CENTER FOR
MACHINE PERCEPTION

CZECH TECHNICAL
UNIVERSITY

ACTIVITY REPORT

Center for Machine Perception ACTIVITY REPORT 1998

Václav Hlaváč, head of the CMP
Jiří (George) Matas, editor

{hlavac,matas}@cmp.felk.cvut.cz

№ K335/98/175

October 18, 1999
version 2.0

Available at
ftp://cmp.felk.cvut.cz/pub/cmp/articles/activity_report98.ps.gz

Center for Machine Perception, Department of Cybernetics
Faculty of Electrical Engineering, Czech Technical University
Karlovo náměstí 13, 121 35 Prague 2, Czech Republic
fax +420 2 2435 7385, phone +420 2 2435 7465, www: http://cmp.felk.cvut.cz

1 Executive summary

The Center for Machine Perception (abbreviated CMP) is a research unit active in the fields of computer vision, pattern recognition, and mathematical modeling of uncertainty. The CMP was established in August 1996 under the “Support of Research at Czech Universities” initiative of the Department of Education of the Czech Republic through a five year grant (No. VS96049). The CMP is a part of the Department of Control Engineering, Faculty of Electrical Engineering, Czech Technical University (CTU).

Current main CMP research interests lie in the following areas: reconstruction of 3D models from range images (Pajdla, Hlaváč, Krsek) or unorganised 3D points (Šára, Zýka, Pajdla), stereo matching (Pajdla), physics-based vision (Šára, Drbohlav), design of a color-coded range finder (Smutný, Vydržel), representation of 3D scenes by a collection of 2D images (Werner, Pajdla, Hlaváč), reconstruction of scene from multiple images (Pajdla, Werner, Urban), panoramic vision (Pajdla, Svoboda), image compression (Hlaváč, Fojtík), quantum and fuzzy logic (Navara, Pták), Markov random field models for vision (Haindl), virtual reality models from real world scenes (Haindl), object recognition (Matas, Hlaváč). Summary of main **scientific results**:

computer vision We improved on our previous theoretical results concerning *image-based scene representation*. The difference between image based and model based approaches to visualization was further investigated [88]. An efficient algorithm for rendering a projective model was presented [85]. A new concept of oriented projective reconstruction [89] allows topologically unique reconstruction from uncalibrated cameras. T. Werner submitted his PhD on image-based visualization [86].

Four camera stereo rig to test the approach proposed by Sara in [63] has been built.

Epipolar geometry and egomotion estimation algorithm for *central panoramic cameras* was developed and presented [77, 58, 79]. Design and image formation for newly defined central panoramic cameras have been studied [76].

A robust planar face range data segmentation algorithm was proposed [25] with segmentation quality and speed of performance comparable to state-of-the-art algorithms.

A new multiresolution approximation of a Markov random field-based colour texture model was developed [21] for natural textures.

Interesting results have been obtained in the study of *topologies for image processing* [32].

mathematical modeling of uncertainty Characterizations of spaces of measures on quantum and fuzzy logics were generalized and submitted to refereed journals (Journal for Mathematical Analysis and Applications, International Journal of Theoretical Physics). A comparison of semantical strength of various fuzzy logics was given in [45]. A progress was made in the analysis of mathematical foundations of fuzzy controllers (publication accepted for CIMCA 1999).

consultancy The CMP performed **consultancy** (e.g. Rockwell Automation.) and **research and development** for the industry (e.g. Boeing, Hewlett-Packard, Air Force Technical Institute Prague, Czech Republic).

industrial applications. CMP expertise is channelled to the industry via Neovision, a spin-off company specialising in machine vision. For successful applications, see (`http://www.neovision.cz`)

More details about ongoing research at the CMP and recent **publications** can be found at

`http://cmp.felk.cvut.cz`

To see **demos** of our research results, visit

`http://cmp.felk.cvut.cz/cmp/cmp_demos.html`

2 The CMP Research Group

The CMP group is more than twenty members strong, comprising eleven members of academic and research staff (two part-time), ten PhD students, a group administrator and a system manager. In 1998, the academic and research staff was unchanged.
Václav Hlaváč became a full professor. T. Werner submitted his PhD. thesis.

Academic and Research Staff

Prof. Václav Hlaváč	head, professor
Prof. Pavel Pták, DrSc.	professor (part time)
Dr. Ing. Michal Haindl	lecturer (part time)
Dr. Ing. Mirko Navara	senior lecturer
Dr. Ing. Jiří (George) Matas	research fellow
Ing. Tomáš Pajdla	lecturer
Ing. Vladimír Smutný	lecturer
Dr. Ing. Radim Šára	research fellow
Ing. Tomáš Werner	research fellow
Ms. Eva Matysková	group administrator
Ing. Dan Večerka	system administrator

Doctoral students

	supervisor	proposed thesis title
Tomáš Svoboda	V. Hlaváč	Panoramic vision.
Vít Zýka	R. Šára	Shading consistency analysis for local shape modeling.
Pavel Krsek	V. Hlaváč	Differential surface characteristics and their use in creating 3D model from range images.
Martin Urban	V. Hlaváč	Image interpolation based on the trilinear relation among views.
Jan Vydržel	V. Hlaváč	Improving correspondence algorithms.
Jaroslav Fojtík	V. Hlaváč	Lossless image compression.
Ondřej Drbohlav	R. Šára	Physics-based surface features for computer vision.
Pavel Mrázek	M. Navara	Modeling uncertainty in image processing.
Jan Buriánek	V. Hlaváč	to be decided
Jan Černík	V. Hlaváč	to be decided
part time students		
Svatopluk Kraus	V. Hlaváč	Image analysis tools for precise optical measurement (gaging).

2.1 CMP Scientific Advisory Board

The role of the the CMP Scientific Advisory Board is to comment on CMP scientific goals and research results and to advise on future directions of research. The scientific advisory board consists of:

Prof. Ruzena Bajcsy	University of Pennsylvania, USA
Prof. Josef Kittler	University of Surrey, U.K.
Prof. Walter Kropatsch	Technical University Vienna, Austria
Prof. Jan Uhlíř	Dean of the Faculty of Electrical Engineering CTU Praha, Czech Rep.
Prof. Shimon Ullman	Weizmann Institute, Israel
Prof. Luc Van Gool	Catholic University Leuven, Belgium
Prof. Vladimír Mařík	Head of the Dept. of Control Engineering, CTU, Czech Rep.

3 Research

3.1 Representation of 3D scene by collection of 2D images

We have continued research in obtaining correspondence from a dense image sequence [83, 84]. We focused on a simplest yet generic situation when camera undergoes translation along a straight line and no specularities are present.

We have presented results concerning the difference between image based and model based approaches to 3-D scene visualization [85]. The most important insights are that the boundary between image based and model based approaches to 3-D scene visualization is not sharp and that a reconstruction cannot be avoided for a correct visualization.

We have introduced a new concept of oriented projective reconstruction [89]. This is a special class of projective reconstruction which preserves convex hull and hence topology of the reconstructed scene. We present an algorithm for computing an oriented projective reconstruction from two or more uncalibrated cameras. This result is in accordance with Hartley's latest result, quasiaffine reconstruction.

We have created two powerful software tools in MATLAB. The first [3, 4] allows semiautomatic acquisition of correspondence and various levels (projective, oriented projective, Euclidean) of reconstructions from multiple uncalibrated images, using the latest available knowledge. The second system [5, 6] allows fast 3-D visualization of projective reconstruction under a MATLAB shell.

Werner has put forward his doctoral thesis on image based 3-D visualization [86].

3.2 Reconstruction and representation of 3D shape

Project "RECCAD - Reconstruction and Analysis of Complex Objects for Building CAD Models Based on Measured Data" was successfully completed this year. The results of the project lead into a technology of a CAD model construction from measured three-dimensional data. The technology was demonstrated by reconstructing the part of a Fiat car body.

Two main directions were followed in basic research, (i) automatic matching of partial surface measurements and (ii) construction of a consistent surface model from registered point clouds.

Comparison of the alternative methods for computing surface differential characteristics [34] has shown that the way we compute them is suitable for extracting features for surface matching. An algorithm [36, 35, 33] for surface matching has been proposed and implemented. A hierarchy of surface features (faces, curves, points) is used to speed up the matching procedure so that the automatic matching can be used for building complete models from partial measurements.

An advance has been made in the construction of a consistent surface model from registered point clouds. We pursue the bottom-up 3D model reconstruction paradigm. Recently, local shape primitives and a corresponding reconstruction algorithm have been proposed [63]. We now study the issues of local 3D model verification and parameter refinement [93], hierarchical representations built on local geometric primitives, as well as fast algorithms for global model reconstruction by geometric primitive linking. Results are applied in telepresence and telecollaboration research [64, 2, 1].

Camera calibration and auto-calibration has been studied in order to provide an algorithms for metric reconstructions under weaker calibration procedures. An algorithm for camera calibration [56] uses known translation of the camera to solve the auto-calibration linearly. Auto-calibration under most weak conditions, when nothing is known about the scene or motion, has also been studied [81, 80].

The results of complete model construction from partial views were demonstrated by making a copy of a real object via stereo-lithography at the Rapid Prototyping Center of Milwaukee School of Engineering in Milwaukee, USA. The perspectives of using shape reconstruction for digitizing cultural heritage (sculptures, reliefs) were presented to [57] to relevant communities.

3.3 Physics-based vision

We study surface reflectance to discover cues to local geometric shape and intrinsic surface reflectivity. We prefer data-acquisition scenarios with partly controlled illumination. Some of the light parameters (polarization state, color, spatial distribution) are varied and an active sensor (moving camera or stereo rig, polarization and color analyzer) is used to vary and/or analyze some other parameters of light reflected from surfaces. This activity is a preparation for a formal project.

3.4 3D model reconstruction from passive vision

We focus on stereo as a source of 3D data. We believe stereo has more potential for shape reconstruction because it is more flexible: it can work both in a passive mode (natural texture is used as surface markers) and an active mode (uncalibrated random texture is projected on textureless surfaces). During the last year we have built a rigid four-camera stereo rig with four verging digital cameras having concurrent exposure. With the help of this device we want to study in controlled experiments the issues of recovered 3D model geometric accuracy, parameter stability and auto-recalibration, and stereo matching robustness and accuracy.

3.5 Images and other sensor data for autonomous vehicle navigation

The design of an optimal optical sensor for mobile robot navigation has been studied. Egomotion estimation from images taken by a perspective camera becomes ill-conditioned for certain scene arrangements. Corresponding elements can disappear due to limited field of view of perspective cameras. However, they can hardly vanish in the newly defined *central panoramic cameras*. Design of such cameras and their image formation function is presented in [76].

Important result has been obtained by developing the epipolar geometry of central panoramic cameras [77]. Egomotion estimation from correpondencies in panoramic images has been ben studied and a computational algorithm was proposed [58, 79, 74].

New approach to mobile robot localization has been proposed [54]. The approach relies on a visual map comprising panoramic images which are represented in a rotationally invariant manner.

3.6 Markov random fields for pattern recognition

The theory of random field models is one of the basic tools for modeling spatial, temporal and spectral relations in complex pattern recognition and image processing tasks. We have continued our research in fast and robust estimation and synthesis of Markov random field models. A new multiresolution approximation of a non-causal Gaussian Markov random field was proposed [21], [22] together with its parameter estimation and synthesis. The model enables to describe complex spatial relations due to independent Markov submodels for single spectral and frequency factors. This model was successfully applied to natural colour texture modelling [21].

In the area of causal random field models we have proposed [23] an adaptive simultaneous autoregressive model-based algorithm for fast reconstruction of image scratches. Missing data in colour image scratches are reconstructed using spatial and spectral correlation from their corresponding neighbourhoods.

A fast algorithm for unsupervised colour texture mosaic segmentation has been developed [20]. This algorithm does not require any knowledge about textures present in a segmented scene. The method is fully adaptive, numerically robust but still with moderate computation complexity.

We acknowledge the partial research support from European Union grant INCO Copernicus no. 960174 Autonomous Acquisition of Virtual Reality Models from Real World Scenes (VIRTUOUS) and the Dept. of Education grant No. OK 276 (1997).

3.7 Mathematical studies of descriptions of uncertainty

The investigation of uncertainty continued in the directions of basic and applied research. One of the main results is a comparison of fuzzy logics according to their semantical strength — several interesting relations were proved and presented in [28, 45]. According to this comparison, a new class of fuzzy logics seems to be very perspective — fuzzy logics based on residuated implications and strong fuzzy negations [11]. One of the main new results is the characterization of measures on tribes of fuzzy sets [47]. It reopened basic questions of properties of fuzzy logical operations, in particular fuzzy conjunctions (t-norms) [73, 51]. The study of their relation to applications in fuzzy controllers brought quite promissing results: we succeeded to motivate some procedures that were — up to now — used without sufficient theoretical background.

We almost finished basic studies which possess a new view on quantum logics together with a very general tool for modelling of state spaces using hypergraphs [48, 60].

New results required also the use of computers in mathematical proofs. Here we found modern computer algebra systems (especially Maple V 5) very useful [27].

Other publications include: [28, 40, 46, 50, 50, 61, 32].

3.8 Other research results

Doctoral student Pavel Mrázek studied interpolation and approximation methods for application to data processing. A nonlinear filter based on scale-space theory and locally adaptive smoothing has been developed to ensure the desired monotonicity of data from color-coded range finder [43, 44], and combined with an edge-detector to preserve discontinuities in the data [42]. Further research should concentrate on nonlinear diffusion as general framework for image smoothing.

Doctoral student Jaroslav Fojtík further developed a new lossless image compression method based on an unusual nonlinear predictor. The method was extensively tested on pseudocolour images; compression rates often outperform reference methods [12], [13].

4 Projects

Representation of 3-D Scene by 2-D Images

Duration: January 1997 - January 2000

Investigators: Václav Hlaváč , Tomáš Pajdla, Vladimír Smutný, Radim Šára, Tomáš Werner.

Funding: Czech Grant Agency, Grant No. 102/97/855 385K Kč (US$ 11K) (in 1998)

Objectives: The project addresses the problem of rendering a real 3-D Scene from an arbitrary viewpoint. The scene is represented by a sparse set of 2-D views. Arbitrary views are obtained by interpolation of coordinates and intensity. Geometrically consistent correspondence algorithms will be investigated. Scene structure will be expressed as a projective reconstruction based on trillinear relations among view. The approach will be tested on images from uncalibrated videosequences for virtual reality.

COMORI - Construction of Complete 3D Models from Range Images

Duration: March 1997 - March 2000

Investigators: Tomáš Pajdla , Václav Hlaváč, Vladimír Smutný, Radim Šára.

Funding: Grant Agency of the Czech Republic, Grant No. 102/97/480 366K Kč (US$ 11K) (in 1998)

Objectives: The goal of the project is to develop and improve existing methods for matching and registration of surfaces and for fusion of partial surface measurements into a consistent geometrical model. Measurement planning for complete surface model acquisition will be investigated as well. Theoretical results will be demonstrated on an experimental prototype of the system for model construction of an industrial object.

RECCAD, Copernicus CP941068

Duration: March 95 - March 98

Investigators: Václav Hlaváč , Tomáš Pajdla, Vladimír Smutný, Pavel Krsek.

Funding: European Union, 138K Kč (US$ 4K)

Objectives: The project aims at creating automatically a CAD model from several range images taken from different viewpoints. The CMP contribution focuses on range image acquisition, range image registration from different views based on point clouds, and differential surface characteristics. Structured light range finders developed at the CMP are used (laser stripe, one-shot binary-coded, color-coded). Industrial applications are planned in the following areas: 1. measurement of patient's body for planning cancer irradiation treatment and 2. rapid prototyping for car manufacturer Škoda Mladá Boleslav.

Partners: University of Wales, College of Cardiff, Dept. of Computer Science, Cardiff, U.K., Dr. Ralph Martin; Institute for Computer Science and Automation, Hungarian Academy of Sciences, geometric modeling group, Dr. Tamas Varady; University of Ljublana, Department of Computer Science, Ljubljana, Slovenia, Prof. Franc Solina.

Mathematical Models of Uncertainty

Duration: January 1997 - December 1999;

Investigators: Mirko Navara, Josef Hekrdla (Dept. of Mathematics), Pavel Pták, Josef Tkadlec (Dept. of Mathematics).

Funding: Grant Agency of the Czech Republic No. 201/97/0437, 280K Kč (US$ 8K)

Partners: Dept. of Mathematics, Faculty of Elec. Eng, CTU.

Objectives: The principal aim of the project is the improvement of mathematical foundations of fuzzy logic. Recently some types of tribes (fuzzy generalizations of Boolean σ-algebras) and measures on them were characterized in our co-operation with foreign experts. We intend to generalize these results and investigate their consequences for the theory of games and fuzzy propositional and predicate calculi. Besides enriching the mathematical theory, a long-term task is to establish a group of experts providing advisory service for people from application areas.

Mathematical Formalism of Quantum Theories

Duration: January 1996 - December 1998;

Investigators: Jan Hamhalter (Dept. of Mathematics), Mirko Navara, Pavel Pták, Josef Tkadlec (Dept. of Mathematics).

Funding: Grant Agency of the Czech Republic No 201/96/0117, 266K Kč (US$ 8K)

Partners: Project is held by the Dept. of Mathematics, Faculty of Elec. Eng, CTU with participation of investigators from CMP.

Objectives: The project deals with operator algebras and ordered structures with orthocomplementation, investigation of mathematical structures of quantum logic: operator algebras (von Neumann algebras, Hilbert lattices), orthomodular lattices and posets, orthoalgebras, effect algebras (difference posets), together with measure-theoretical aspects.

Omnidirectional Vision for Mobile Robots

Duration: January 1998 - December 1998

Investigators: Tomáš Svoboda, Tomáš Pajdla, Václav Hlaváč

Funding: Grant CTU 3098096 , 50K Kč (US$ 1K)

Objectives: Design of an omnidirectional vision system for a mobile vehicle. Investigation of related geometry and motion estimation algorithms.

Many-valued logics for computer science applications

Duration: January 1996 - November 1999;

Investigators: Mirko Navara, Pavel Pták

Funding: COST Action 15, 50K Kč (US$ 1K)

Partners: The project is a part of a large net of cooperators from EU, Cyprus, Czech Republic, Poland, Slovakia and Turkey. The Czech part of the project is coordinated by the Institute of Computer Science, Academy of Science of the Czech Republic, Prague.

Objectives: Theoretical studies of multivalued logics, their mathematical and computational properties, and problems of application of nonstandard logics in computer science.

Intelligent Technologies in Signal Processing and Quality Control

Duration: May 1997 - April 1998;

Investigators: Mirko Navara, Pavel Mrázek, Pavel Pták, Jan Vydržel, Vít Zýka.

Funding: Aktion Österreich – Tschechien 16p12(Intelligent Technologies in Signal Processing and Quality Control), 12K Kč (US$ 0K)

Partners: Johannes Kepler Universität Linz, Austria.

Objectives: The project deals with theoretical studies and practical applications of intelligent technologies based on nonstandard logics (multivalued, fuzzy or quantum logics). The main application areas are automatic control, expert systems and signal processing, including computer vision. Several basic mathematical questions should be solved in order to get criteria for the existence and stability of solutions for concrete problems.

5 Consultancy, Applied R & D, Industrial Applications

Boeing, grant no. FCS-CR-01-98 part A

Duration: March 98 - December 98

Investigators: Václav Hlaváč , Jiří (George) Matas, Jan Buriánek.

Funding: Boeing Corp., 850K Kč (US$ 25K)

Objectives: The project focussed on applications of wavelet transform to image compression, recognition and model-based and model predictive control. A bibliography based on literature review was prepared. A selected wavelet-based object recognition algorithm was implemented.

Virtual Reality, Hewlett Packard ISE-86L8-13

Duration: September 98 - September 99

Investigators: Michal Haindl.

Funding: Hewlett Packard, 700K Kč (US$ 21K)

Objectives: The project aims at developing a new course in virtual reality as an extension of the computer vision and pattern recognition programs of the CMP. The course will address the problem of building virtual reality models from real world scenes with focus on automatic methods. Many difficult outstanding problems in computer vision are related to automated model building; these include scene segmentation, data registration, 3D model building, texture analysis, synthesis and mapping, virtual data representation, ray tracing, dynamic scene viewers.

Partners: ÚTIA AV ČR

EUREKA project 1518 VIMP - Orthoscope

Duration: July 1996 - 1998

Funding: Dept. of Health, Dept. of Education, Czech Rep., 500K Kč (US$ 15K) (in 1998)

Investigators: Vladimír Smutný.

Description: 'Orthoscope' – a device for acquisition and processing of undistorted images of the teeth arch has been developed. It is expected to improve the process of documenting and evaluating progress of treatment in dentistry (orthodoncy, prosthetics) and dermatology.

Five pieces of the Orthoscope device have been built. A pilot study was carried out in 1998.

Rockwell Automation

Duration: long term

Funding: 250K Kč (US$ 7K)

Investigators: Václav Hlaváč, Tomáš Pajdla, Vladimír Smutný, Radim Šára

Description: CTU researchers are regularly consulted by the Rockwell Automation Research Center in Prague.

Neovision

Duration: long term

Funding: 60K Kč (US$ 2K)

Investigators: Tomáš Pajdla, Vladimír Smutný, Václav Hlaváč

Description: Neovision is a small machine vision company closely associated with CMP. Neovision uses CMP facilities for special measurements and consults CMP members.

Air Force Technical Institute Prague, Czech Republic.

Duration: June 1998

Funding: 57K Kč (US$ 2K)

Investigators: Radim Šára, Vladimír Smutný, Václav Hlaváč, Jiří Janáček (Institute of Physiology, Czech Academy of Sciences)

Description: A sequence of small-depth-of-focus color images from an optical microscope is processed to obtain a single image focused in full depth over the entire visual field. Points in focus are detected in a 3-D space formed by stacking the individual images. Several simple 3D local differential operators are used [65].

6 Facilities and Equipment

The CMP has good facilities for controlled image acquisition and precise radiometric and colorimetric measurements. These include a four meter optical bench, a three-chip Hitachi HV-C20 colour camera and a 16-bit Santa Barbara Instruments SB-7 cooled camera. Four Pulnix TM 9701 digital cameras allow synchroneous acquisition. Pulnix TM 1001 digital camera with 1024×1024 resolution is used for precise measurements. Several computers are equiped with mid-range cameras and frame grabbers. An industrial microscope allows us to measure objects with size in the range of 2–50 mm. Two panoramic cameras utilizing convex mirrors which provide view angles about $360^\circ \times 110^\circ$ were built.

We have built three rangefinders: a laser plane rangefinder (resolution 0.2 mm), one-shot binary coded rangefinder (resolution 64×80 points, video frame rate acquisition) and colour illumination based one-shot rangefinder (video frame rate acquisition, resolution 500×700, precision 2 mm). New laser plane range finder carried by a six degree of freedom manipulator is being built. Panoramic camera and a video radio link were added to an autonomous vehicle that was built in the lab.

The CMP computing facilities comprise 30 computers connected to the university-wide network (ATM). Besides two Silicon Graphic workstations (Indigo^2 and Indy) all the computers are high-end PCs (Pentium, Pentium Pro) running either Linux or MS Windows 95/NT. The CMP computing facilities has been enhanced by equipment donated by Hewlett Packard (grant no. ISE-86L8-13 Virtual Reality). The equipment in overall value 700K Kč (US$ 21K) includes a high-end graphic workstation HP Kayak, a 21” colour monitor, a postersize colour printer HP DesignJet 755CM and the HP ScanJet 6100C scanner.

For more detailed information on CMP equipment, visit

`http://cmp.felk.cvut.cz/cmp/hardware` .

7 Teaching

In 1998, CMP members taught the following courses (**course name,** *lecturer*, laboratory supervisor):

Introduction to computer vision for graduate students *V. Hlaváč*, T. Pajdla and V. Smutný.

3D computer vision for graduate students *V. Hlaváč*, T. Pajdla.

Robotic systems *V. Chalupa*, V. Smutný.

Introduction to computer vision and pattern recognition (for master students, Charles University, Dept. of Mathematics and Physics) *V. Hlaváč.*

Computer Vision for Informatics *T. Pajdla*, V. Smutný.

Intelligent Robotics *V.Hlaváč*, *T. Pajdla*, V. Smutný.

Pattern Recognition *J. Matas*, *M. Haindl*

Fuzzy sets for master students *M. Navara.*

Numerical Analysis for master students *M. Navara*

Computer Algebra Systems for master students *M. Navara*

Calculus (English course) *P. Pták.*

Mathematics for vision for graduate students *P. Pták.*

CMP members participated in the following teaching-related project:

Fuzzy Control and Fuzzy Logic

Basic facts: Coordinator Radko Mesiar (Slovak Technical University in Bratislava, Slovakia), contact person at CTU Mirko Navara, CEEPUS network, No. SK-042; financed by EU programme CEEPUS; funds in 1998 31K Kč (US$ 1K); started September 1995, ends August 1999.

Project topic: Coordination of education in fuzzy control and fuzzy logic, mobility of teachers, undergraduate and postgraduate students.

Miscellaneous: Participating institutions: Slovak Technical University (coordinator); Technical University of Budapest, Hungaria; Linz University, Austria; Ostrava University in Ostrava, Czech Republic.

8 Visits to CMP

(ordered by the length of the visit)

Jonsson, Kenneth	University of Surey, Guilford, Britain, September 98, 6 months
Melzer, Thomas	PRIP TU Wien Treitlstr., Wien, Austria, March 98, 2 months
Stupnanova, Andrea	STU Bratislava, Slovakia, May 98, 1 month
Schlesinger, Michal	Ukraine Academy of Sciences, Kiev, Ukraine, November 98, 11 days
Drossos, Costas	University of Patras, Patras, Greece, November 98, 9 days
Harding, John	New Mexico State University, Las Cruces, May 98, USA, 8 days
De Simone, Anna	University of Napoli, Napoli, Italy, October 98, 7 days
Zolotová, Iveta	TU Kosice, Slovakia, June 98, 7 days
Moser, Bernhard	Johannes Kepler University, Linz, Austria, June 98, 6 days.
Cenker, Christian	University of Viena, Viena, Austria, September 98, 4 days
Kuzmin, Sergej	IBM East Europe/Asia Ltd., Moscow, Russia, November 98, 4 days
Antero, Heikki	Lappeenranta University of Technology, Lappeenranta, Finland, June 98, 3 days
Mikula, Karol	STU, Bratislava, Slovakia, May 98, 2 days
Lughofer, Edwin	Johannes Kepler University, Linz, Austria, April 98, 2 days
Winkler, Roman	Johannes Kepler University, Linz, Austria, April 98, 2 days
Wechsler, Harry	George Mason University, USA, June 98, 3 days
Burge, Mark	Johannes Kepler University, Linz, Austria, May 98, 2 days
Messer, Kieron	University of Surrey, Guilford, Britain, June 98, 3 days
Lanser, Stefan	TU Munchen, Germany, August 98, 2 days
Radig, Bernd	TU Munchen, Germany, August 98, 2 days.
Schlesinger, Michal	Ukraine Academy of Sciences, Kiev, Ukraine, November 98, 2 days
Zatko, Bedrich	Slovak Academy of Sciences, Bratislava, Slovakia, June 98, 1 day
Kiryati, Nahum	Technion - Israel Institute of Technology, Israel, July 98, 1 day
Frydrych, Michael	Lapeenranta University of Technology, Finland, April 98, 1 day
Peters, Gabriela	University of Bochum, Germany, January, 1 day

9 Selected CMP Seminars

M. Schlesinger	Institute of Cybernetics, Kiev, the Ukraine *Polynomial solution of a special case of the logical formula satisfaction problem*
C. A. Drossos	University of Patras, Greece *Mathematics in Postindustrial Information Society*
M. Schlesinger	Institute of Cybernetics, Kiev, the Ukraine *The N shortest paths problem*
N. Kiryati	Technion - Israel Institute of Technology *Adaptive Color Structured Light.*
K. Messer	University of Surrey, UK *Feature Selection for Image Retrieval.*
H. Wechsler	George Mason University, UK *Face recognition*
K. Mikula	STU Bratislava, Slovakia *Nelinearni difuze ve zpracovani obrazu.*
M. Burge	Johannes Kepler University Linz, Austria *The Representation and Analysis of Document Images.*
J. Harding	New Mexico State University, USA *The Axioms of an Experimental System.*
A. Stupnanova	STU Bratislava, Slovakia *Aritmetics of fuzzy intervals.*
M. Frydrych	Lapeenranta University of Technology, Finland *Colour sensors based on bacteriorhodopsin.*
G. Peters	University of Bochum, Germany *Segmentation-Based Tracking of Rotating Objects in the Context of Viewpoint-Invariant.*

Selected 1998 publications of CMP members.

[1] Ruzena Bajcsy, Reyes Enciso, Gerda Kamberova, and Radim Šára. A 3D geometric model acquisition system for a tele-collaboration testbed. In *Proc. ICASE/LaRC/ARO/NSF Workshop on Computational Aerosciences in the 21st Century*, Norwell, USA, April 1998. Kluwer Academic Publishers.

[2] Ruzena Bajcsy, Reyes Enciso, Lucien Nocera, and Radim Šára. 3D reconstruction of environments for virtual collaboration. In *Proc. 4th IEEE Workshop on Applications of Computer Vision*, Los Alamitos, California, October 1998. IEEE Computer Society, IEEE Computer Society Press.

[3] Jan Buriánek. Korespondence pro virtualní kameru. Master's thesis, Czech Technical University, FEL ČVUT, Karlovo náměstí 13, Praha, Czech Republic, 1998. In Czech.

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