expected in the safety of industrial systems.

**Members of the consortium:** MTA SZTAKI, Atomic Energy Research Institute, Hungarian Academy of Sciences (MTA KFKI), Department of Control Engineering and Information Technology, and the Department of Measurement and Information Systems of the Budapest University of Technology and Economics, (BME), Paks Nuclear Power Plant Ltd., and MOL Hungarian Oil and Gas Plc. The project co-ordinator is Dr. Péter Inzelt, Director (MTA SZTAKI).



-----> **DEMAND-DRIVEN INFORMATION TOOLS AND SYSTEMS OF INFORMATION SOCIETY**

One of the first decisive steps on the way towards information society is the Act on digital signatures, which, however, only creates the legal framework for the introduction of electronic public administration. A theoretical - and subsequent - experimental model of electronic public administration is offered by the project in which all the important functions of a town/region are embraced. The new public administration model is based on the use of advanced mathematical and computer science tools (database theory, reengineering, decision support, artificial intelligence) along with a concept devoted to the continuation of the process marked by the legislation of electronic signature and leading to further developments in public administration (electronic administration, electronic public documents).

Special attention is paid to human aspects, demand-oriented services, the interrelationship of information society and demands, the possibilities of services related to the quality of living and the equality of chances, regional issues (e.g. remote teaching, atypical employment, EU-requirements), with legal aspects also playing an essential part. This is an interdisciplinary project, in which public administration experts, sociologists, legal consultants, and experts in mathematical modelling, decision support, artificial intelligence, reengineering, and information technology take part.

As one of its main features, the completion of the project will be marked by the implementation of an operating model system in town Kaposvár, with the active co-operation of the municipal government. MATÁV, as member of the project consortium, will be taking part in developing new technologies, and content provision.

**Members of the consortium:** Budapest University of Economic Sciences and Public Administration (BKÁE), MTA SZTAKI, Municipality of Kaposvár, MATÁV. The project co-ordinator is Prof. Attila Chikán (BKÁE).

-----> **INFORMATION SECURITY TECHNOLOGY AND DATA INSURANCE**

The primary aim of the project is to lay the foundation of an information technology risk management and data insurance system. As the value assessment in data insurance greatly differs from the evaluation of other properties, an objective information technology value determination methodology is a vitally important research area.

The Information Security Technology (ISyS<sup>®</sup>) to be created by this project shall provide the basis for a homogenous, simple and organized IT infrastructure, upon which we can start planning the introduction of procedures that can guarantee a higher level of information technology infrastructure security in the future.

Based on their vast experience in data recovery, KÜRT ([www.kurt.hu](http://www.kurt.hu)) have gathered a large amount of information about information technology catastrophes and the reasons of data loss. This reservoir of knowledge has not been analyzed scientifically yet.

In cooperation with MTA SZTAKI and the Department of Mathematics and Computing at the University of Veszprém, we intend to determine the factors constituting an information technology threat for companies or organisations. The project co-ordinator is Sándor Kürti.