- Computer Networks
- Computer Vision
- Multimedia Systems
- Quantum Informatics

Institute of Theoretical and Applied Informatics
Polish Academy of Sciences

IITiS
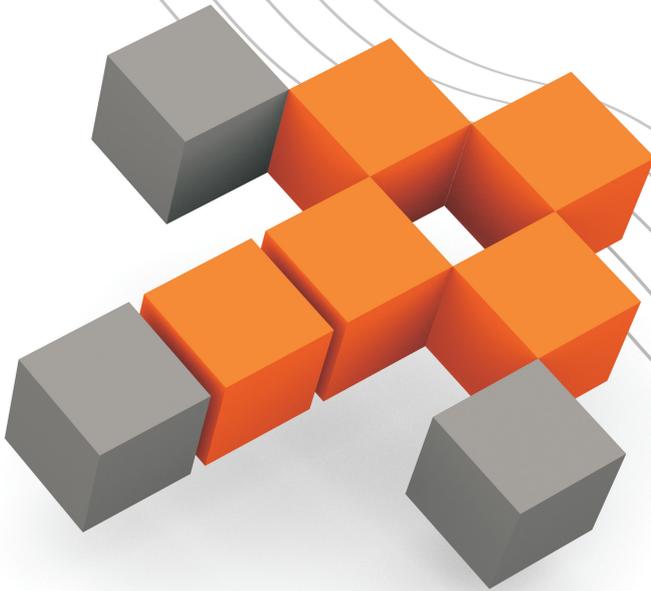
Scientific and academic activity

- 3D space exploration - reconstruction, processing, encoding
- Advanced modelling and simulation of complex systems and computer networks
- Future Internet - architectures, protocols, services
- Human-machine interaction
- Quantum information systems
- Virtual reality in ICT platforms for creative industries
- Internship for students of all Higher Education degrees

Research and development cooperation

- 3D digitalization for cultural heritage
- Computer vision algorithms in hi-tech applications
- New media streaming in Internet 3D
- Performance evaluation of computer networks and systems
- Serious games to aim limbs rehabilitation
- Software tools for technical and medical diagnostics

Knowledge, experience and competence

- Conferences and summer school organization
- Opinions on innovativeness
- Patent and forensic opinions and expertises
- Technology transfer and knowledge commercialisation in ICT domain
  (bussiness plan, consulting, feasibility study, project management)

The Institute of Theoretical and Applied Informatics of the Polish Academy of Sciences is a research institute whose science activity concentrates in the area of Information Technology. The Institute is also involved in training an advanced level technical and scientific staff and both initiates and participates in projects aimed at development of innovative commercial sector. ITAI takes part in realization of Polish Academy of Sciences' mission of advancement promotion, integration and dissemination of Polish science and contributes to education and national culture.

The current scientific activity of ITAI PAS includes both applied and theoretical research. The applied research is centered around issues of acquisition, processing and presentation of three-dimensional and multimedia content. Fundamental research is focused on quantum computing systems as well as modeling and evaluation of networks and computer systems, among others, for the purpose of Future Internet engineering.

The Institute has a history of innovative IT projects, including: systems supporting medical diagnosis in orthodontics, digitalization of cultural heritage objects, mechanoscopy of physical evidence of tool application, quality analysis of images, optimized document scans processing and compression, assisting people with disabilities in using multimedia computer systems, "serious games" for supporting the limb rehabilitation, specialized simulation tools for modeling and evaluation of computer networks, innovative methods and algorithms for quantum computation.

We are open to interdisciplinary collaboration within both national and international projects of innovative character. Theoretical and applied research are performed by ITAI PAS as statutory activities, research projects and cooperation with commercial entities. The Insitute was among the first three Polish participants in the fourth Framework Program before Polish accession to the European Union.

Director of the Institute
prof. Tadeusz Czachórski

Computer Networks

The Systems Modelling and Performance Evaluation Group (SMaPEG) conducts research on models of computer systems and novel methods of modelling. In the scope of interests of the Group there are mainly models of computer networks. We are engaged in simulation and analytical modelling, both queuing models and other methods. Our experience embraces using of well-established modelling packages, like NS, OmNET++ or PRISM as well as creation of advanced proprietary software working in parallel environments.

Modelling of large, modern computer networks require the creation of advanced software. That is why we are developing new methods of modelling, susceptible to the use of parallel computing, which allows us to create parallel simulators and analytical packages for calculations, especially with the use of Markov chains.
The team also participates in the development of new network protocols for the Future Internet. Another area of our interest is classification of Internet traffic.

Computer Systems Modelling and Performance Evaluation Group
Wireless Network Optimization Group

Research areas

Parallel simulations

- simulations of wireless networks with physical phenomena and transient states

Diffusion Approximation Models

- models of new types of protocols including sensor networks or WLAN mechanisms

Analytical modelling with Markov chains and other methods

- OLYMP-2 – Software for CTMC modelling able to hadle models over 10^9 states
- fluid-flow approximation for Internet modelling (10^6 nodes) with differential equations

Network protocols for Content-aware or Information-centric networks

- methods and protocols for content identification, distribution, resolution and search

Network traffic classification

- Classification methods analysing flow context, e.g. host behaviour and DNS queries

Conducted projects

COLOCAN (COntent LOcalisation for CAN)
Algorithm and software for content resolution in Content-aware Networks, being created within Polish project Future Internet Engineering
(ERDF Innovative Economy Programme grant no. POIG.01.01.02-00-045)

Models of transmission dynamics, congestion control and QoS
Analytical and simulation modelling of chosen problems arising in the Internet
(Polish Ministry of Sciences and Higher Education grant no. 4796/B/T02/2011/40)

Internet traffic sources based on Markovian Models:
We use Markovian modelling (DTMC, B-MAP, HMM) to create an realistic models of Internet traffic sources.
(Polish Ministry of Sciences and Higher Education grant no. N N516 441438)

MuTriCs: Multilevel Traffic Classification
Internet traffic classification system working in real-time
(Polish Ministry of Sciences and Higher Education grant no. 2011/01/N/ST6/07202)

Implemented software tools

OLYMP (Object-oriented Library for Markov Processing)
Library (with Java front-end) allowing Markovian modelling of system as large as 10^9 states

SMiLE (Shared Memory sImulator of LargE models)
Parallel event-driven simulator exploiting features of shared-memory multi-processor (multi-core) systems

PATERNOSTER (PArallel Time-stEpped wiReless NetwOrks SimulaToR)
Parallel simulator with time-stepped synchronization, dedicated for 802.11 wireless networks.

Above tools are currently developed under the Polish Ministry of Sciences and Higher Education grant no. N N516 407138 „Methods and tools of distributed modelling of wireless networks".

The current research subject of Computer Vision Systems Group is the development of computer vision methods for active acquisition and analysis of spatial data.

Data acquisition applies both to surface structures derived from 3D scanners and to volumetric data resulting from computer tomography and magnetic resonance imaging.

For the purposes of spatial data analysis algorithms are being developed to process 3D meshes and point clouds, including filtration, segmentation, registration and merging of heterogeneous data, including combining information from 2D and 3D imagery. Another research direction is the fitting of measured data to surface models.

Computer Vision Systems Group

Research areas

Medical applications

- diagnosis and operation planning in orthodontics

**Digitalization of cultural heritage**

- 3D digitalization for Virtual Museum (in cooperation with Silesian museums)

3D vision

- acquisition and processing of geometric models
- interrelating the coordinate systems of different imaging devices
- embedding virtual 3D objects in a stereoscopic image

Exploration of 3D space

- navigation in 3D space, 3D occupancy grids
- stereoscopic tracking of objects
- immersive stereoscopic display
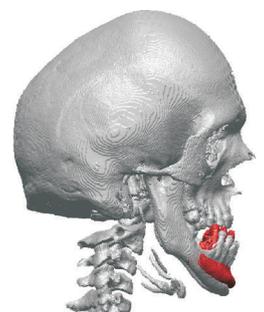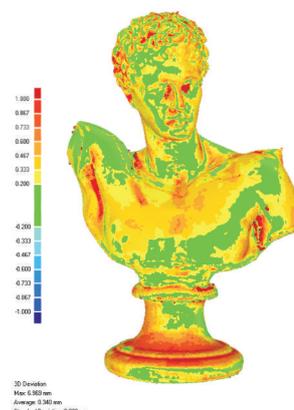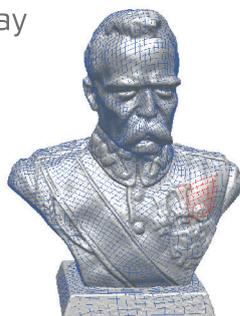
Conducted projects

Multisensory perception, representation and analysis of 3D shapes by computer, taking into account the presence of incomplete and imprecise information
Proposing a data format to represent a shape and the uncertainty and incompleteness of acquired information. Exploring new techniques to collect information about 3D shapes. Merging information about arbitrary 3D shapes from different imaging devices.
(Polish Ministry of Science and Higher Education grant no. 3 T11C 028 27)

Computerized, parametric and deformable geometric model of the human head for the purposes of its reconstruction and of the analysis and modelling of its growth
Proposing a parametric, deformable model of the geometry of the bone structures of the cranium and the mandible (X-ray, CT) and a simplified deformable model of the soft tissues of the head based on optical CD scanning. Developing methods to integrate information from various imaging devices into this model. Adapting existing methods of quantitative statistical deformation analysis for the purposes of developmental cephalometry.
(Polish Ministry of Science and Higher Education grant no. 3 T11F 004 27)

Computer vision techniques to collect, process and deliver multimodal, hierarchic models of 3D objects for the purposes of digitizing cultural heritage
Developing techniques to represent, collect, process and deliver geometrical data on historical monuments and artefacts to become part of a virtual museum capable of handling spatially complex exhibits.
(Polish Ministry of Science and Higher Education grant no. N N516 1862 33)

Active creation of a model of space using a 3D scanner and an autonomous robot
Analysing and processing image data acquired from a stereo pair of cameras; representing the data as 3D occupancy grids. Processing and integration of multimodal spatial data. Localizing and navigating an autonomous robot.
(Polish Ministry of Science and Higher Education grant no. N N516 440738)

Experimental system for integration and presentation of 3d views
Embedding virtual objects in a scene perceived by a stereo pair of cameras, taking into consideration depth and occlusion. Tracking a moving observer and displaying views of the 3D scene compatible with their changing point of view.
(Polish Ministry of Science and Higher Education grant no. N N516 482340)

Future Internet Engineering – 3D Internet, Digital Cinema, UHD
Preparing 3D models for the purposes of display in a distributed virtual museum; implementing methods of progressive representation of surface models.
(ERDF Innovative Economy Programme grant no. POIG.01.01.02-00-045)

The work of Multimedia Team at ITAI PAS is focused on various theoretical and practical issues of multimedia acquisition, processing, coding, transmission and presentation.

Our area of expertise includes the design and implementation of algorithms for coding and pattern recognition, applied to specific problems related to 2D and 3D vision data processing. We are also proficient in construction and evaluation of 3D virtual space interactions, 3D data acquisition and interactive visualization.

Participation of the Team in a number of projects allowed us to gain a considerate know-how in analysis of theoretical aspects of multimedia systems as well as implementation of dedicated solutions for requested commercial specifications.

Multimedia Systems Group

Research areas

Multimedia coding and compression

- design and performance analysis of coding systems (MPEG, JPEG, DVD)
- optimized implementation for embedded systems (DSP/FPGA)

Image processing

- camera stabilization, denoising, binarization
- object tracking and recognition

Natural interaction

- human motion analysis
- gesture recognition

3D vision

- virtual/augumented reality
- 3D data processing

Conducted projects

Representation of dynamic 3D scenes using the Atomic Shapes Network model
The objective is to develop a unique approach for recovering 3D representation of a dynamic physical scene observed with cameras and/or 3D scanners.
(National Science Center grant no. 2011/03/D/ST6/03753)

Future Internet Engineering - 3D Internet, digital cinema, UHD
Preparation of advanced techniques allowing to provide functionality related to remote navigation, storing and streaming of multimedia data with the preservation of high-quality and high-availability of services.
(ERDF Innovative Economy Programme grant no. POIG.01.01.02-00-045)

Implementation of a demonstrator of tracking, stabilisation, and panorama building for an airplane vision channel
Preparation and implementation of a prototype algorithm for UAV operator support through image enhancement and object tracking.
(Commissioned by Flytronic Ltd.)

User interface based on natural gestures for exploration of virtual 3D spaces
Design and analysis of natural gesture interaction for virtual exploration tasks with a range of motion capture devices.
(Polish Ministry of Science and Higher Education grant no. NN516405137)

Application of contourlet transform for coding and transmission stereo-images
Study of the algorithmic issues and performance evaluation of application of contourlet transform for stereo image coding.
(Polish Ministry of Science and Higher Education grant no. 3 T11C 045 30)

Study of possibility based on the long term theoretical knowledge of the JPEG2000 algorithms and his implementation in the DSP TMS320C6414 and FPGA from Xilinx
Design and implementation of optimized coding implementation for JPEG2000 standard in a hybrid DSP/FPGA embedded system.
(Commissioned by BAP IS GmbH)

Methodology for detection of encoding methods to DVD for conformity assessment standards
Design and implementation software analyzers for detection of methods of DC suppression control applied during encoding data on DVD.
(Commissioned by PATPOL Ltd. and Koninklijke Philips Electronics)

Interactive devices for rehabilitation of children and adolescents with impaired mobility
Preparation of game-like rehabilitation systems using custom-designed motion capture units for rehabilitation of selected leg and arm conditions.
*(Polish Ministry of Science and Higher Education R&D grant no. 0533/R/2/T02/07/02
In cooperation with the Silesian University of Technology)*

Quantum Informatics

The research in quantum information science conducted by the ITAI PAS aims to create and develop new algorithms and theory for modelling and analysis fundamental aspects of quantum internetworks, quantum machine learning, quantum game theory and quantum control. Quantum Systems of Informatics Group of ITAI PAS is highly interdisciplinary and is formed by researchers representing computer science, mathematics, physics and automatic control. QSIG contributes tools for quantum information community by providing symbolic (QI) and numerical (scikits.qinf) libraries, which are being developed by the group. The first library implements number of functions used in the analysis of quantum states, while the second one focuses on efficiency and utilizes many advanced methods such as cone programming, GRAPE algorithm for optimal control and Monte Carlo based on random matrix theory. The ITAI is one of the main coordinators of Quantiki portal, which is the free-content WWW resource for quantum information science community.

Quantum Systems of Informatics Group

Research areas

Geometry of Quantum Information Systems

- analysis of geometrical aspects of quantum entanglement
- restricted numerical ranges and shadows of matrices

Modelling and analysis of quantum internetworks

- analysis of quantum information transfer using models of quantum Markov models
- development of algorithms for distributed quantum computing

Quantum Game Theory

- investigation of the influence of the environment on the course of quantum games
- investigation of security and possible application of quantum games

Quantum Control

- investigation of controllability criterion's for complex quantum systems
- development of algorithms for optimal control with constraints of quantum systems

Quantum Machine Learning

- developing an expectation-maximization algorithm for quantum Bayesian networks
- comparing the efficiency of classical and quantum Bayesian networks

Conducted projects

Methods of development, modelling and analysis of quantum internetworking protocols
Development of new protocols for controlling the networks of quantum processing units connected by quantum channels.
(National Science Centre grant no. 2011/03/D/ST6/00413)

Distributed numerical analysis environment for the quantum information theory
The aim of the project is to create tools for architecture allowing for parallel simulation tests of quantum states and channels.
(National Science Centre grant no. N N519 442339)

Modelling methods of information systems using quantum queue theory
The purpose of the proposed research project is to develop methods for modelling systems with quantum theory of queues.
(National Science Centre grant no. N N516 481840)

Controllability of quantum systems
The main aim of the research project is to formulate and prove the local controllability criteria for quantum systems when the control is performed only on a subsystem of a given complex quantum system.
(National Science Centre grant no. N N514 513340)

Application of quantum game theory in modelling of quantum information transmission
The aim of the project is the use of quantum game theory to create and analyse scenarios for transferring quantum information that can be described in the language of game theory.
(National Science Centre grant no. N N516 475440)

Ministry of Science and Higher Education under the "Iuventus Plus" programme for young researchers:

Quantum games in open systems
(IP2010 009770)

Application of geometrical methods for the analysis of quantum states and operations
(IP2011 036371)

Analysis and modelling of local properties of quantum states and operations
(IP2010 052270)

Entanglement effects in quantum games
(IP2011 014071)

Application of geometric methods to quantum control
(IP2011 036371)

Controllability of quantum information systems
(IP2011 044271)
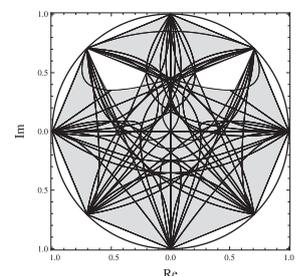
Exploration of 3D Space Laboratory

3D space exploration laboratory has been created for the purpose of research on acquisition, processing, coding and presentation of three-dimensional information. Additionally, it is used for conducting research on contact and non-contact human-machine interfaces based on gestures.

The lab consists of range scanners for both precise digitization of small objects and wide area acquisition, motion-capture systems, stereoscopic acquisition and visualization equipment, 3D printer and mobile spatial-acquisition platform with interchangeable cameras, rangefinder, and sonar arrays.

Modelling and Parallel Computing Laboratory

Laboratory of Networks and Parallel Computations is equipped with computing cluster and experimental wired and wireless network. The cluster „leming", consisting of over 20 servers with x64 and Cell processors, controlled with Linux operating system, having ca. 200 GB of RAM and 24 TB of storage, allows to carry out parallel computations of various types. Thanks to programmable nodes with wireless (802.11a/b/g/n) and wired (Ethernet) connectivity, Laboratory allows for physical verification of software network models of protocols of Layer 2 and above.