2014 The Future Internet
Research in Hungary
FIRCC Report, 2014
The Future Internet National Research Programme (JINKA) has been initiated by the Future Internet National Technology Platform and organised by the Future Internet Research Coordination Centre (FIRCC) established in the frame of the Hungarian FIRST (Future Internet Research, Services and Technology) project co-financed by the European Social Fund at the University of Debrecen in January 2013. The National Research Programme was based on the research programme of FIRST project (JINKA1.0) and it was completed by all the research themes which are proposed by the participants of the National Research Programme. In February 2014 the Future Internet National Research Programme (JINKA 2.1) has 34 participating institutions and 132 registered research themes clustered into nine chapters and can be considered as a total coverage of the Hungarian research activities in this field. This FIRCC Report presents the results of 83 research themes selected from JINKA 2.1, including the short description of the theme and results, as well as the international relations and the main publications.

Péter Bakonyi and Gjula Sallai
editors
## Future Internet National Research Programme (JINKA)

1. Internet basic research
2. Future Internet modelling, analysis and design
3. Future Internet network architectures
4. Data and content technologies
5. 3D Internet and cognitive infocommunications
6. Internet of Things (IoT)
7. Cyber-Physical Systems and applications
8. Future Internet community applications
9. Experimentation, standardization, regulation
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Future Internet Research in Hungary, 2014

Report of the Future Internet Research Coordination Centre, FIRCC Report 2014

Editors:
Péter Bakonyi and Gyula Sallai
The Internet may be the most significant engineering construction in the last decades, its impacts spread on almost all areas of the society, economy, science and culture. Therefore the research of the future of the Internet has outstanding importance. The research of the Future Internet is intensive in Hungary and the Hungarian researchers reached recognized results in the national and international research programmes. Especially I highlight the cooperation and collaboration realized among the universities, the research institutes and the business sphere in the Future Internet research and applications. I welcome this publication with a great pleasure and I promise that the Hungarian Academy of Sciences is continued to follow and support this research area.

László Lovász academician
President of the Hungarian Academy of Sciences
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FOREWORD (Béla Kardon)...

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It has been 25 years since the first website ever dedicated to the World Wide Web project at CERN (European Organization for Nuclear Research) was launched. Since 1989 the World Wide Web and the Internet has become a widely accessible system, a constantly evolving network of networks that exerted massive influence on society and business. In its infancy, not many have perceived it as a potentially global network, not many have foreseen its necessary security requirements, and almost no one has predicted the Internet of Things, and its heavy influence on society and economics. Nowadays these are the most important issues about the Internet that prejudice the redesign of its very fundamentals.

Today 50% of the Earth’s population, about 3 billion people, have access to the Internet; this figure may exceed 5 billion by 2020. Currently portable devices and personal computers dominate the scene, but in the near future the number of intelligent devices will make up the majority of the Internet. The number of online devices may rise up to 50 billion by 2020. The upswing of the already existing Internet of Things directed the evolution of the Internet towards the use of intelligent devices. The result is a large scale transformation that influences the economy, society, politics and science.

This is already the Internet of the Future, an ever developing system that is characterised by a higher number of interfaces, the connection of billions of online devices, the always and anywhere accessible contents, high quality and secure services, energy efficiency and more efficient manageability. Nonetheless the rising number of users, the need to integrate a huge number of new devices into the network, the countless services presume a new concept of the Internet and of its design. Therefore Future Internet research today have become extremely important and got into the focus of interest. The economic and societal goals of Europe presuppose research, modelling, analysis and design of complex Internet network infrastructures, data sets, technologies and social applications. The establishment of a necessary knowledge base and the collection of good practices in coordination and management are of utmost importance.

This booklet gives an account of such an endeavour: the “Future Internet Research, Services and Technology – FIRST” project, realized with the support of the European Social Funds in the framework of the Social Renewal Operational Programme (TÁMOP). One of the aims of the FIRST project was the establishment of a research coordination centre that strives to harmonize Future Internet research projects in Hungary. The Future Internet Research Coordination Centre (FIRCC) was responsible for the Future Internet National Research Programme (JINKA) that over the past years in addition to the topics of the FIRST project incorporated other research topics on Future Internet pursued in Hungary.

The general aim of the Future Internet National Research Programme is to support the emergence of an R&D and innovation programme that is in accord with the directions of R&D agenda of the EU and that can enhance the competitiveness of Hungarian economy. Specific aims of the project include encouraging the cooperation of the academic and the industrial sphere, and to increase Hungarian participation in international R&D projects in the field of Future Internet.

By presenting several research results on numerous fields of internet research, this booklet is aiming at the demonstration of the interplay between the Internet and society. This publication summarizes the results achieved in the frames of the Future Internet National Research Program, in this respect this booklet can be perceived as an inventory of Hungarian Future Internet research. The reader is welcome to get an insight into various topics of great importance of Future Internet research, among others network architectures of Future Internet, Cloud Computing, challenges of Big Data, 3D Internet and networked media, 4D content creation, Internet of Things, embedded and intelligent engineering systems and smart community applications.

The aims of the Future Internet National Research Programme are in line with the goals of the National Research and Development and Innovation Strategy (2013-2020) and the National Science Policy Strategy, and its long-term sustainability is secured by – apart from H2020 – the new Human Resource Development Operational Programme and the Economic Competitiveness Operational Programme. These programmes supported by the European Structural Funds guarantee the existence of research programmes, the renewal of research infrastructure, the training of necessary human resource and the international networking that are necessary for the development of Hungarian Future Internet Research.

The publication of this booklet can be also accredited to the fact that Hungarian Internet research is already looking back a successful history, with high quality workshops and internationally renowned research teams. Some fields already received international attention; these are network planning, traffic modelling, internet security, mobile internet, sensor networks and new network architectures, etc.

This booklet could prove to be an important assistance to researchers, might stimulate their research, encourage their cooperation, and can undoubtedly contribute to the effort of rethinking the fundamentals of the Internet and the use of the results.
Future Internet and Innovation

In the past 30 years the Internet triggered a lot of changes in every field of our life. The Internet, which originally was an academic research network, has become the global infrastructure of the Information Society, however, nowadays the network system that was designed in the 70’s can not meet the current technological requirements and the users’ needs. To make the Internet to become the global information infrastructure of the 21st century and to be able to fulfill its functions we need new solutions based on the current technology. In order to achieve these goals, the European Union (EU) paid particular attention to the research of the new generation Internet in the 7th RTD Framework Programme and launched several R&D initiatives for radical renewal of the Internet technology, networks and services (Future Internet). The National Innovation Office (NIH) has been actively involved in the EU’s FI programmes. NIH is one of the founding members of the Future Internet Forum of the EU Member States, which provides us an opportunity to influence the EU’s FI policy. It was a great success for Hungary that in May 2011 Budapest could be the European centre of the Future Internet during the Future Internet Week organized by the NIH in cooperation with professional organizations and institutions. The Future Internet Week embraced the following events:

- FIRE Concentration Day
- Internet of Things (IoT) Workshop
- Conference of the European Network of Living Labs (EnoLL)
- Future Internet Assembly (FIA)
- Future Internet Forum (FiF).

To join the efforts in the country, the Future Internet National Technology Platform (FiNTP) was established by the initiative of the NIH in 2011. Since then it has a great number of members from the academic and the business sector. The FiNTP closely cooperates with the Platform to strengthen the position of Hungary and our researchers in the FI activities of the EU.

Future Internet is one of the ICT technologies that has special importance in the development of the national economy because it is a Key Enabling Technology (KET) affecting the innovation and efficiency of almost all areas, and it determines – directly or indirectly – the competitiveness of the different regions and countries. This fact is valid for Hungary too, since the ICT sector produces approx. 12 % of the Hungarian GDP and the employment rate in this industry is quite high even in comparison with other OECD countries.

Future Internet as a paradigm is characterized by smart applications and services based on advanced information and communication technologies. The development of the Future Internet gives a boost to the innovation from the business sector, via the healthcare to the manufacturing industry. Recently, many start-up enterprises have been founded and they have achieved great success in the market with some kind of smart digital application or service. This process has begun in Hungary too, and it fits well into the National R&D and Innovation Strategy accepted by the Government in 2013. This strategy aimed at supporting at least 300 SMEs – so called “gazelles” – to get to the global market till the end of this decade. The NIH’s strategic objective is to build up the start-up ecosystem in Hungary and to provide a broad range of innovation support and services for start-up companies. We hope that NIH’s Accredited Incubator Support Programme, the JEREMIE venture capital programme and a lot of events, meetups will help the start-ups to realize successful businesses abroad and in the country, making Budapest to be the start-up hub of the region. In many cases, the national start-up initiatives focus on the market with Internet applications and solutions, and we have a number of Hungarian SMEs, IT companies which have already generated keen interest in the world.

To play an active role in the Future Internet world and to exploit the generated innovation wave, the main stakeholders, the Government, the academic sector and the industry have to cooperate with each other in the field of Future Internet, as it is implemented in the PPP programmes. This goal is well supported by the collaboration and the joint thinking in the FiNTP. Besides the FiNTP (Future Internet Research, Services and Technologies) project – funded from the EU Structural Funds (TÁMOP 4.2.2.C) in the framework of the New Széchenyi Plan – promotes the cooperation and the development of the Internet research. The Future Internet National Research Programme (INNASA) prepared in the frame of the FiNTP project, together with the FiNTP stimulates the collaboration of the academic institutions and the industrial companies that is considered to be one of the priorities in the Hungarian innovation policy. NIH relies on the FiNTP project and uses the results of the Fi research programme in its work related to H2020, and supports their appearance and participation of the research community in the EU’s professional bodies.

According to the latest figures and foreign analysts, the Hungarian economy is on a growth track. To make Hungary prosperous we need structural changes in the economy and we have to increase the ratio of the products having high intellectual added-value. We are thriving to make such structural changes by developing Hungary into an innovation centre and by helping innovative companies to get to the global market.

The research and development work which was done in the field of the Future Internet contributes to the implementation of our objectives and to the work that helps innovation to be the engine of the economy of Hungary.
Future Internet National Research Programme in Hungary

The Hungarian project titled Future Internet Research, Services and Technology (FIRST) supported by the European Union and co-financed by the European Social Fund, (Project number: TAMOP-4.2.2.C-11/1/KONV-2012-0001) has been launched on 1 October 2012, ending on 31 December 2014, headed by the University of Debrecen. The participants of the Consortium are the University of Debrecen, the Inter-University Centre for Telecommunications and Informatics (ETIK), the National Information Infrastructure Development Institute (NIIFI) and the Institute for Nuclear Research of the Hungarian Academy of Sciences (ATOMKI).

The Future Internet Research Co-ordination Centre (FIRCC) has been established in the frame of the FIRST project. The participants of the Future Internet Research Coordination Centre are the member of the FIRST Consortium and the Budapest University of Technology and Economics. The basic role and function of the FIRCC is to co-ordinate the Future Internet research activity in Hungary and to promote the international cooperation in this field. Furthermore, to strengthen the participation of Hungarian researchers in EU programmes, like FP7 and Horizon 2020 in the coming years.

The Future Internet National Research Programme (JINKA) has been initiated by the FIRCC and the Future Internet National Technology Platform (FI NTP) in March 2013, and organised by the FIRCC. The National Research Programme was based on the research programme of the FIRST (JINKA1.0) and it was completed by all the research themes which are proposed by the participants of the National Programme. Today the Future Internet National Research Programme (JINKA 2.1) has 34 participating institutions and 132 proposed research themes. It can be considered as a total coverage of the Hungarian research activities in this field. The research themes are clustered into nine chapters and each chapter contains 5-7 ranges of themes.

The basic objectives of the Programme is to integrate all R&D&I activities in Hungary in the field of Future Internet and to support those activities which are in line with EU programmes and has an influence for the technological, economic and social developments in Hungary. In the frame of the program we intend to:

- co-ordinate and support the ongoing research and innovation activities in Hungary;
- to initiate new research directions;
- to search for synergies;
- to strengthen the Hungarian participation of international research programmes especially in Horizon 2020;
- to support the co-operation among academic-university institutions;
- to support the co-operation with the business sphere, and
to promote the Internet Science and Engineering in Hungary.

The Programme is managed by the FIRCC in co-operation with the Future Internet National Technology Platform. There are two types of new memberships: ordinary and supporting members:

- Ordinary members: actively participate in the implementation of the Programme with one or more research themes.
- Supporting members: aid the implementation of the Programme with experiences and advices.

Until today the following 34 institutions joined to the Programme:

**Founding members:**
- University of Debrecen (UD)
- Future Internet Research Coordination Centre (FIRCC)
- Budapest University of Technology and Economics (BME)
- Inter-University Centre for Telecommunications and Informatics (ETIK)
- National Information Infrastructure Development Institute (NIIFI)
- Institute for Nuclear Research of the Hungarian Academy of Sciences (MTA-ATOMKI)

**Ordinary members:**
- AITA International Ltd.
- Campden BRI Hungary
- Conviva University of Budapest
- Corvinus University of Budapest (ELTE)
- Eötvös Loránd University (ELTE)
- Eszterházy Károly College, Eger
- Hungarian IPv6 Forum
- Institute for Computer Science and Control of the Hungarian Academy of Sciences (MTA-SZTAKI)
- Magyar Telekom
- OpenFuture Internet Research Group of MTA-BME
- National Media and Infocommunications Authority
- National Szechenyi Library
- Ötád University (ÖTUD)
- Pázmány Peter Catholic University
- Szent István University, Göd (SZI)
- University of Pázmán, Vaszelem
- University of Pécs (PTE)
- University of Pannonia, Veszprém
- University of Pecs (PTE)
- University of Sopron (NyEM)
- XDDC Laboratory
- 3DICC Laboratory

**Supporting members:**
- Antenna Hungaria
- Fujitsu Hungary
- IBM Hungary
- National Labour Office - ICT Dialogue Committee
- Oracle Hungary
- SafePay Systems
- SAP Hungary
- Scientific Association for Infocommunications

The Programme is supervised by a Steering Committee, the operative coordination is carried out by the Editorial Board consisting of the delegates of the member institutions.

This document presents the research results achieved in the frame of the National Research Programme. By following the structure of the Programme, the results of 83 research themes selected from JINKA2.1 are summarized.
Introduction to the Future Internet Research Results

The challenges of the Current Internet, the tangible and potential demands, and the technical opportunities determine the critical research issues, research objectives, and need the reconsideration of the classic Internet concept and the construction of the vision of the future of Internet. A layered model for clustering the Future Internet research issues is also shown as an ordering scheme to the presentation of the research results.

Future Internet Visions

Japan’s National Institute of Information and Communications Technology (NICT) prepared the first vision for New-Generation Networks (NWGN) in 2008 focusing on the technology requirements for solving social problems (energy shortage, medical care, crime prevention, technology gap, etc.) and creating new values to achieving a future knowledge society, using the NWGN [1]. Five network targets were identified for an NWGN R&D strategy, which scheme was used for the Future Internet and continuously evolved on the Future Internet Assemblies (FIA 2011 in Budapest and Poznan, FIA 2012 in Aalborg, FIA 2013 in Dublin) aiming at an intelligent, sustainable world, an innovative, secure society as a generic goal of the Future Internet [2, 3, 4, 5, 6].

A Future Internet vision is based on the standardization work of the Future Networks (FNs) performed by International Telecommunication Union Telecommunication Standardization Sector (ITU-T). The ITU-T has started the standardization of FNs as networking systems to be deployed in the 2015-2020 timeframe. FN standardization combined two complementary approaches: a top-down method starting from objectives and design goals, and a bottom-up method starting from relatively matured candidate technologies. Recommendations ITU-T Y.3001, 3011, 3021 and 3031 identify four essential objectives which were not concerned enough in designing current networks [7, 8]. The Future Network is described like Future Internet as a unified infrastructure of communication, computing and storage resources which connects and orchestrates the future Internet of people, devices, content, computers, clouds and things.

Figure 1 suggests a vision for the Future Internet, combining the research oriented NWGN vision scheme and the standardization oriented FN vision of the ITU-T, taking also into account the achievements of the Future Internet Assemblies. Figure 1 demonstrates three concepts (Internet of People and Internet of Things and their unification: Internet of Everything) as pillars, indicates the smart, high-value applications provided as services in the Cloud (smart city, home, office, intelligent transport, energy, e-business, e-government, e-health, e-education, 3D media, etc.) and shows five strategic objectives. The strategic objectives are based on the ones of the NWGN and FN visions, as follows:

- **Scalable, flexible, service aware network** refers to scalable network architecture with functional flexibility, which can accommodate wide range of services with diverse and evolving requirements. Future network architectures are expected to support not only current services such e-mail and web browsing, but also emerging services, including mission critical services, by providing additional functionality without drastic increases in communication, computing and storage resources, deployment and operational costs. Furthermore the network architecture should support advanced mobility features, enhanced reliability and security requirements. (Service awareness concept).

- **Virtual, resource aware network** refers to the virtualization of combined communication, computing and storage resources, called network resources and a unified efficient network resources management. Network virtualization means the process of partitioning of the network resources, abstracting the partitions as virtual network resources, and combining virtual network resources and network functionalities – using them according to necessity – into logically isolated software-based virtual networks. Such a way, flexible usage of the virtualized resources is allowed by the services, and multiple virtual networks can be created in a single physical network. (Resources awareness concept).
• **Data and content awareness** embraces goals on efficient usage, handling and transportation of huge amounts of various data (Big Data) generated by the Internet of Things (IoT) and the media content sources including 3D and cognitive content. Communication in current networks is based on the globally unique location identity (IID) and location based routing. If identical contents (data, information) are placed in multiple data locations, identical contents may have the same content ID and the content can be accessed via a nearest location using content ID based routing (Content centric networking).

• **Sustainability, environmental awareness** refers to energy awareness, efficient spectrum usage and any other ecological aspects. The enormous increase in Internet traffic means increase in energy consumption; hence energy awareness is a key objective (Green network). To save energy we should optimize the network to reduce the network capacity and traffic loads, as well as improve the energy efficiency using lower power electronic technology and dynamic control techniques.

• **Intelligent, innovative and secure society**, as a generic target of Future Internet, comprises the societal objectives and aspects (social interaction, augmented reality, etc.). Internet becomes essential infrastructure utility; the right to have access to a global network will be one of the fundamental rights in the future. Future Internet should consider socio-economic objectives as governance issues (e.g. the barrier to enter the market, the lifecycle cost for operation and deployment, service universalization), Internet-based innovation, the information security, personal data protection.

### Arrangement of the Future Internet Research Themes

Recent FRICG Report presents the themes and results of the research on Future Internet in Hungary. The research themes are aligned according to their code based on the classification of the Future Internet research themes elaborated and suggested by the FRCC.

Studying the research themes on the Future Internet in the literature, in particular on Future Internet Assemblies from 2010 to 2013 [2, 3, 4, 5, 6], Working Programme of Horizon2020 (9) as well as the Hungarian Future Internet research activity, including 132 themes [10], the relevant research topics can be identified and arranged into main research areas. We defined the main research areas as the chapters of Future Internet research activity in a layered model from basic research on Internet Science through Internet Engineering up to Future Internet applications and experiments [11]. Figure 2 shows the nine layered chapters and their main research goals and spheres. The Internet Science basic research is Chapter 1, the Internet Engineering applied research is divided into five chapters (Chapter 2…6), the applications and experiments are comprised in three chapters (Chapter 7, 8 and 9). Figure 2 also indicates the possible relations of the chapters to other research goals and spheres. In the following the research chapters and their relevant topics, topic ranges are presented [12].

#### 1 Internet basic research (Internet Science)

Internet Science aims at an integrated and interdisciplinary scientific understanding of Internet networks and their co-evolution with society, embracing all disciplines which study Internet from any technological or humanistic perspective. Relevant research topics are:

- Network science: modelling and investigating large scale networks;
- Computer science, from computational theory to computer architecture;
- Basic enabling technologies, as quantum and nanotechnologies, etc.;
- Cryptography, cyber security;
- Human aspects: social and behavioural attributes, trust and aversion, cognitive processes and biases, social networks;
- Network economics, game theory;
- Legislation and governance (privacy, data protection, net neutrality …).

#### 2 Future Internet modelling, analysis and design

These research topics target the modeling of future internet enabling infocommunication systems, network concepts and technologies, for analyzing their performance, scalability, stability, availability, resilience, quality of service, etc. as well as the elaboration of novel analysis and design paradigms. Relevant topics are as:

- Network modelling and performance analysis;
- Queueing systems: traffic analysis and design;
- Communication systems: modulation, coding, access, spectrum usage;
- Resource allocation and optimization methods;
- Investigating networking media services: video streaming, VoIP, IPTV;
- Monitoring, failure exploration.

#### 3 Future Internet network architectures

Novel architectural solutions are needed to meet the societal challenges, which the Current Internet may not be able to support sufficiently. This central research area focuses on service aware network architectures, new protocols, virtualization of resources, mechanism enhancements, as:
8 Future Internet community applications

Users demand "always on" access to cheap, easy-to-use, secure, mobile, personalized and context-aware applications, which are to be realized over highly interconnected, increasingly complex infrastructures. Internet of Things is implicated for smart environments and smart spaces. Cross-disciplinary research challenges should be addressed:

A) Mobile crowd-sensing platform and functions;
B) Smart home and office applications;
C) Smart health and well-being applications;
D) Smart business applications;
E) Smart governance applications;
F) Other intelligent and cognitive community applications.

9 Experimentation, standardization, regulation

Themes of this practical chapter embrace the requirements and design of comprehensive test facilities, the federation of test-beds, the technical and social experiments, the standardization activity as well as the emerging complex regulatory issues. The relevant topic ranges are defined as:

A) Experimental systems, test-beds;
B) Experimental methods, demonstrations, field results;
C) Socio-economic studies, business models;
D) Technical standards, recommendations, standardization issues, e.g., identification, communications, virtualization, interoperability, security;
E) Technical, economic and content regulatory issues.

Each research theme registered in the Future Internet National Research Programme (JINNAK) was classified according to this arrangement, and has a identifying code with a form of TNMP, where T denotes the topic range, N(A, B, C, D, E) the relevant topic range within the chapter, P(1, 2, 3) the number order within the topic range, e.g.: TNMP. JINNAK2.1 contains 132 registered research themes, arranged into the 52 topic ranges [10]. In some topic ranges there is no registered theme, in others there are five or more registered themes.

This FIRCC Report presents the results of 83 research themes selected from JINNAK2.1. By chapters, grouping into topic ranges we enumerate the registered research themes and present the selected ones, including the short description of the theme and results, as well as the international relations and the main publications.
INTERNET BASIC RESEARCH

Topic ranges, research theme reports and further registered themes:

A) Network science: modelling and investigating large scale networks
   - T1A1 Theoretical foundation of infocommunication networks
   - T1A2 Models and analysis of large networks and their processes
   - T1A3 Theory and mathematical modelling of large networks

B) Computer science, from computational theory to computer architecture
   - T1B1 Unconventional computing paradigms and architectures
   - T1B2 Investigations relying on set approximations
   - T1B3 Process algebra
   - T1B4 Non-classical logics and their applications in coding theory and AI

C) Basic enabling technologies, quantum and nanotechnologies
   - T1C1 Molecular switches as information storage systems
   - T1C2 Information processing, encryption and transfer based on quantum mechanical principles
   - T1C3 Device-independent quantum information processing

D) Cryptography, cyber security
   - T1D1 Data security, cryptographic protocols
   - T1D2 Research for secure Internet - Malwares
   - T1D3 Software security questions of the Future Internet
   - T1D4 Network security procedures, firewall models and rules
   - T1D5 Security of critical systems

E) Human aspects: social and behavioural attributes, trust, cognitive processes, social networks
   - T1E1 Role of trust in digital world

F) Network economics, game theory
   - T1F1 Game theoretic approaches in Internet economics

G) Legislation and governance, privacy, data protection, net neutrality
Theoretical foundation of infocommunication networks

A well-known feature of large real-life networks is their scale-free property, in other words power law degree distribution. The WWW, several social and biological networks are scale-free. To describe the evolution of networks in 1999 Barabási and Albert offered the preferential attachment rule. We studied a network evolution model which is based on the interactions of N nodes. In our model the preferential attachment rule is combined with the uniform choice of nodes. The interactions of a node are described by its weight. We proved scale-free properties for the weights and the degrees of nodes. Moreover, we proved asymptotic theorems for the degree and weight of a given vertex, we also described the asymptotic behaviour of the maximal degree and the maximal weight. We gave numerical evidence for our mathematical results. We analysed by computer simulation several characteristics of our model, moreover we studied mixtures of models. To understand the properties of networks, results on discrete random structures can be useful. The generalized allocation scheme is a framework which contains several models such as the usual allocation and certain random forests. We obtained several theorems for that scheme. Among others we obtained strong law of large numbers for trees with k vertices in the random forests. We defined new versions of the generalized allocation scheme. We described their asymptotic behaviour: We obtained limit theorems for the number of cells containing k particles.

International relation:
- A topic in Theme 1 of FIRST project (TÁMOP-4.2.2.C-11/1/KONV-2012-0001, Hungary)

Relevant publications:

Models and analysis of large networks and their processes

We have shown that deterministic and non-deterministic property-testings are equivalent in the case of dense graphs. A further main result is that the limits-objects of local-global convergence are the grafings. It was proved that the convergence of dense graphs is equivalent to the convergence of the relevant models in statistical physics. Several basic parameters of large networks were studied, e.g. how much the degrees of the nodes determine the properties of the entire network. A low-latency algorithm was constructed for listing all the graphs realizing a given degree sequence, and it was also analysed how far graphs of a given degree sequence can be apart from each other. Several parameters of large networks (the Internet, social and communication networks) were studied from the point of view of the application of different sampling techniques. In the field of the investigation of networks, determining the shortest paths between all pairs of nodes is an important tool. Regarding this problem, a new algorithm was given for certain non-conservative weighted graphs, and efficient algorithms were constructed for solving minimum-cost flow problems. According to the measurements, these algorithms proved to be far faster implementations than the other available programs. The complete selection of codes is available in the software library LEMON.

International relation:
- A topic in Theme 1 of FIRST project (TÁMOP-4.2.2.C-11/1/KONV-2012-0001, Hungary)

Relevant publications:
6. A low-latency algorithm was constructed for listing all the graphs realizing a given degree sequence, and it was also analysed how far graphs of a given degree sequence can be apart from each other. Several parameters of large networks (the Internet, social and communication networks) were studied from the point of view of the application of different sampling techniques. In the field of the investigation of networks, determining the shortest paths between all pairs of nodes is an important tool. Regarding this problem, a new algorithm was given for certain non-conservative weighted graphs, and efficient algorithms were constructed for solving minimum-cost flow problems. According to the measurements, these algorithms proved to be far faster implementations than the other available programs. The complete selection of codes is available in the software library LEMON.
We study how to find shortest path in weighted graphs. Namely, we investigate first passage percolation on inhomogeneous random graphs. In the random graph model we study, each vertex has a type from a type space $S$ and edge probabilities are independent, but depending on the types of the end vertices. Each edge is given an independent exponential weight. We determine the distribution of the weight of the shortest path between uniformly chosen vertices in the giant component and show that the hopcount, i.e. the number of edges on this minimal weight path, possesses a central limit theorem. Barabási introduced a priority model in his paper: A.L. Barabási, The origin of bursts and heavy tails in human dynamics, Nature, 435 (2005), 207-211. We generalized this Barabási’s priority model. We generated complex networks models from fractals. These networks are deterministic networks and show the same features as the real life networks and the most well-known random network models. We studied clustering and bi-clustering of networks. Namely, we used the normalized modularity matrix to find volume-regular cluster pairs of the vertices of an edge-weighted graph with small discrepancy. For dense large, edge-weighted graphs we proved that the existence of k-1 eigenvalues of the normalized modularity matrix, separated from 0, is an indication of a k-cluster structure and the clusters themselves can be recovered by applying the k-means algorithm for the vertex representatives obtained by the eigenvectors corresponding to these structural eigenvalues.

International relation:
* A TAMOP-4.2.2.C-11/1/KONV-2012-0001 FIRST projekt 1.2e.

Relevant publications:
- Istvan Kolossvary, Julia Komjáthy, László Vágó. Degrees and distances in random and evolving Apollonian networks, submitted, CPC.

Future Internet requires new approaches, such as new architectures, new ways of managing data. The goal of our research is the investigation of formal models based on novel, unconventional paradigms of computation in order to study different types of parallel architectures and the formulation of dynamic, decentralized and parallel interaction models which might provide a theoretical basis of Future Internet architectures. Our objectives include the study of unconventional automata providing models for parallel computation. With Friedrich Otto (Kassel, Germany), we introduced cooperating distributed systems of stateless restarting automata, which are able to efficiently describe rational and context-free trace languages (traces are formalisms describing parallel processes), see publication 4. below. We also studied the computational power of Watson-Crick automata (publication 3.) and the properties of different, massively parallel membrane computing algorithms for the solution of the satisfiability problem of Boolean formulae (publication 5.). Concerning membrane systems as parallel computational models based on the so-called chemical computational paradigm, in cooperation with Erzsébet Csuha-Vajda (Eötvös Loránd University, Budapest), we also studied membrane automata and their relationship of so called restricted counter machine acceptors (publication 1.), and the programs specified in the so called “higher order chemical language” of J.Baratint, P.Frada, V.Radenac (publication 2.)

International relation:
* Topic 1.2 of project TAMOP-4.2.2.C-11/1/KONV-2012-0001.

Relevant publications:

ETIK BME Dept. Stochastics
Károly Simon, simonk@math.bme.hu

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Theory and mathematical modelling of large networks

Unconventional computing paradigms and architectures

Maria Bolla, Spectral Clustering and Biclustering, J. Wiley, 2013.
Investigations relying on set approximations

Aim: Studying theoretical background of decision systems without certainty and building practical models for such systems.

Results: Generalizing rough set theory considering partial knowledge about the objects of interest. Giving non-Pawlakian approximation pairs and formulating partial fuzzy membership functions with the help of them. Elaborating a new clustering algorithm based on partial approximation spaces. Developing a new logical system investigating semantic values of predicate parameters based on the set-theoretical partial approximation framework. Constructing a practical model that adequately reflects partial nature of real-life problems, and demonstrating how it works. Generalizing set approximation for multisets and applying it to membrane computation, in particular, forming abstract notion of membrane boundaries.

International relation:
• A TÁMOP-4.2.2.C-11/1/KONV-2012-0001 Project FIRST Theme 1.2d.

Relevant publications:

Non-classical logics and their applications in coding theory and AI

The aim of the research is the investigation of certain non-classical logics, and their applications in the fields of coding theory and artificial intelligence (AI). A particular attention is devoted to substructural logics and their algebraic counterparts, called residuated lattices. Substructural logics encompass among many others, classical logic, intuitionistic logic, superintuitionistic logics, relevance logics, many-valued logics, mathematical fuzzy logics, linear logic, and their non-commutative versions. The result of the research comprises several constructions, structural descriptions and also classifications of certain classes of residuated lattices related to Involutive Uninorm Logic.

International relation:
• Cooperation with University of Siena and Johannes Kepler University of Linz.

Relevant publications:
Information theoretical research of information processing, encryption and transfer based on quantum mechanical principles

Quantum walks, the generalizations of random walks are prevalently investigated model systems of quantum information research. Supplemented with the definition of a measurement protocol they yield a classical stochastic process which is a possible model of an information source involving quantum elements. One of our aims is the investigation of such systems. We also investigate transformations of the quantum state of a system used for information processing which are not feasible due to fundamental physical limitations. We determine their approximate realizations via semi-definite programming and analyze their properties.

International relations:
• Research Centre for Quantum Information, Slovak Academy of Sciences, Bratislava, Faculty of Informatics, Masaryk University, Brno (informal collaborations)

Relevant publications:
2. L. Dani and M. Koniorczyk: 1 to 2 qubit cloners via semidefinite programming, poster, 10th Central European Quantum Information Processing Workshop 5-9 June 2013, Valtice, Czech Republic

Device-independent quantum information processing

Quantum nonlocality is a central aspect of quantum mechanics, and it is instrumental in device-independent quantum information processing. As the effect of nonlocality is not falsifiable, this way the appropriate functioning of a device may be checked without knowing the details of its inner mechanism. Several quantum information tasks can be accomplished and made more secure in a device-independent manner. We have been working in this framework. We have devised simple and general dimension witnesses for quantum systems of arbitrary Hilbert space dimension. They can be used to test the dimension of an unknown physical system in a device-independent way. We have also been able to find protocols in the multipartite setting by exploiting the rich structure of multipartite nonlocality. The limited efficiency of the present photon detectors makes the application of some quantum information protocols impractical. We have shown that for multipartite systems the required detection efficiencies can be significantly lowered compared to the bipartite case. The notion of nonlocality is strongly connected to entanglement, but their relation is still not fully understood. We have achieved some progress in this direction. We have shown that, contrary to what previous work suggested, quantum nonlocality does not imply entanglement distillability. We have also shown that the nonlocal character of a multipartite quantum state may be proven by only having information about its separable subsystems. We have discovered a link between the behaviour of nonlocality under particle loss in multipartite quantum systems and the symmetry of the state, which leads to a device-independent estimation of the asymmetry.

Relevant publications:
Data security, cryptographic protocols

We deal with security evaluation of cryptographic protocols, especially we research anonymity and its applications. We introduced several e-voting, e-exam and e-payment schemes reaching higher level of security. We have analysed a key exchange protocol, it is based on the difficulty of solving diophantine equations. We have investigated possible solutions of message authentications in client-server systems operating in broadcast mode. We have developed a modified version of protocol TESLA, which tolerates longer stops on server side. We have developed theoretical bases of a pseudorandom number generator based on normal distributions. We have examined the possible applications, especially for lattice based encryption that is one of the most well-known candidates in post quantum cryptography. We could implement a pseudo random number generator on FPGA, that is more efficient, then the traditional constructions.

International relations:
- Investigation of the ASP-COM communication protocol with encryption algorithms and web 2.0 driver for the actuation of the RKV ASP

Relevant publications:
- Levente Buttyán, buttyan@crysys.hu

Research for secure Internet - Malwares

While the Internet has a tremendous positive impact on our life, it is also source of and place for malicious and criminal activities. We are exposed to spam and web pages that host malicious content and software (malware). Malware received in e-mail attachments or through infected web sites take control of machines of millions of users, and attackers use those compromised hosts to build remotely controllable botnets. Botnets can be used to launch large scale attacks on major services or on the Internet infrastructure of an entire nation. Web based services are attached routinely gaining access to personal information which is used for identity theft and privacy violations. Behind all these attacks, there is a well-organized underground world of criminals with their own currency (bitcoin) and ecosystem. The problem is global, and the resulting loss can be measured in billions of dollars per year.

We are focusing on the detection and analysis of previously unknown malware, and on efficient incident response techniques. As in the Future Internet there will be more embedded systems than regular PCs, we also look at security problems in embedded systems including mobile platforms, industri-al networks, and sensor and actuator networks. One major problem is the information asymmetry between attackers and defenders: attackers know almost everything about protection tools, while defenders know almost nothing about attacking techniques. In order to overcome this problem, we study the possibility of using honeypots and honeystones. Finally, an important part of our research is to develop privacy enhancing technologies for social networks and to prevent the tracking of web users.
Software security questions of the Future Internet

Nowadays with the increasing number of attacks everywhere around the world the issue of IT security is becoming more essential than ever. One of the most significant parts of the security of information systems is the security of the applications. Attacking techniques will be presented on the basis of the attack forms of the future will be the return oriented programming and the jump oriented programming. The aim of this research is to improve the theoretical background of the internet of the future for the sake of the safety of the compiled code and the operation systems. As the protection of the operation systems and the compilers is getting stronger the attack methods are getting more sophisticated too. Thus the basis of the attack forms of the future will be the return oriented programming and the jump oriented programming. During the research the so-called dispatcher gadgets - that are the most critical parts of the jump oriented programming – are investigated. They are special memory parts in the shared libraries that direct the run of the jump-oriented programs. During the research the demand is a kind of simplified description of the attacking code in the case of both return and jump oriented programming.

Relevant publications:

Game theoretic approaches in Internet economics

In recent years, there has been an increasing interest in the socio-economic aspects of network systems. As an example, recent research initiatives promote economic incentives as a first-order concern in future network design. Decision-makers trying to work out a plausible solution for the telecommunication and Internet markets would greatly benefit from an in-depth understanding of economic processes inside the user-ISP hierarchy. Furthermore understanding the impact of end-users’ behaviour on the operation as well as the business of the current Internet is crucial for designing a successful Next Generation Internet. To understand economic behaviours when multiple stakeholders are involved, game theory can be an efficient tool to apply. In our work, we focus on the application of game theory in three areas, namely, the pricing of Internet access under user loyalty, game-theoretic analysis of IPv4-IPv6 migration process; design and analysis of spectrum auction based on game-theoretic methods. With respect to game-theoretic analysis of Internet access pricing, the loyalty model was applied in a game-theoretical framework where optimal Internet access pricing strategies are expressed. The game-theoretic framework includes both short-term and long-term interaction cases (single-shot and repeated games, respectively) and is capable of dealing with uncertain as well as dynamic scenarios (Bayesian and Stackelberg games, respectively). Next, IPv4-IPv6 migration process was modelled using game-theoretic approaches where the utility functions of different stakeholders are considered and based on the game-theoretic approaches, economic aspects of IPv4-IPv6 were investigated. Finally, based on game-theoretic models, 900 MHz spectrum auctions were designed and implemented.

Relevant publications:
Topic ranges, research theme reports and further registered themes:

A) Network modelling and performance analysis
   T2A1 Future Internet network modelling
   T2A2 Planning and optimization of secure IT infrastructure and services

B) Queuing systems: traffic analysis and design
   T2B1 Planning methods to Future Internet networks

C) Communication systems: modulation, coding, access, spectrum usage
   T2C1 Cognitive wireless infocommunication technologies
   T2C2 Routing and spectrum allocation in spectrum elastic optical networks

D) Resource allocation and optimization methods
   T2D1 Scalable resource allocation algorithms for Future Internet
   T2D2 Spectrum allocation and cooperation techniques

E) Investigating networked media services: video streaming, VoIP, IPTV
   T2E1 Online analysis of media QoS/QoE on high speed networks

F) Monitoring, failure exploration
   T2F1 Monitoring network topology, localizing faults
Future Internet network modelling

We have introduced a finite source retrial queueing model to investigate the performance characteristics of the wireless transmission problem in sensor networks. The results of the work were the computation of the system characteristics of different models. A sensor network with two different types of finite sources (emergency and normal) expanded with non-reliable server, network of sleeping state sensors. A model with multi-state server’s breakdowns.

Wireless networks are increasingly exposed to the risk of unauthorized access. There are encryption standards to encrypt data traffic to ensure the safety of wireless networks. Our question is to what extent the security of the network affects network performance. The answer of the question that encryption should be used because it does not cause too significantly slower speed. In wireless networks where devices on the network are compatible and security matters, always should be used WPA2/AES encryption. The weaker encryptions switch back the more modern devices, on the older devices do not give a significantly better rate, but their security is worse. If speed is more important than safety (e.g. media playback with wireless), you can disable the encryption speed of 10-30 per cent gain can be obtained.

We have created a model of information spreading in real social networks. We have worked out a well tuneable method to generate a large variety of scale-free networks, which have different topological properties. We managed to find a smaller range of the wild parameter space, where the generated networks behave like real social networks. Using these networks we have founded out that in social network which are in declining phase of their lifecycle the speed of information spreading is slower, so the efficiency of advertisements are smaller.

Our purpose is to create a mathematical model describing the transmission of optical signals. Generally, we try to get analytical results; if it is too complicated one uses the simulation. In this case it is useful the regenerative approach, we illustrated it on the M/G/1 system and it led to the Pollaczek-Khinchin formula. The transmission of optical signals was described by an embedded Markov chain; we proved the possibility of its application and found the transition probabilities when the system was characterized by the number of present customers.

International relation:
- Theme 2.1 of FIRST project (TÁMOP-4.2.2.C-11/1/KONV-2012-0001, Hungary)

Relevant publications:
Planning methods to Future Internet networks

Our working group carried out research in two main topics throughout the year. The first one was the modelling of queueing systems and the analysis of these models. The second one was the investigation of Markovian and canonical representation of different Markovian structures. Our aim was to extend the theoretical background that can be used in the planning of Future Internet networks.

Analysis and modelling of queueing systems: We introduced a generalised model for the investigation of performance parameters based on the sQ100 benchmark of Standard Performance Evaluation Corporation SPECpower. We achieved important results for MM/1/G/1, MM/c-retrial queueing systems, for M/M/1 queues with negative requests and working vacation, and for queues with two priority classes and feedback control. We developed efficient algorithms for the calculation of the steady state probabilities and other important measures of these systems. In the M/M/c queue’s case we worked we simplified equations, in the other cases we were able to derive exact equations. We also demonstrated the behaviour of some of these systems using numerical examples. We developed a model for opportunistic spectrum renting in cellular mobile systems with a spectrum pooling approach. We made a recommendation for a cooperation scheme and modelled this approach and showed that this model can be used to determine the performance measures of the system in case of lognormal holding times.

Analysis of Markovian and canonical representation of Markovian structures: We developed a heuristical algorithm for numerical transformation of rational arrival processes to Markovian representation with a significantly better performance than prior methods. Our algorithms included a method for the case where the size of the representation had to be increased.

We produced foundational results for canonical representation of Markovian structures. We determined canonical representation sets for both order 2 and order 3 DPHs. Using these canonical structures we developed fitting algorithms for order 2 DPHs and DMAPs.

Relevant publications:


Cognitive wireless infocommunications technologies

The research programme “Wireless Cognitive Infocommunications Technologies” deals with the main aspects and the establishment of terrestrial radio using cognitive devices. In the first phase of the project we overview the state of the art, based on international publications. We summarize the knowledge relating to the spectral bands in cognitive radio (CR), overview the equipment and technologies in the CR field and the applicable modulation technologies. We discussed the use of software-radio devices and specific equipment are also introduced. We are dealing with the spectrum management and overview the devices that are capable for this kind of operation. Measurements are prepared in order to survey the use of TV bands and the frequencies of mobile radio access network. We design a wide band omnidirectional antenna and develop measurement technologies and software tools for data processing. Measurements are performed in several frequency bands using USRP and spectrum analyser: digital terrestrial TV bands (DVB-T), the frequency bands of the mobile access network and the ISM band between 2.3-2.6 GHz. We are dealing also with automatic spectrum detection and user identification which is an emerging technology in the theme of spectrum management.

International relation:
- The 3.5 theme of project TÁMOP-4.2.2.C-11/1/KONV-2012-0001 FIRST closely related to EU FIRE (Future Internet Research and Experimentation) initiatives.

Relevant publications:

Routing and spectrum allocation in spectrum elastic optical networks

The gridless spectrum elastic optical networks will provide a more elastic and more efficient bandwidth utilisation. The OOFDM (optical orthogonal frequency division multiplexing) modulation is one of the solutions, where the capacity of multiple small-bandwidth subcarriers is utilised jointly in elastic way. Here we perform routing, protection and grooming jointly with elastic spectrum allocation. The emphasis is on algorithms and their evaluation. So far we have proposed and evaluated the Spectrum aware shortest path routing method with various spectrum filling strategies for routing and spectrum allocation. End-to-end grooming and dedicated path protection methods are implemented. We work towards shared path protection and distributed traffic grooming. We have proposed a new Routing and Spectrum Allocation (RSA) method that searches for the shortest path while considering the used parts of the spectrum along all the links, i.e., the shortest path is found among those, that have sufficient free contiguous spectrum along all of its links. We have implemented and evaluated various spectrum filling strategies.

Scalable resource allocation algorithms for Future Internet

Scalable data centre (DC) architectures have been proposed and investigated; multipath TCP protocol implementations have been tested and evaluated, and resource allocation mechanisms have been researched. The increasing popularity of both small and large private clouds and expanding public clouds pose new requirements to DC architectures. First, DC architectures should be incrementally scalable allowing the creation of DCs of arbitrary size with consistent performance characteristics. Second, initial DC deployments should be incrementally expandable supporting small-scale upgrades without decreasing operation efficiency. A new scalable DC architecture has been proposed possessing both properties.

Multipath TCP implementations have been tested and evaluated on GEANT OPEN Flow environment and PlanetLab. The performance of the protocol has been evaluated by extensive measurements on these platforms.

Weighted proportional allocation mechanisms (as possible models of bandwidth sharing) have also been investigated and shown that certain constrained optimization can help in identifying the state space of these models.

International relations:

• CAIDA, UCLA, USA,
• University of Cambridge, UK
• NTNU, Norway

Relevant publications:


László Gyarmati, Balázs Sonkoly, Gergely Biczók, Free-scaling your data center, Computer Networks, Volume 57, Issue 8, 4 June 2013, pp. 1758-1773
Presently, mobile network operators have exclusive right for the use of given frequency bands, which were assigned to them by the governments on spectrum auctions. Each mobile operator is restricted to its dedicated channels when allocating an incoming call and the requests for speech channels will be rejected if the dedicated speech channels are occupied. However, the exclusive frequency usage may lead to an inefficient use of the spectrum. To handle the inefficiency, several researchers proposed spectrum sharing techniques such as spectrum renting or opportunistic spectrum access (OSA). In our work, we focus on the model operation and give a detailed description about the opportunistic spectrum access policy. In a nutshell, the mobile operators can opportunistically rent each other’s unutilized frequency bands (blocks of speech channels). If a certain mobile operator must withdraw its own frequency band for serving its incoming call, the renter operator must vacate the rented frequency band. Therefore, the frequency withdrawal leads to the forced termination of ongoing calls served on the given frequency band. In our proposal, we apply a call admission control procedure to decrease the forced termination probability.

Relevant publications:
Future Internet Network Architectures 03

Topic ranges, research theme reports and further registered themes:

A) Future Internet network requirements and concepts
   T3A1 Reliable and scalable Future Internet with network coding

B) Future Internet routing methods, transport protocols, path selections
   T3B1 Transport protocols for Future Internet
   T3B2 Self-organized networks
   T3B3 Optimisation of multicast trees with protection
   T3B4 Distributed, dynamic and proactive mobility management in IPv6 networks
   T3B5 Modelling of multicast routing protocols

C) Mobile networking technologies: mobility handling, FMC, 5G network infrastructure
   T3C1 Efficient methods for mobile content distribution
   T3C2 Methods for energy efficient operation of FMC networks
   T3C3 Investigation of multihoming support using VoIP communications on mobile devices

D) Future media networks, content-centric networks, content delivery networks
   T3D1 New network architectures and methods for 3D media delivery

E) Network computing: ubiquitous, grid, cloud computing
   T3E1 Network computing - Cloud systems

F) Virtual networks, software defined networks, network function virtualization
   T3F1 Implementing new addressing schemes in Software Defined Networks

G) Cloud infocommunications
   T3G1 Security, compatibility, interoperability issues of cloud infrastructure and their solutions
**Reliable and scalable Future Internet with networking coding**

With the rise of Future Internet applications service providers are pushed towards building connections with higher reliability and lower delay between the communication endpoints. In the topic we are focusing on protection and restoration approaches with network coding and the corresponding routing and optical failure localization problems, which can provide a reliable and scalable transport networks infrastructure for Future Internet. In specific, our goal is to investigate the possibilities and scope of the application of network coding in transport networks, and implement a scalable and robust network coding architecture in OpenFlow, which provides a highly available backbone network infrastructure for Future Internet applications.

Our research focus is mainly on the minimization of the number of network coding nodes, as well as on the complexity of the coding operations which have to be performed to provide capacity-efficient protection with instantaneous recovery. Furthermore, novel multi-path routing schemes and failure localization algorithms are required, which supports this novel way of information delivery.

**Transport protocols for Future Internet**

In our research we have worked out the concept of a novel transport protocol without congestion control (DFCP, Digital Fountain based Communication Protocol), which can provide a serious alternative to the currently used TCP for future networks. We designed and built a testbed and a simulation environment in which our transport protocol and widely used TCP variants can be investigated. The operating mechanism and the main features of DFCP have been validated on three different platforms: including a laboratory testbed, the Emulab network emulation environment and the ns-2 network simulator. A performance comparison with different TCP versions (TCP Cubic, TCP NewReno) was also carried out on various network topologies. The multi-platform test environment makes performance evaluation possible both on complex topologies and in realistic network conditions. In this environment we investigated many important properties of DFCP and TCP including the sensitivity to packet loss and round-trip time, the buffer space demand, the fairness behaviour in case of competing flows, as well as the performance in networks with multiple bottlenecks. The results pointed out that DFCP can provide efficient data transfer in various network conditions even when TCP suffers from performance degradation.
Self-organized networks

Our goal was to focus on networking solutions and protocols, which can provide the autonomous operation of self-organized networks, using bio-inspired techniques. We have developed a new communication protocol, the Direction Based Handshake Gossiping (DiBHG), which was implemented in our self-organizing network simulator, together with three other location based data dissemination protocols from the literature. The results showed that our solution outperforms the other three solutions. To be able to carry out more complex examinations by using a realistic and detailed model of wireless communication, we have demonstrated a new research platform, integrating the M7 Proto spatial computing suite with the OMNeT++ network simulator framework. To demonstrate the enhanced capabilities gained from integrating these two systems together, we have implemented an urban target-tracking scenario. We have also implemented our DiBHG protocol in the Proto spatial computing system. From the simulation results it can be observed, that the implementation of the DiBHG protocol was successful, we can achieve a more energy efficient functioning of the system when trying to disseminate static information in the network. Implementing the DiBHG protocol in Proto and making it available in an easy to use Proto plugin takes it one step further, to enable Proto become a real life spatial computing system and move away from “simulator only” use. We are planning to put this (or these) protocol(s) to an emergency simulator. As in this case the hazard is coming from a well-defined location, so it will be important to keep the communication in the right direction: from the sensor node which have identified the source of the fire, to the other nodes directing them the exits. This way our solution can be tested in a real life application, measuring the performance of our algorithm in a use case scenario, which can save lives in our everyday urban environment.

International relations:

- The 3.3 research theme of the TÁMOP-4.2.2.C-11/1/KONV-2012-0001 FIRST national project. At international level: close cooperation and joint publication with Jacob Beal (Massachusetts Institute of Technology), the developer of the Proto spatial computing language.

Relevant publications:


Optimisation of multicast trees with protection

The main motivation of this research is the spreading HD video multicast. In a two-layer optical board network the content or signal multiplication is performed either by the upper electronic layer or by the lower optical layer. For this architecture we have proposed models and algorithms for defining the multicast tree and we have evaluated them by simulations. The methods define the trees along with their branching method and layer as well as various protection approaches and methods for restoring parts of the tree for various failure cases. We propose a new, faster way of restoring multicast demands after link failure that is based on preplanning. We prove its optimality if a few preconditions are met. To do so a new formalisation of the wavelength graph transformation (WGT) is presented. We show, based on simulations, that the beneficial properties of our method hold even when one or more preconditions are not kept. We have used the wavelength graph model that allows decomposing the problem to sub-problems of smaller dimension and solving them separately. Our methods gain on their importance as the amount of the content spread over the Internet grows.

International relation:

- University of Montpellier, France

Relevant publication:

**Distributed, dynamic and proactive mobility management in IPv6 networks**

Existing wireless and mobile telecommunication infrastructures are not prepared to handle the traffic increase prognosticated by the emerging application areas of mHealth, M2M, C-ITS, etc., and the novel mobility scenarios in heterogeneous radio environments of the near future. As a consequence, architectural changes are required for dealing with the ongoing traffic evolution and the more frequent IP level handover events. In our researches we analysed issues of scalability and advanced mobility use-cases, and proposed a special, Host Identity Protocol based, distributed, dynamic and proactive mobility management architecture called UFA-HIP. The proposed scheme was extensively analysed in a complex, INET/OMNET++ based simulation environment.

**International relations:**
- Task 3.3 of EURESCOM P1857 (http://archive.eurescom.eu/Public/Projects/P1800-series/P1857/)
- Theme 3.4 of IST project (TANDEM-4-2.2.2.1/1/305-2012-0001, Hungary)

**Relevant publications:**
1. László Bokor, Zoltán Fasig, Sándor Imre, Flat Architectures: Towards Scalable Future Internet Mobility. LECTURE NOTES IN COMPUTER SCIENCE 6636: pp. 35-50. (2011)

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**Modelling of multicast routing protocols**

The deployment of the IPv6 protocol and the fast spread of the IPTV solutions make the modelling of the multicast routing protocols a hot research topic. Our results include:
- The survey of the different multicast routing protocols and their most important characteristics.
- Examination of the fault tolerance of the PIM-SM (Protocol Independent Multicast - Sparse Mode) protocol by a series of experiments with different fault scenarios and preparation of theoretical models for the service outage time.

Our goals include:
- The survey of the popular network simulators: how and to what extent do they support the different multicast routing protocols?
- The selection of a promising network simulator for the extension of its multicast routing model.
- The design, implementation, verification and validation of the new modelling elements.
- The demonstration of the capabilities of the completed simulation environment by the modelling of a complex real life multicast system.

**Relevant publications:**
Methods for energy efficient operation of FMC networks

In the access part of the Future Internet the fixed and mobile access is expected to converge not only to better utilize the resources, but also to decrease the power consumption, to increase the availability and also to improve the QoE of users. We present architectures and algorithms to show what energy saving benefits can be reached. We support our approach by intensive simulations. The electric energy consumption (kWh) grows from year to year. The share of Information and Communications Technologies (ICT) grows even faster. In this paper we focus primarily onto reducing energy consumption of the access part of modern heterogeneous mobile networks that leads to “greening” of this part of the network. The idea of our “greening” algorithm is based on selective switch-off and on consolidation of resources, employed jointly with both, the vertical and the horizontal handover (handoff). We demonstrate the energy saving benefits by simulations. We show two simulation scenarios. First, the right architecture and right topology can significantly enhance the availability figure of the network while the CAPEX is negligibly increased. Second, in morning and afternoon busy hours when masses of people commute the power consumption is increased; however, after busy hours it is again reduced, only the territorial distribution of power consumption decreases.

Investigation of multihoming support using VoIP communication on mobile device

The research focuses on the increasingly popular mobile clients, which connect to the internet using networks of various providers (ISP), which are different from numerous points of view. The handover, caused by the mobility of clients, may cause problems in applications, where the uninterrupted connection and the quality of service support are both necessary (e.g.: VoIP). Our plan is to devise a method, which secures continuous connection while maintaining the required service quality. We plan to achieve this by utilizing parallel connections and by switching between them in an efficient way. One of our conclusions is that the network layer that is being used nowadays to solve this problem is not the best possible choice. Instead, the OSI transport and session layers seem to work better. Concerning HSDPA we found that setting the frame size to a proper value results in a reduction of delay in radio access network.
New network architectures and methods for 3D media delivery

Free Viewpoint Video is special category of 3D video, allowing users to freely change their viewpoint. In our research works we focused on 3D Free Viewpoint Video transmission in IP networks, viewpoint synthesis and distributed viewpoint generation architectural model and caching solutions. We proposed an energy efficient caching scheme that keeps balance between the consumed energy and the cache delay. We analysed the optimal cache size and the caused delay using the on-off based energy efficient method. A software tool was also implemented to find the optimal topology for the distributed viewpoint generation topology. The developed software is capable to find the best topology setup and serve the clients requesting the lowest occupied bandwidth in the network. Our third task was to propose a multicast scheme in order to decrease the required time of new viewpoint stream pay-out in FVV streaming service. As a first step we analysed the multicast group changing delays in the implemented NS2 simulation environment. Finally a viewpoint predictive based multicast FVV streaming scheme was developed that is able to prevent the FVV viewpoint synthesizer algorithm from starvation. The obtained results show, that requested camera views for the viewpoint generation arrives in time to the client and no interruption occurs during the pay-out in 95% of the cases.

International relations:
• EGI-InSPIRE / European Grid Initiative: Integrated Sustainable Pan-European Infrastructure for Researchers in Europe (FP7 RI-261323),
• CloudSME / Cloud Simulation for Manufacturing & Engineering (FP7 608886),
• SCI-BUS / Scientific Gateway Based User Support (FP7 RI-283481),
• agINFRA / A data infrastructure to support agricultural scientific communities (FP7 RI-283770)

Relevant publications:

Network computing - Cloud systems

Further research on cloud systems is an essential part of the infrastructure serving the goals of Future Internet. This research addresses or involves their optimal usage, security issues, handling big data, automatic deployment of high performance and high throughput computing systems, and creation of cloud federations. One of the important achievements enabled the full range monitoring and performance analysis in the framework of accreditation of cloud systems. Moreover, solutions for automatic scaling and deployment of dynamic, cloud-based e-infrastructure became available in the European federated cloud and also for other cloud-based initiatives.

International relations:
• A TÁMOP-4.2.2.C-11/1/KONV-2012-0001 FIRST project 3.6 theme Participation in EU FP7 Concerto project.

Relevant publications:

Network computing - Cloud systems

Further research on cloud systems is an essential part of the infrastructure serving the goals of Future Internet. This research addresses or involves their optimal usage, security issues, handling big data, automatic deployment of high performance and high throughput computing systems, and creation of cloud federations. One of the important achievements enabled the full range monitoring and performance analysis in the framework of accreditation of cloud systems. Moreover, solutions for automatic scaling and deployment of dynamic, cloud-based e-infrastructure became available in the European federated cloud and also for other cloud-based initiatives.

International relations:
• A TÁMOP-4.2.2.C-11/1/KONV-2012-0001 FIRST project 3.6 theme Participation in EU FP7 Concerto project.

Relevant publications:
International relation:
• Collaboration with CSA (Cloud Security Alliance), adoption of the relevant security documents and frameworks.

On ICT2013 event (EC event) (Vilnius, Lithuania 6-8 November 2013) in “The future of Clouds – accreditation and building the trust with special focus on SMEs” section, invited presentation about “Cloud vulnerability assessment and Critical infrastructure security”.

Relevant publications:


❸ M. Kozlovszky; Improving cloud data security by communication geofencing; CGW2013, Computer Science, ISSN 1508-2806, accepted/under publication

Implementing new addressing schemes in Software Defined Networks

Recently, with the spread of Software Defined Network (SDN) concept the software of the routers became open. By building up a network with OpenFlow routers already available on the market a through a centralized controller a large network can be fully maintained remotely. In our research we investigate new addressing and routing schemes of the Internet through OpenFlow prototypes. In particular we are interested in stateless multicast addressing. The research in IP Fats Re-Route was carried out in collaboration between the Lendület Future Internet Research Group and Ericsson Hungary. The scientific results were published in top tier computer communication conferences, and also influenced the Internet standardization through two IETF drafts. The proposed algorithms are implemented in a related network planning software.

The new compression methods developed for routing tables received international impact. The research group won a Google Faculty Award to show the applicability of the new compression methods in other applications of general data processing. These methods were implemented and tested with hardware and software prototypes.

The research group is the winner of the GEANT OpenFlow competition. The GEANT OpenFlow facility provides a realistic environment to measure resilience mechanisms and convergence times. The proposal focuses on network resilience research at the transport layer, utilizing OpenFlow capabilities to provide edge disjoint routes on top of a network core. The research aims to eliminate the need for concurrent resilience mechanisms at the physical, transport and network layer and associated complexities/costs.

Our research work during 2013 was focusing on the laas (Infrastructure as a Service) type clouds and their user related security issues. We have created frameworks, which are capable to do security assessment of virtualized infrastructures and provide IT solutions to overcome security problems related to geolocation parameters of user-user/service communications.
DATA AND CONTENT TECHNOLOGIES

Topic ranges, research theme reports and further registered themes:

A) Data, text and media mining
   T4A1 Efficient data engineering, WEB classification
   T4A2 A collaborative datamining framework
   T4A3 Scientific data warehouse and analytics
   T4A4 Applications of data mining for university database

B) Big Data challenges and solutions
   T4B1 Big Data research and application in wind energy systems
   T4B2 Mobility analytics
   T4B3 Big Data research: elaborating video data flows
   T4B4 Sentiment analysis in financial news and social media

C) Semantic multimedia search methods, knowledge discovery
   T4C1 Application of semantic technologies
   T4C2 Semantic multimedia search algorithms
   T4C3 Ontology models for semantic search in digital libraries
   T4C4 Semantic content modelling for digital library retrieval
   T4C5 Image classification - Semantic multimedia retrieval methods
   T4C6 Content analysis of natural languages
   T4C7 Web searching algorithms

D) Presentation, visualisation
   T4D1 Visualisation methods and standards on client side
   T4D2 Efficient and scalable visualization of Big Data

E) Digital library functions
   T4E1 Information retrieval in digital libraries
   T4E2 Digital library contents: name spaces and semantic descriptions
   T4E3 Web archival system
   T4E4 Dissemination of digital library contents
Efficient data engineering, WEB classification

We gave a comprehensive overview of features devised for Web spam detection and investigate how much various classes, some requiring very high computational effort, add to the classification accuracy. We collected and handled a large number of features based on recent advances in Web spam filtering, including temporal ones; in particular we analyse the strength and sensitivity of linkage change. We show that machine learning techniques including ensemble selection, LogitBoost and Random Forest significantly improve accuracy.

We summarized the Web classification best practice with a listing of various configurations depending on collection size, computational resources and quality needs. To foster research in the area, we make several feature sets and source code public (https://data mining.sztaki.hu/downloads/web-spam-resources), including the temporal features of eight .uk crawl snapshots that include WEBSPAM-UK2007 as well as the Web Spam Challenge features for the labelled part of ClueWeb09.

International relation:
• FP7 258105 (LAWA: Longitudinal Analytics of Web Archive data (Internet Memory, FR; Hanzo Archives, UK)

Relevant publications:
1. Miklos Erdelyi, Andras Benczur, Balint Daroczy, Andras Garzo, Tamas Kis, David Siklosi. The classification power of Web features. Internet Mathematics, submitted

Scientific data warehouse and analytics

Via organizing forestry- and geophysical measurement data into a unified data-warehouse system, we were able to create an analyst-environment, in which various measurement results can be analysed using one interface. It makes inter- and multidisciplinary relations easily exportable and analysable, which provided great help for inter- and multidisciplinary researchers.

During the project we have created a data-warehouse able to safely receive large amounts of data. High-frequency geophysical data (e.g. ionosphere data, seismic data, weather data, etc.) can be loaded into the very same environment, which contains high-value, but low-frequency forestry data sources.

Special attention was paid to respect the rights of the data owners. Data-owners can control the process of the usage of their own datasets, not just in the context of exploring and mining new relations in their data, but also with their data.

We have added a special analytical software-package to the developed data warehouse. RapidAnalytics was the core of this analytical software-package; it opens the possibility to schedule resource-intensive, high run-time processes. This RapidAnalytics server application can be accessed via RapidMiner client. This method (RapidAnalytics server + RapidMiner client) not just allows the data analysis, data manipulation, data conversion, but gives the opportunity to run different series based models and machine learning algorithms offered by RapidMiner.

Having the first phase of the project closed, we have concluded that researchers using data-analytics can greatly benefit seeing and analysing data from various data sources in one interface. Besides the obvious time-effectiveness, we have realized that it has special added value and relevance in time series forecasting and in spatial measurement data interpolation.

International relation:
• FP7 258105 (LAWA: Longitudinal Analytics of Web Archive data (Internet Memory, FR; Hanzo Archives, UK)

Relevant publications:
1. Miklos Erdelyi, Andras Benczur, Balint Daroczy, Andras Garzo, Tamas Kis, David Siklosi. The classification power of Web features. Internet Mathematics, submitted
Applications of data mining for university database

The aim of the research is to investigate large university databases, such as ETR and Neptun, in order to enhance adaptivity and success of universities. The aim of the research is to point out that data mining techniques can successfully be used in Education Science, and to gain relevant related knowledge and insight via data mining large university databases such as ETR and NEPTUN. Our goal is to use such knowledge in Education Science, thus enhancing student retention, adaptivity and overall success of universities. We investigated the ETR database of University of Pécs from 2008 to present. After a thorough data cleaning we made an investigation into “students’ career”, which is the graph of their average score on a half-year bases. We investigated the connection between students’ career and several other variables such as prior degree, faculty, chosen training etc. Interestingly, these variables together with a few others (such as sex, region, type of town they grew up ALLOWED FOR AN almost 50% hit of their first semester average score in a 10 degree equidistant scale. We plan to use our results to identify and to fix problems and difficulties in the trainings.

Relevant publication:
[Di Blasio Barbara, Jenei Sándor. The study career models among students of University of Pécs, Hungary by Data Mining methods. In: 5th World Conference on Educational Sciences. Roma, Italy, 2013 02.05-2013.02.08.]

Big Data research and application in wind energy systems

"Big Data" (BD) problems require handling extremely large or complex datasets that would be difficult and expensive using traditional relational databases. Software solutions with distributed processing, weakened consistency requirements and well-designed data models help overcoming scalability issues. The size of available data sets pushes towards new algorithms (typically, approximate or distributed) and new computational frameworks (e.g., MapReduce, NoSQL, and streaming data). In our experiments, big data problems unable to fit into the internal memory may be solved by using three different distributed computing paradigms: Distributed key-value stores, Map-Reduce and Bulk Synchronous Parallel.

Wind energy systems produce extremely large datasets. Today’s wind farm operators either do not collect all available data in a central, easy to access database, or they delete valuable data, because of scalability issues of traditional databases. Emerging “Big Data” tools and algorithms enable collecting all of the most detailed data; moreover, data may not be deleted at all. This is a huge advantage for wind farm operators, because detailed information can be (re)used later for many purposes: e.g., building failure detection and prognosis models, ad-hoc analysis of the past becomes feasible.

Relevant publication:
[Di Blasio Barbara, Jenei Sándor. The study career models among students of University of Pécs, Hungary by Data Mining methods. In: 5th World Conference on Educational Sciences. Roma, Italy, 2013 02.05-2013.02.08.]

International relation:
- GAMESA, Spain: Gamesa Health Monitoring (HMS) System project (2012-2013): Health Monitoring System (HMS) for Gamesa wind turbines, Industrial Project

Relevant publications:
- Whith, Zs.; Sidó, Cs.; Benczúr, A. A.; Comperges, J.; Kiss, K. B.; Petrus, I.; Garda, A.; “Big Data” Initiative as an IT Solution for Improved Operation and Maintenance of Wind Turbines, European Wind Energy Association (EWEA) Conference; “Make your vision reality”; 4-7 February, 2013, Vienna, Austria, 596.p. 184-188

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Mobility analytics

Location prediction over mobility traces may find applications in navigation traffic optimization, city planning and smart cities. Due to the scale of the mobility in a metropolis, real time processing is one of the major Big Data challenges. We deployed distributed streaming algorithms and infrastructures to process large scale mobility data for fast reaction time prediction.

We evaluate our methods on a data set derived from the Orange D4D Challenge data representing sample traces of Ivory Coast mobile phone users. As a key performance indicator of our real time applications, we measure throughput and latency. Over a cluster of a few old dual core servers, we are capable of processing hundreds of thousands of records in a second. Our results open the possibility for efficient real time mobility predictions of even large metropolitan areas. We also demonstrate our results via a fast reaction visual dashboard application.

International relations:
• Ericsson, Nokia Siemens Networks, SAP
• EIT ICT Labs Cloud Action Line

Relevant publications:
❷ Andras Garzo, Andras A. Benczur, Csaba Istvan Sidlo, Daniel Tahara, Erik Francis Wyatt: Real-time streaming mobility analytics. IEEE Big Data, 2013, Silicon Valley, USA

Big Data research: elaborating video data flows

Recently, information obtained through various sensors is often referred to as one of the sources of the ‘Biggest Big Data’. We can take video streams as a typical example for such data which are transmitted by cameras usually used for monitoring certain scenes or processes. Data collection through image acquisition is a rather simple and a relatively cost-effective technique. It is also a common approach when cells or cell cultures’ reaction to drugs or to light are recorded continuously by video cameras. We plan to develop distributed and efficient algorithms to process online streams in this field. We will develop image/video processing algorithms which automatically extract the desired objects. Following the step of segmentation, the descriptive features of the segmented objects will be calculated automatically in order to describe the characteristics of their shape. These automatic steps will replace the corresponding manual annotation process which would be basically incapable of realizing such a large amount of data, especially in a scalable and a sustainable way. As a primary target field, we plan to analyze how the shape characteristics of cells and cell groups will change when these respond to an effect like illumination or abnormal genetic behaviour. The reaction of cells can be checked when specific illumination is applied or a specific gene is knocked out. This knowledge may help introduce novel treatments or test new possible medicines. We have already developed video processing algorithms for the efficient segmentation of cells and we have assigned quantitative shape descriptors for the segments so that statistical analysis can be performed on a much larger scale in contrast with the use of manual annotations. The exploitation of the planned research is more diverse, which means that the techniques planned to be elaborated for the primary biological target field can also be used for sensors not transmitting image information but providing some other type of data. For cases when more sensors are used for the observation of the examined object or event, we plan to develop fusion techniques by the application of ensemble-based systems.

International relation:
• FP6-004218, SHARE: Mobile Support for Rescue Forces, Integrating Multiple Modes of Interaction, EU FP6 Information Society Technologies
Sentiment analysis in financial news and social media

In this research topic we focus our effort to extract sentiment information from social and traditional media sources and see if there is some connection between stock market returns and sentiment. Results indicate that while it is harder to extract sentiment information from social media (Twitter) the sentiment scores have more correlation with future returns of stocks, while traditional media is easier to transform and extract sentiment from, but have less correlation with future stock returns.

International relation:
• FUTURICT project, TÁMOP-4.2.2.C-11/1/KONV
Relevant publication:

Application of semantic technologies

Storing, managing, and searching information is solved primarily on a free-text basis, and in relational databases. Both are somewhat unstructured, and they are not based on internal semantic relations of texts. The primary goal of the present research is to study and develop a semantic mapping of pieces of information, which can be stored and retrieved at a later time. Semantic technologies are strongly connected with processing natural language information. Natural language analysis often refers to semantic mapping while it results in a logic formula. A task of semantic knowledge is to transform, verify, and recall this logic formula. All these assume a detailed ontological knowledge base, which stores everyday world knowledge as a kind of dictionary specification, thus allowing for interconnecting different business applications. The development of these (and similar) technologies may stimulate a new generation of intelligent business applications.

Our technology is built upon the general paradigm of logic programming and extends it to modal logics.

International relation:
• One of the topics of the III.2 subproject in the SIROP-4.2.2.C-11/1/KONV-2012-0005 project
Relevant publications:
A semantic image search system is developed, in which the end user can search by combination of names of more objects. State-of-the-art image processing, information extraction and machine learning methods (like Fisher vector and C-SVC classifier) were used for semantic analysis before searching. We have constructed more algorithms for combined image search, and we have focused on queries dealing with two and three objects.

In multimedia retrieval area we have implemented an image ranking solution, where the system orders the unknown images from relevance and diversity viewpoints. The possibilities of using visual and textual information are investigated to improve the ranking of photos about famous places, and we have elaborated improved textual, visual features, and combination of them. Our results have indicated that this combination is better than the original two solutions. At the comparison with a known image search Web system it can be concluded that the results of our solution exceeds the Flickr results by using search result clustering and reordering.

Furthermore an image browsing system is developed, where only visual information is available for users and computers as well. Large image set is structured in albums and the idea was to select the most representative image from each album in the level of hierarchy, and then the next upper level in the hierarchy consists of these representative images. Selection of the most representative image is based on semantic features, which helps end users in browsing process.
Semantic content modelling for digital library retrieval

At present, Wikipedia became the world largest Encyclopaedia with open public access to its content. This modern Library of Babel stores an enormous amount of information. The hyperlinks of citations between Wikipedia articles represent a directed network that can be used for building semantic models of the language concerned. We analysed the time evolution of Wikipedia network. We studied the time evolution of ranking and spectral properties of the Google matrix of English Wikipedia hyperlink network during years 2003-2011. The statistical properties of ranking of Wikipedia articles via PageRank as well as the matrix spectrum are shown to be stabilized for 2007-2011. A special emphasis is done on ranking of Wikipedia personalities and universities. We show that under various parameters, the most important entities are dominated by politicians while others give more emphasis on personalities of arts. The Wikipedia PageRank of universities recovers 80 percents of top universities of Shanghai ranking during the considered time period.

International relation:
- FP7 288956 NADINE: New tools and Algorithms for DIrected NEtwork analysis. CNRS Toulouse (FR)

Relevant publication:

Image classification - Semantic multimedia retrieval methods

Visual words have recently proved to be a key tool in image classification. Best performing Pascal VOC and ImageCLEF systems use Gaussian mixtures or k-means clustering to define visual words based on the content-based features of points of interest. In most cases, Gaussian Mixture Modeling (GMM) with a Fisher information-based distance over the mixtures yields the most accurate classification results.

In our work we summarized the theoretical foundations of the Fisher kernel method. We indicate that it yields a natural metric over images characterized by low level content descriptors generated from a Gaussian mixture. We justified the theoretical observations by reproducing standard measurements over the Pascal VOC 2007 data. Our accuracy is comparable to the most recent best performing image classification systems.

International relation:
- FP7 288956 NADINE: New tools and Algorithms for DIrected NEtwork analysis. CNRS Toulouse (FR)

Relevant publication:
Efficient and scalable visualization of Big Data

Having a comprehensive view of the visualization of Big Data is a problem in many fields; however, models generally suggested are in most cases far from being optimal. We wish to examine how general visualization models can be developed further according to the users’ needs, e.g. meeting the demand of 3D sensor controllability, effective representation of attributes and relations and the ability of assigning annotations. As different forms of representation are optimal for different data structures, we plan to organize the information deriving from Big Data by data mining in hierarchical structures in which different visualization models can be assigned to the given levels. Beyond the structural representation, the scalable representation of Big Data is also an important task for which we plan to develop fractal-based models. This sort of representation is typically suitable for the visualization of genetic data.

Relevant publications:

Information retrieval in digital libraries

One of our results on ranking for information retrieval apply boosting, a class of methods found successful in many areas of machine learning. For typical classes of weak learners used in boosting (such as decision stumps or trees), a large feature space can slow down the training, while a long sequence of weak hypotheses combined by boosting can result in a computationally expensive model. We propose a strategy that builds several sequences of weak hypotheses in parallel, and extends the ones that are likely to yield a good model.

In another result we exploit the connectivity structure of edits in Wikipedia to identify recent events that happened at a given time via identifying bursty changes in linked articles around a specified date. Our key results include algorithms for node relevance ranking in temporal subgraph and neighbourhood selection based on measurements for structural changes in time over the Wikipedia link graph. We measure our algorithms over manually annotated queries with relevant events in September and October 2011; we make the assessment publicly available (https://dms.sztaki.hu/en/download/wimmut-searching-and-navigating-wikipedia). While our methods were tested over clean Wikipedia metadata, we believe the methods are applicable to general temporal Web collections as well.

Relevant publications:
Web archival system

We implemented a Virtual Web Observatory prototype of the showcasing a suite of applications that support experimentally driven analytics on Internet data. Most applications integrate the work of several partners, which are integrated into a unified application. Implementations have been driven by the overall aim supporting typical tasks in temporal Web analytics. The developed software supports, e.g., the processing of large data sets for integration into the reference collection, large scale entity disambiguation, creation of temporal indices, and Web page classification. LAWA (Longitudinal Analytics of Web Archive data) developments serve as a reference architecture that includes research data developments serve as a reference architecture that includes research data sets, open source software, public showcases and best practice documentation.

While English language training data exists for several Web classification tasks, we face an expensive human labelling procedure if we want to classify a Web domain in a language different from English. We showed how models can be “translated” from English into another language, and how language-dependent and independent methods can be combined. Our experiments are conducted on the ClueWeb09 corpus as the training English collection and a large Portuguese crawl of the Portuguese Web Archive. To foster further research, we provide labels and precomputed values of term frequencies, content and link based features for both ClueWeb09 and the Portuguese data.

Dissemination of digital library contents

We presented a three-dimensional virtual system which visualizes some interesting rooms of the University of Debrecen and makes the most cherished and carefully guarded treasures of the Collection of Rare and Early Printed Books of the University and National Library of the University of Debrecen virtually available. Our system is based on the Virtual Collaboration Arena (VirCA) developed by the Cognitive Informatics Research Group of the Computer and Automation Research Institute of the Hungarian Academy of Sciences.

The online libraries of the next generation library users would mean creating 3D virtual spaces where they would navigate as they do in traditional libraries. To achieve this goal the surface has to be built and this new environment has offer options with which non-library educated users would navigate effectively. Reaching this state the activities of present day online library users and library systems should be thoroughly analysed.

The sources of the analyses are the library log files. well-designed log files would reveal, on one hand, the patterns of the users’ activities which are crucial in building algorithms for the mental representation of searches. On the other hand, the analyses of these log files would shed light on the operation of the system.

International relation:
- FP7 258105 LAWA: Longitudinal Analytics of Web Archive data (Internet Memory, FR; Hanzo Archives, UK) BonFIRE project funded by the European Commission’s Seventh Framework Programme (FP7/2007-2013) under grant agreement nº 257386 and 287938.
- FP7 258105 LAWA: Longitudinal Analytics of Web Archive data (Internet Memory, FR; Hanzo Archives, UK) BonFIRE project funded by the European Commission’s Seventh Framework Programme (FP7/2007-2013) under grant agreement nº 257386 and 287938.

Relevant publications:
- Erzsi Attila, Gilányi Attila. A long way from traditional Corvinian codices to digitized ones. Universitas Gedanensis, ISSN-1230-0152, Poland, Vol. 43.
Topic ranges, research theme reports and further registered themes:

A) 3D Internet architecture and content technology
- T5A1 3D Internet and media content
- T5A2 Research on search and navigation behaviours in 3D Internet
- T5A3 Collaborative virtual views and 3D models
- T5A4 Investigation of Quality of Experience for 3D Video
- T5A5 Analysis of 3D Internet multimedia contents using voice mining methods

B) Multimodal human-computer interactions
- T5B1 User interface to multimodal human-computer communications
- T5B2 Algorithms for human-computer interactions
- T5B3 Intelligent multimodal man-machine interactions with smart devices
- T5B4 Intelligent multimodal human-robot interactions

C) Cognitive infocommunications, cognitive contents and channels
- T5C1 Cognitive Infocommunications, CogInfoCom channels
- T5C2 Joint coordination of human and machine systems
- T5C3 Collective intelligence: community coordination supported by infocommunications

D) Virtual collaboration, 3D Internet based control and communications
- T5D1 3D Internet based collaboration
- T5D2 Virtual NeuroCognitive Space

E) Devices and procedures of 3D and 4D content creation and presentation
- T5E1 Creation of 3D and 4D content
Research on search and navigation behaviours in 3D Internet

As research efforts begin targeting the deployment of 3D Internet infrastructure, it is important to be able to directly collect large amounts of experimental data from augmented/virtual environments. A number of studies have shown that interacting with and searching for physical objects is qualitatively different from interacting with and searching for virtual objects, and that space and environment recognition tasks are also performed differently in physical and virtual spaces. The 3-component CAVE system deployed at MTA SZTAKI, along with the VirCA software system developed at the institute together represent a unique opportunity for the design and implementation of experiments targeting these capabilities. Several different approaches have been tested, in which the relationship between the position and orientation of the user, and the position and orientation of the virtual avatar representing the user are mapped to each other in different ways. For the purpose of designing future 3D Internet technologies, it is essential that a deep understanding is arrived at on search, recognition and navigation capabilities from various points of view, including neuro-cognitive processes, behavioural psychology and human ethology. The 3-component CAVE system deployed at MTA SZTAKI, as well as the Virtual Collaboration Arena (VirCA) system developed for the hardware platform are offering unique opportunities for experimentation in these directions. The analysis of human performance in search tasks is facilitated by the large variety of audio-visual devices and approaches accessible through the system – including various graphical formats (e.g., OGRE mesh, WRML, DAE, STL and STEP) as well as audio libraries (e.g., Csound, SuperCollider). Regarding spatial and environmental recognition tasks, the fact that the infrastructure behind VirCA allows for the human-sized display of augmented virtual worlds is enabling researchers to investigate recognition phenomena in a truly immersive environment. The VirCA NET extension to VirCA, which has fully opened the possibility for remote collaboration tasks, has also made clear the necessity to address questions of how the position, viewpoint and actions of various participants are to be indicated to different users. Finally, in terms of navigation, a number of studies have been centred on the virtual 3D pointer employed by the VirCA system, which allows users to alter their viewpoint, navigate within the space as well as grasp and manipulate objects within the space. Several navigation modes were developed, including the free mode (which allows users to modify their virtual body position and orientation, and viewpoint and viewing angle independently of each other), the chasing mode (which links the parameters of viewpoint and viewing angle to those of body position and orientation through a certain dynamics of choice – e.g. through a spring model), and the attached mode, which simplifies the chasing mode by using an identity dynamics. These various navigation modes can be seen as cognitive infocommunication channels that create a link between the sensory feedback experienced by users during navigation and the actual changes of body position, orientation and viewpoint and viewing angle.

International relation:
- Participation in EU FP7 project - 262044 - VISIONAIR - Vision Advanced Infrastructure for Research
- Chuo University, Japan

Relevant publications:
Collaborative virtual views and 3D models

The main goal of this research project is to develop collaborative visual information processing algorithms by making use of the communication capabilities of mobile devices. The results of the theoretical basic research will be applied to various real problems in order to demonstrate the possible application areas.

Currently three main topics are investigated:

1) Collaborative 3D Reconstruction: When several users with smart phones are taking pictures a 3D scene, then they are able to reconstruct the scene based on the individual 2D images. The algorithms developed here are based on a collaborative infrastructure where participating mobile phones share their visual data and/or their computing capacity while respecting individual users’ privacy. This technology opens new ways for fast environment mapping in case of e.g. natural disasters or large events. In contrast to Street-View technology opens new ways for fast environment mapping in case of e.g. natural disasters or large events. In contrast to Street-View, this method allows to reconstruct the current state of a scene.

2) Collaborative Panorama Stitching: Considering the scenario under 1), it is also possible to construct a wide field of view panorama by registering the images into a common coordinate frame. The main challenge is that individual cameras have different viewpoints. In 3D Computer Vision (BigData3DCV), pp. 668-675, Sydney, Australia, December 2013. IEEE.

3) Collaborative Synthetic View: Either from the 3D individual images or from a collaborative 3D reconstruction, it produces a picture corresponding to a virtual camera view. This allows e.g. the generation of a bird-eyes view picture of a scene which is useful for many applications like traffic jam or crowd monitoring.

International relations:

• A TÁMOP-4.2.2.C-11/1/KONV-2012-0013 FuturICT.hu project

• MTA- SZTAKI

• Technical University of Cluj-Napoca, Romania

Relevant publications:


Investigation of Quality of Experience for 3D Video

Video streaming over the Internet is one of the most important applications and 3D video streaming is expected to become even more popular than 2D multimedia applications. Provisioning 3D video stream-based services online in an acceptable quality of experience (QoE) requires a suitable network quality of service (QoS) even in a wireless environment. This is a great challenge for Future Internet service providers. The main focus of this research is an investigation of the relationship between QoE, network QoS and service attributes for active 3D stereoscopic live stream transported through a GPON based architecture and delivered by Wi-Fi connection at the customer side based on results of subjective tests with full-reference method carried out by 90 persons. Participants watched 3D test cases of the full reference based subjective quality test suffering transport network QoS degradations, Wi-Fi TX-Power value changing and existence of secure and not secure (i.e., with and without IPsec) 3D stereoscopic video delivery. QoE was also affected by human factors like acceptance rate of 3D technology by the participants, which could cause dissonant states of cognitions. The investigation based on subjective and objective QoE metrics and human factors correlation could help in the design of future QoE-aware 3D video streaming systems and in “m-Health” mobile-health scope via mobile telecommunication and modern multimedia technologies utilization.
Intelligent multimodal man-machine interactions with smart devices

During our research activities on the one hand intelligent applications have been created (e.g. smart TV control, smartphone+PC platform for supporting the speech impaired), while on the other hand we have developed interfaces that allow the implementation of new categories of applications (e.g. Spemoticon concept, Kinect-based mouse replacement, new text-to-speech -TTS- solutions, etc.). One of the obvious application fields is artificial speech generation from text appearing on relatively small displays. These applications may spread from reading out news, TV schedules through voice presentation of user manuals, text, e-mail, twitter, Facebook messages up to navigation and information services for vehicle drivers.

In case of reading aloud longer texts current TTS systems typically produce deterministically the same waveform output for the same input text. That is very tiring and boring for the user. One of our fields of research is to reproduce the variability available in human speech in various TTS technologies. Each TTS technology (diphone/triphone, corpus, HMM) has application target-dependent advantages. During our research we strive for hybrid solutions combining the advantages. It is an important feature of intelligent interactions to provide as much relevant information as possible in the shortest time available. The Spemoticon technology allows the implementation of communicative contexts relevant according to subjective evaluation but at the same time definable by objective parameters.

We have also created modality conversion demo applications that provide new opportunities for disabled and elderly people. The voice-controlled TV app helps those who are limited in mobility but who can speak the multi-functional use of TV sets. The technology can be easily transplanted to the control of other devices of homes. VoxAid technology helps speech impaired people (aphasia, dysphonia, larynx operated, etc.) in face-to-face speech communication and telephone calls by reading out pre-stored or real-time generated texts.

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International relations:

- The research was partly supported among others by the BelAmi (ALAP2-00004/2005)
- Etocom (TÁMOP 4.2.2-09/1/KMR-2008-0002)
- TÁMOP-4.2.1/B-09/1/KMR-2010-0002
- FuturICT (TÁMOP-4.2.1.C-11/1/KONV-2012-0013)
- EIT-KIC (EITKIC_12-1-2012-001) and PAELIFE (AAL-08-1-2011-0001) projects.

Relevant publications:

Cognitive Infocommunications, CogInfoCom channels

Cognitive infocommunications (CogInfoCom) is an emerging interdisciplinary research field that was created as a synergy between infocommunications and the cognitive sciences. CogInfoCom deals with novel approaches to extend the cognitive capabilities of human users through the artificial cognitive capabilities of infocommunications devices, enabling them to interact more flexibly with IT infrastructure. As a result, the field has both theoretical and industry-oriented motivations. An important challenge within CogInfoCom is the development of ecologically more flexible devices, enabling them to interact capabilities of human users through the artificial cognitive capabilities of infocommunications devices, enabling them to interact more flexibly with IT infrastructure.

The joint evolution of 3D Internet and the Future Internet is leading to the emergence of collaboration spaces and networks allowing for the augmentation of 3D virtual worlds with physically existing devices and objects. MTA SZTAKI is developing such a networked platform known as the Virtual Collaboration Arena (VirCA). The above motivations contributed decisively to the definition of CogInfoCom: Cognitive infocommunications (CogInfoCom) is an emerging interdisciplinary research field that was created as a synergy between infocommunications and the cognitive sciences in order to reflect this merging process. CogInfoCom has both theoretical and industry-oriented motivations. Its goal is to extend the cognitive capabilities of human users through the artificial cognitive capabilities of infocommunications devices, enabling them to interact more flexibly with IT infrastructure.

International relation:
• Participation in the project EU FP7 - 262044 - VISIONAIR - Vision Advanced Infrastructure for Research
• Osaka University, Japan

Relevant publications:
Virtual NeuroCognitive Space

With the rapid evolution of Future Internet in general, and the Internet of Things and 3D Internet in particular, it is becoming increasingly important to gain deeper insight into the effect of human interaction with complex communication systems on users. The goal of MTA SZTAKI with respect to this challenge is to develop an ecologically valid online collaboration platform for space- and location-independent experimentation. The system developed to achieve this serves as a unique synthesis of concepts from virtual and augmented reality as well as Internet-based remote collaboration.

Based on the existing system, preparations have begun for conducting experiments targeting a deeper understanding of how people carry out search, recognition and navigation tasks in 3D augmented-virtual environments, and how user performance in these tasks can be ameliorated. The research experiments under preparation will apply neuro-cognitive, psychological as well as ergonomics-based factors in assessing user comfort and performance.

With the evolution of various branches of the Future Internet initiative, including those of the Internet of Things and 3D Internet, it is becoming increasingly important to obtain repeatable experimental data in augmented-virtual spaces, both at the level of neurophysiology and psychology. With respect to this challenge, the goal of MTA SZTAKI is to develop an online collaboration platform for location-independent experimentation that is capable of merging the physical world with virtual spaces and of augmenting – through the virtual space – the computational capabilities of both virtual and physical objects and components. Through this platform, the goal is to support strongly interdisciplinary research for the engineering and neuro-biological sciences. Using the virtual space and its real-time connection with physical systems and measurement equipment will allow for the development of applications which would be too cumbersome and/ or cost-ineffective to assemble in real-world situations. In its current form, the VirCA system allows for rapid knowledge transfer and for the reconstructability and reproducibility of previously implemented experiments. The VirCA NET extension to the system, in turn, makes it possible to conduct online collaborative experiments with research partners across the globe, such that visual and auditory feedback from the experiment is synchronized in real-time. By curbing transportation and hardware-replication expenses in this manner, the VirCA and VirCA NET systems allow for significant cost reductions.

The virtual laboratory that is being deployed by MTA SZTAKI together with two departments of BME is about 70% complete, and preparations have begun for conducting experiments. The experiments will use a radically new set of tools, including EEG-recordings, heart rate variability measures and eye-movement recordings to further broaden the scope of post-experiment data analysis.

International relation:
- Participate in the project entitled “Virtual NeuroCognitive Space for research and development of future immersive mediated technologies” NeuroCogSpace, TKTK_AIK_12_1-2013-0037.

Relevant publications:
Creating 3D and 4D content

An important condition of the success of the Future Internet is the ability to create 3D and 4D content. Besides visual information (images, video), this requires other, multimodal intelligent sensors. A key task is 3D and 4D reconstruction from multimodal data, including seamless, multilevel integration of partial models. The result is rich mixed reality, sophisticated 4D content: its realistic visualisation on modern, especially, mobile platforms is a critical research and development problem.

One main objective is the high level scene recognition and change interpretation based on heterogeneous Remote Sensing (RS) data sources (mainly optical and TerraSAR satellite images and LiDAR, SAR or DEM data). We aim to develop novel recognition and visualisation methodologies relying on 4 dimensional (3 spatial and 1 temporal) data representation. We focus on highly multi-modal, multi-scaled and multi-temporal data collections, and build a unified database which is appropriate for answering user queries about events or changes in the RS data. 4D content is a growing field of interest in various application areas, such as monitoring agricultural activity; detection of pollution and environmental crimes; management of urban area expansion, crisis management, including civil protection, or homeland security. However, the necessity of automated recognition problems in remote sensing is raised by both national and international demands.

Our work focuses on the research towards a generalized framework and procedure library for representing different targets, hierarchical structures and various levels of changes. The developed methods attempt to collect similar tasks appearing in different application areas, and handle them in a joint methodological approach. An important feature of the proposed models is the separation of the data and application dependent elements from the abstract hierarchical structure which has various levels, such as pixel, region, object, object group and land cover class.
INTERNET OF THINGS (IOT)

Topic ranges, research theme reports and further registered themes:

A) IoT enabling technologies, sensors, actuators, energy and spectrum awareness
   - T6A1 RFID/NFC technology research: unification and combination by other technologies
   - T6A2 Sensor technologies and energy efficiency challenges

B) Identification: naming, addressing, privacy awareness, IPv6-based IoT
   - T6B1 Integration of the Internet of Things and IPv6 systems
   - T6B2 Investigation of IPv6 transition technologies

C) Communication architectures for constrained devices, IoT infrastructures, self-aware networks
   - T6C1 Self-optimized and self-managed communications on the Internet of Things
   - T6C2 Sensor networks: self-organizing and fusion of modalities

D) Data management, software solutions, security technologies, self-managed secure IoT
   - T6D1 RFID based localisation

E) Services support platforms, heterogeneous data collection and processing infrastructures
   - T6E1 ICT tools for smart homes and assisted living for elders
   - T6E2 Developing distributed processing system for weather data
   - T6E3 Distribution of sensor information in distributed heterogeneous networks
Three subtopics were evaluated:

A) Efficiency analysis of the multipath communication in IPv4/IPv6 environment. The developed software protocol stack being both TCP/UDP and IPv4/IPv6 protocols independent is utilised with success to analyse IETF MPT (Multi Path Transmission) transmission efficiency in different types of wired and wireless network environments.

B) Development of stochastic models for systems distributed in space and time and application of it in the description of radio channel noise characteristics in WiFi system with high number of base stations running as sensor nodes. The new knighting method is useful applicable to continuous extrapolation of the signal field intensity in 4D physical coordinates (space-time domain) not sampled by the discrete sensor nodes.

C) Clustering method development for information extraction from sensor network data sets and application for characterization of the resource usage of a supercomputer system. The method based on cluster analysis and wavelet reductions by one order of magnitude the number of variables sampled and the amount of data and presages surprise events at the CEP (Complex Event Processing) and ESP (Event Stream Processing) supported services based on huge number of logical and physical sensor nodes.

Due to the exhaustion of the public IPv4 address pool, the transition to the IPv6 protocol became inevitable. We surveyed the most up to date IPv6 transition technologies and their most important implementations. We took measurements to test the performance and the stability of some selected implementations and we continue it with some other ones. We analyse their security issues and give suggestions for improvements if necessary. We build simulation models for some selected IPv6 transitions technologies. We hope that our results will help the network administrators in the selection of the appropriate IPv6 transition technologies.

Relevant publications:


Self-optimized and self-managed communications on the Internet of Things

The goal of this research is supporting context-aware communication on the Internet of Things. In the first phase we aimed at determining relevant context parameters of a given application using the HTM (Hierarchical Temporal Memory) framework. Compared to other machine learning solutions, HTM reduces significantly the learning time, the necessary memory, and takes into account the spatial and temporal correlations between the different parameters. To evaluate the efficiency of the classification approach, we wrote an Android test application which logged continuously 24 different context parameters and executed a specific task in case certain parameters matched a set of given values.

Sensor networks: self-organizing and fusion of modalities

Progress towards the networks of multimodal cameras and other sensors is a main challenge in the near future. Investigating their behaviour and developing new algorithms for high level fusion of the distributed information is an existing demand. The project aims to find cooperative structures in dense multimodal camera and other sensors’ network. Possible applications are related to emerging sensor network technologies, like intelligent city control, surveillance, traffic control, assisted living and augmented reality events, cell phone data gathering networks, robot motion, and medical aid to the handicapped or even smart homes.

International relations:
- FP7 PROACTIVE (PRedictive reasOning and multi-source fusion empowering Anticorps of attacks and Terrorist actions In Urban EnVironmEnt)
- EDA MEDUSA (Multi Sensor Data Fusion Grid for Urban Situational Awareness, 2009-2011)

Relevant publications:

Relevant publications:

Relevant publications:

Related publications:

International relations:
• FP7 PROACTIVE (Predictive reasoning and multi-source fusion empowering Anticorps of attacks and Terrorist actions In Urban EnVironmEnt)
• EDA MEDUSA (Multi Sensor Data Fusion Grid for Urban Situational Awareness, 2009-2011)

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ICT tools for smart homes and assisted living for elders

Our research aims to assist elderly or sick people every day by automating independent activities using the latest assistive technologies. The system consists of three major components: intelligent ambient assisting living system, the health and activity monitoring and recognition system, and an assistive robot providing personal assistance. This is a complex support system, which must have learning and adaptative behaviour, and for this reason we use artificial neural networks. Related to Web-based intelligent energy measurement and adaptive behaviour, and for this reason we use artificial neural networks. This is a complex support system, which must have learning recognition system, and an assistive robot providing personal assistance. Our research work was focused in designing the recognition system based on neural networks simulated in Matlab.

International relations:
Participating researchers:
- Ahn Tian, Anglia Ruskin University, Cambridge/Faculty of Science & Technology (UK)
- Sebestyén-Pál György and Lung Claudiu, Technical University of Cluj-Napoca (Romania)

Relevant publications:
4. A. Buchman, C. Lung: On the relationship between received signal strength and received signal strength index of IEEE 802.11 compliant radio chips. We have developed a method for this and started the development of the software which implements the method. For activity and health state recognition we developed a module for vital parameters monitoring (temperature, heart rate, acceleration). The acquired data is sent to a remote server for logging and for advance processing. These data can be used for training neural network for recognition of activity and health status of the patient, alert in case of unusual states detection or emergency.
5. Our research work was focused in designing the recognition system based on neural networks simulated in Matlab.

Distribution of sensor information in distributed heterogeneous networks

Collecting data from distributed sensors raises several issues, which has been widely discussed in the literature. The solution depends on the environment in which the sensors are implemented. In this research we reviewed several targeted scenarios, based on Near Field Communication technology and Android OS based smartphones. We analysed the task of collecting sensor information for these scenarios using distributed harvesters (mobile data collector). Our proposal is a network coding based solution that solves the inherent reliability and scalability issues. We have built a prototype tested based on Android smartphones which will serve as a testing platform for our proposals.

We have implemented a collector vehicle, the communication interface from the Android smartphones to the NFC sensor tags and the random linear network coding based communication between the Android phones. We implemented, tested and demonstrated a live streaming solution, and a real time control application based on Android smartphones. We use random linear coding techniques to collect and sensory information in a distributed environment.

International relation:
- This research was supported by the European Union and the State of Hungary, co-financed by the European Social Fund in the framework of TÁMOP 4.2.4.A/1-11-1-2012-0001 National Program of Excellence

Relevant publications:
Topic ranges, research theme reports and further registered themes:

A) Embedded and intelligent engineering systems
   T7A1 Development of Cyber-Physical Systems
   T7A2 Detecting and fixing software vulnerabilities
   T7A3 Remote controlling, remote operating over Internet
   T7A4 Developing sensor-computer interfaces
   T7A5 Quality assurance of embedded software controlling things
   T7A6 Distributed cyber-physical systems and applications

B) Intelligent production applications, measuring and controlling physical processes
   T7B1 The future role of the internet in the field of industrial communications
   T7B2 Cyber-physical production systems
   T7B3 Cubilog: cloud based measured data collecting and controlling systems

C) Intelligent transport, cars and logistics
   T7C1 Smart car: integrated, ad-hoc transport optimisation
   T7C2 Logistic decision support systems

D) Smart agriculture-food applications
   T7D1 Smart food processing
   T7D2 Smart agriculture

E) Smart energy systems, green Internet
   T7E1 Energy efficient IT systems
Cyber-Physical Systems consist of complex, interconnected embedded systems, where the nodes provide information about the physical world, and cooperate to fulfill common missions. We aim at developing a universal cyber-physical system, where the new tasks arising from different users can be dynamically developed and deployed to the embedded nodes in runtime. Each node is universal in some extent and provides services through the internet for the other members of the system. The dynamic allocation and reconfiguration of the resources are accomplished also in runtime. In order to fulfill these requirements we need to solve the following problems:

A) develop an architecture with well-defined interfaces at the different layers, where the layers provide services with guaranteed service levels. The common interfaces are accomplished through virtualization techniques (embedded virtualization, sensor virtualization).
B) Tasks requiring extremely intensive computations are delegated to cloud computing services.
C) Semantic data integration is supported by Sensor Instance Semantic Registry Ontology (SISRO).
D) We develop a framework to support the development of the new algorithms arising from different users based on design schemes, according to the demands of the users, according to required resources and services. To schedule the resource allocation and react to the continuous changes in the environment we use design space exploration methods.

Development of Cyber-Physical Systems

The devices connected to and forming the base of the Internet contain a large amount of code of high complexity. Monitoring the stability and vulnerability of software is an important topic in the field of IT security. We will develop enhanced program analysis techniques (e.g., symbolic execution, abstract interpretation), which will help analyze and comprehend the behavior of software deeper and more precisely. The better view of the behavior might even help to optimize the code execution capabilities of hardware with power and resource constraints.

Detecting and fixing software vulnerabilities
Remote controlling, remote operating over Internet

The aim of the research is to control unmanned vehicles over Internet. Controlling and monitoring vehicles can be achieved distance independently. Telemetry and vehicle control data are sent using a custom designed protocol. During sending and receiving data, latency needs to be taken to consideration and encryption is required for security reasons. Integrity check must be used for reliable and error-free transmission. Because of the possibility of high latency, real-time control methods (joystick) are not applicable. This problem can be solved by using high-level commands (e.g. waypoints), which are executed by the intelligent robot, based on local conditions when it is possible. The system developed during the research is built on client-server architecture that provides real-time monitoring and controlling of autonomous vehicles using a text based (ASCII) communication protocol over an encrypted channel. Testing has been performed using wired LAN and high latency Wireless connection. Results of the experiments shows that remote controlling of vehicles has been carried out successfully despite of high latency.

Relevant publications:


Quality assurance of embedded software controlling things

In this research new methods will be elaborated which is able to detect software errors and other quality issues in embedded systems. Statically (and automatically) analysing the source code of embedded systems and discovering their program faults is of critical importance. Connecting “smart” devices (like home appliances, sensors, etc.) to the internet makes them vulnerable, and exploiting their software’s faults and vulnerabilities can cause serious dam- age both in the devices and in their environment. We will research and develop novel solutions for this special application area.

International relations:

- The Astrée Static Analyzer - http://www.astree.ens.fr/
- ISO 26262 – Functional safety standard

Relevant publications:

The planned research will have two main directions:

- One direction is the research of the applicability of the internet in the field of industrial communications, especially in the field of Functional Safety.
- The second research direction is in the field of Social SCADA (SCADA – Supervisory Control and Data Acquisition).

The industrial SCADA concept can be extended to collect data provided by the internet-enabled equipment used in everyday life. The result of the research will provide a proposal for the applicable protocols and IT infrastructure.

International relations:
- GOP 1.1.1-09-/1-2010-0109
- TÁMOP-4.2.2-08/1/2008-0008

Relevant publications:
Topic ranges, research theme reports and further registered themes:

A) Mobile crowd-sensing platform and functions
   T8A1 Open, mobile-based communication platform for social applications
   T8A2 Dynamic distribution of independent NFC applications
   T8A3 Digital community spaces and mobility in the future

B) Smart home and office applications
   T8B1 Platform-free intelligent home and office applications

C) Smart health and well-being applications
   T8C1 eHealth, TeleCare, TeleHealth
   T8C2 Real-time control in medical devices
   T8C3 Applications of cloud-based robotics in e-Health
   T8C4 HealthCare Mobile platform
   T8C5 Real-time e-Health telemonitoring
   T8C6 Automatic screening systems
   T8C7 Speech-based monitoring of health and emotion state

D) Smart business applications
   T8D1 Resource management of business processes
   T8D2 Mobile-Wallet application: NFC and mobile phone based complex payment method and ecosystem

E) Smart governance applications

F) Smart city applications
   T8F1 Data management and knowledge discovery for Smart City applications
   T8F2 Smart city applications
   T8F3 Smart path selection based on crowd-sourced data
   T8F4 Cognitive campus applications
   T8F5 Smart City applications: network influences

G) Other intelligent and cognitive community applications
   T8G1 Digital library: complex, interactive content services
   T8G2 Measurement of performance and efficiency of localization technologies
Recently, the necessity of smartphones in everyday life is inevitable. Especially their offered communication, computational and multi-utility sensor capabilities make the community capable to collect information about the environment providing potential for useful applications deployment. The aim of this theme is to investigate and design a communication platform based on the requirements of such crowd-sensing and crowd-sourcing applications, described above.

The theme results convey investigations of recent implementation of XMPP protocols to accomplish requirements derived from social crowd-sensing and crowd-sourcing applications. The practical aspects of performance evaluations show that through extension of implementation for multiserver architecture XMPP capable to operate real-time in a demanding application environment. Besides the above scope, the theme involves implementation of a platform, based on the from-the-sketch requirements. The implementation of this communication and application platform nowadays is under the functional and performance tests.

The DIAD_NFC project (Dynamic Distribution of Independent NFC Applications) has implemented the complex service architecture which realizes the dynamic, remote, independent deployment and removal of NFC applications into and from secure elements. The solution is unique in its approach as instead of the present practice where all technical details and specifications need to be elaborated in advance between the parties, it provides a generic solution agnostic to the type of the secure element used and the application to be loaded. We have defined the scope of information necessary for the assessment of compatibility between the secure application and the secure element, and submitted the missing data elements to Global Platform for consideration in future standards. We also specified and implemented the open back office architecture which is capable of performing the necessary card content management transactions. For some key elements of the technology patent applications were also submitted. As a conclusion of the project work a pilot operation was organized at the Budapest Technical University where an access control and payment service was implemented.

International relations:
• Cooperation with Global Platform the industry organisation for smart card standardisation.

Relevant publications:
Real-time control
in medical devices

Monitoring and automatic control of medical devices represents a critical point in engineering challenges of healthcare. The Physiological Controls Group of the Obuda University has investigated this problem through the artificial pancreas topic under in-silico simulated environment. Local (patient-based, like insulin pump and blood glucose measurement devices) and global (medical interpretation and intervention at patient side by telemedical aspects) were investigated in order to investigate the robustness of the system, hence, global stability properties.

International relations:
- University of Bern,
- Technical University of Denmark,
- University of Gent,
- University of Porto

Relevant publications:

eHealth, TeleCare, TeleHealth

Health-related information collection (blood pressure, ECG, pulse meter, sleep monitoring etc.). Activity and behaviour monitoring based on passive sensors (power consumption meters, motion sensors, contact sensors, temperature/humidity sensors etc.). Information sharing and communication between patients, doctors, relatives and others through web portal and mobile devices (Android). Handling different device communication issues (serial to USB devices, pure USB devices, ZigBee devices, Powrline devices, Bluetooth devices etc.). Serious games. JS-based framework and game development, game log collection and evaluation. 3D motion monitoring based on XBox or Kinect cameras.

International relations:
- Participation in EU AAL IP funded CCE, CARE, Inntrom-CIC, CVN and MSN projects. Participation in WP-NSC, Taiwan Joint Research Projects funded TeleCalm++ project. Participation in Hungarian-Croatian Intergovernmental S&T Cooperation Program funded EmBassi project.

Relevant publications:
HealthCare Mobile platform

HealthCare Mobile is a nationally and internationally completely new and unique ICT solution - optimized for smart phone and tablet. Due to the solution, patients can be informed about several different, but important issues according to their health care via smart phone application.

These issues are the following:
- expected waiting time;
- information about their illness;
- how to prepare guide for their examination;
- interpretation of laboratory findings;
- guidance for local parking;
- lists of on-duty hospitals and pharmacy;
- indoor navigation.

Patient can also make appointments, download their electronic health records and ask for health advice in 7/24 via the same application.

Relevant publications:
- Healthcare research and development project at Magyar Telekom http://article.wn.com/view/2013/09/13/Healthcare_research_and_development_project_at_Magyar_Telekom/

Making efficient automatic clinical screening systems has been a serious requirement claimed worldwide long time ago. The motivation is that by applying screening systems the number of expensive doctor-patient visits could be reduced and also developing countries could have access to such tools, where there is no sufficient medical care. We wish to focus on developing screening systems in a field where users with the help of image capturing devices can take shots on their own which they can forward through the Internet for evaluation. Such special domains are e.g. the complication of diabetes affecting the eyes, or the presence of skin cancer (melanoma). Higher precision of detection can be assured by using complex ensemble-based systems; however, they demand rather high costs. The improvement of mass screening programmes and that of the resolution of image processing fore-shadow the significant growth of data. Because of this challenge, we plan to develop distributed image processing algorithms, and also the extension of ensemble-based systems to distributed environment (e.g. for finding optimal parameter settings). One can expect a further significant improvement of the screening systems’ precision due to the inclusion of proteomic data besides image data. In order to achieve the aim we set, machine learning systems handling Big Data and data mining systems are needed.

Relevant publications:
on this built-up data warehouse an analytical layer is created that will be formed containing the data forwarded by the previous layer. Based on this layer, various projects are performed firstly. Then, a data warehousing layer is designed containing the data and to analyse the data collected there. The local analysis, corresponding branching processes is also investigated and described. To complement these results, the asymptotic behaviour of the corresponding branching processes is also investigated and described.

Stochastic models were developed, which can serve as an analytical layer for smart city applications. During the development the following issues were taken into consideration: changes in the position of the sensors and connections between participants in data gathering. In this context, we progress in the study of large random graphs, analysis of large amounts of mobility data and development of intelligent search algorithms.

The goal of this research is to design distributed data warehouse architectures which are suitable for analysing web-log and sensor data and to analyse the data collected there. The local analysis, cleaning, and possible compression of the data gathered by the technologies which are developed by the 6.1 theme of the FIRST project are performed firstly. Then, a data warehousing layer is formed containing the data forwarded by the previous layer. Based on this built-up data warehouse an analytical layer is created that will drive the 6.1 theme applications of the FIRST project. These applications include intelligent scheduling, intelligent parking, intelligent searching etc. The system should be based on such Big Data technologies which go beyond the modern standards like Hadoop and NoSQL system, see for example: Storm, Pregel, Naadu, (Stratosphere, GraphLab). To design the analytical layer we should take into account the spatial and time dependent uncertain nature of the resulting data. This requires a focus on stochastic and statistical methods and we must rely on robust, fault-tolerant algorithms. Moreover, theoretical results are also achieved in the study of large random graphs under various types of preferential arrangements and in describing the asymptotic behaviour. These results have an immediate application in the analysis of large social networks or social sensor networks. To complement these results, the asymptotic behaviour of the corresponding branching processes is also investigated and described.

Relevant publications:
- EIT KIC ICTLabs project, 13064 CityCrowdSource activity
- NFŰ EIT KIC_12-1-2012-0001 project,
- TÁMOP-4.2.2.C-11/1/KONV-2012-0001 FIRST project, topic 6.3,
- Smart city applications

The aim of this theme is the design and development of smart city applications. We designed a community based public transport information sharing service for mobile users. Later we extended this service with a client side visualization application. We documented our studies in the field of measurement, storage and analysis of public transport related data. With regard to the intelligent civil avatar topic we extended the intelligent soccer fan concept. We implemented and tested the Quantum Consciousness Soccer Simulator (QCSS) mobile client over the XMPP protocol. XML schemes were developed for this avatar system. We began to work on the YANonymous application that investigates the possibility of reproducing social networks from anonymous user connections. We created a document about indoor positioning. We designed a community based course schedule application for smart campus that uses the connections in the widely deployed NÉPTUN system. We used the Facebook and Twitter systems to harvest information and created a prototype that uses Twitter posts to detect real-time events.

Relevant publications:
- BMW Dept. Telecommunications and Media Informatics
- BMW Dept. Networked Systems and Services
- University of Debrecen, Faculty of Informatics
- Eötvös Loránd University, Faculty of Informatics

Data management and knowledge discovery for Smart City applications

International relations:
- TÁMOP-4.2.2.C-11/1/KONV-2012-0001 FIRST project, topic 6.3,
- NFŰ EIT KIC_12-1-2012-0001 project,
- EIT KIC ICT, Labs project, 13064 CityCrowdSource activity

Smart city applications
Cognitive campus applications

The Intelligent fans application has been developed, in which the user can annotate a match using different kinds of mobile devices. The data obtained by this application are used for a professional decision support system in soccer. Intelligent timetable application, which became very popular among the students and the teachers in the Faculty of Informatics, is the data gathering layer in our framework of Intelligent Campus. The development of an analytical layer based on data collected by this application is pending. Finally, a review article was published on the XMPP-based applications of Smart City.

Relevant publications:

Smart City: network influences

Several results show the influence of friends and contacts to spread obesity, loneliness, alcohol consumption, religious belief and many similar properties in social networks. Others question the methodology of these experiments by proposing that the measured effects may be due to homophile, the fact that people tend to associate with others like themselves, and a shared environment also called confounding or contextual influence.

Our goal was to exploit the timely information gathered by the Last.fm and Twitter services on users with public profile to investigate how members of the social network may influence their friends’ behaviour. Our results confirm the existence of influence through the social network as opposed to the pure similarity of taste between friends. We disproved the opinion that homophile could be the reason for friends listening to the same music or behave similarly.

International relation:
Measurement of performance and efficiency of geolocation technologies

The aim of the research is twofold: To give a satisfying solution for the indoor localization problem, and to create a qualitative-quantitative information management model and system architecture, which aims at making the publishing of different location-based services to a wide-spread audience easier, enriches user experience, and decreases development cost.

Nowadays these widespread services are only stand-alone applications, which makes precise and adequate passing of location-information impossible with today’s technologies. One expected result is a throughout insight into the smartphone usage custom of users. We wish to use this knowledge to devise an information management model along with a related system architecture. It is aimed that the resulting information management model and system architecture will beneficially enable users to access several location-based services via a unified platform. There is no satisfying-in-all-respect solution for the indoor localization problem, and our aim is to devise one using techniques from the theory of non-classical logics.
Topic ranges, research theme reports and further registered themes:

A) Experimental systems, test-beds
   T9A1 Testbed as a virtual service platform for Future Internet
   T9A2 Virtualised experimental networking infrastructure for Future Internet research
   T9A3 Future Internet virtualised services
   T9A4 Distributed storage to Future Internet research
   T9A5 Text mining in the cloud
   T9A6 Monitoring solutions for federated Future Internet testbeds

B) Experimental methods, demonstrations, field results
   T9B1 T-City Szolnok, the city of the future

C) Socio-economic studies, business models
   T9C1 Economic models for Future Internet age
   T9C2 Investigating community media systems, supporting offline local communities
   T9C3 Metrics to evaluate the effects of the Future Internet as public utility
   T9C4 Social recognition of RFID technology

D) Technical standards, recommendations, standardization issues

E) Technical, economic and content regulatory issues
   T9E1 Investigating and research of regulatory models fitted to the FI opportunities
   T9E2 Internet of Things: digital rights management
Testbed as a virtual service platform for Future Internet

Provision of a testbed operating in a federated virtual networking environment built on the networking infrastructure of NIIFI and its international connections for supporting Future Internet research activities. Application of a two-factor authentication module for simpleSAMLphp in the federated virtual networking environment and in the testbed system, in order to achieve increased security by pairing a time-based token with other credentials, such as a username and password. SimpleSAMLphp is used as a SAML2 Single-Sign-on solution based on php. Google Authenticator implements time based one-time password (TOTP) security tokens from RFC6248 in mobile apps made by Google. The Authenticator provides a six digit one-time password users must provide in addition to their username and password to log into Google services. The Authenticator can also generate codes for third party applications, such as password managers or file hosting services.

International relation:
• Participation at the EU FP7 GN3plus project

Relevant publications:
2. István Farkas (NIIF Institute): Results of the HBONE 2012 Developments. Networkshop 2013, Sopron, Hungary (Abstract)

A virtualised experimental networking infrastructure for Future Internet research

Provision of national and international services of communication and information access as well as a collaboration platform (remote co-operation and virtual community environment) for the Future Internet research communities on the basis of the R&D and higher education infrastructure (grid, cloud, HPC, collaboration and data infrastructures built on the high speed network) operated by NIIFI. Development of a platform supporting virtual organisations (VO) and making applications VO ready. Development of a Shibboleth 2.x IDP X.509/LDAP authentication module. Basic motivation is to provide the opportunity of using hardware tokens as authentication source. SPs can decide if they want to force the X.509 authentication or simply password authentication. Besides Shibboleth X.509 authentication (with or without PKI), also X.509 + LDAP certificate authentication and combining X.509 with username/password authentication are also possible options.

International relation:
• Participation at the EU FP7 GN3plus project

Relevant publications:
2. Istvan Farkas: Results of the HBONE 2012 Developments. Networkshop 2013, Sopron, Hungary (Abstract)
FUTURE INTERNET RESEARCH IN HUNGARY, 2014
EXPERIMENTATION, STANDARDIZATION, REGULATION

NIIFI - National Information Infrastructure Development Institute

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Future Internet virtualised services

Service virtualization is applied to separate the physical service infrastructure from the logical service layer. The solution to achieve this is based on applying proper middleware that allows collecting the physical resources, make them an easy-to-manage abstract pool in order that the services running over them become more suitable to the users’ needs, and be more fault-tolerant. Special care is taken to storage virtualization that, in essence, differentiates the storage protocols used by aggregating disk chunks from those used by end-users. The available virtualization platforms partially contains the binding features with some disadvantages alongside so one of the main targets is to define those requirements that enable the researchers to transparently implements the services of future internet. To achieve this goal we had to compare and analyse the available solutions and implements the most suitable from the infrastructure to the service level.

Future Internet virtualised services

Distributed storage to Future Internet research

The continuously emerging large capacity data storage devices firmly fuel the evolution of reliable, distributed data management software and services. The purpose of this development is to build a geographically distributed data management solution that enables the structured managing of large amount of large data items, their secure replication, as well as their safe user access. The research spans over the performance analysis of contemporary data storage facilities, with special respect to data delivery over long distance wide area network connections. Not all of the already existing solutions did completely fulfil all of the functional and performance requirements. To provide a coherent integrated solution we had to define a full stack solution from the infrastructural towards the software level.

International relation:
• Participation at the EU FP7 SIM4RDM project

Relevant publications:
❶ Ivan Marton: The new HPC, storage, and cloud infrastructure of NIIFI, Conference on „New opportunities in the research network”, Győr, Hungary, 2012 (Abstract)
❷ Peter Stefan: Upgrading the NIIFI data storage infrastructure, Networkshop 2012, Veszprém, Hungary (Abstract)
One of the most important problems of science today is represented by two paradoxes. The first is that while the production of scientific knowledge exceeds both in scale and quantity all previous measures, the individual ability of researchers to elaborate information and to use knowledge has not expanded comparably. The capacity gap between knowledge-generation and individual acquirement has been widened to a rift by now.

The second paradox is that inter- and multidisciplinary needs of the scientific problems to be solved are increasing due to the advancement of specialization in science, while individual researchers can hardly cope with the up-to-date tracking of their own research fields, not to mention an adequate, deep review of those fields necessary to solve the given problem or the fields adjoining their own research. Therefore an e-science toolkit is needed, that facilitates to dissolve both paradoxes during our more and more Internet-centric activities, by giving the most advanced semantic, knowledge-based services to individual researchers for automatic elaboration of their own and adjoining disciplines.

We established a central (machine and human) system of the unified National Research e-Infrastructure that gives substantial benefits for Hungarian researchers, and that is directly profitable on scientific and technological levels.

In the past years, Future Internet experimental facilities have gone through an enormous evolution. Besides resource virtualization the need arose for the joint usage of multiple testbeds developed for specific purposes, leading to various solutions for infrastructure federation. Harmonizing the management, control and monitoring planes is challenging, since the different testbeds use basically different solutions and provide the users with various capabilities.

This research work focuses on the following topics: the development of new methodologies for supporting monitoring in federated environments, cross-domain active measurements, the applicability of active network measurements in network services like IP geolocation, analysis of how virtualization affects the accuracy of active and passive network measurements, etc.

International relations:
- FP7 258715 LAWA: Longitudinal Analytics of Web Archive data (Internet Memory, FR; Hanzo Archives, UK)
- FP7 288956 NADINE: New tools and Algorithms for Directed Network analysis. CNRS Toulouse (FR)

Relevant publications:
PARTICIPANTS OF THE FUTURE INTERNET NATIONAL RESEARCH PROGRAMME

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Future Internet Research Coordination Centre (FIRCC)
Budapest University of Technology and Economics (BME)
Inter-University Centre for Telecommunications and Informatics (ETIK)
National Information Infrastructure Development Institute (NIIFI)
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Magyar Telekom
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National Media and Infocommunications Authority
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