

AN ANALYSIS AND FORECAST OF SOFTWARE AND SERVICES RESEARCH IN BULGARIA*

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ABSTRACT. In the last 40 years much has been achieved in Software Engineering research and still more is to be done. Although significant progress is being made on several fronts in Service-Oriented Architecture (SOA), there is still no set of clear, central themes to focus research activity on. A task within the EU FP7 Sister project aimed at defining research priorities for the Faculty of Mathematics and Informatics (Sofia University) in the area of Software and Services. A dedicated methodology was proposed and developed, based on various sources of information. The information accumulated was systematised and processed according to this methodology. The final results obtained are described and discussed here.

1. Introduction. In the last 40 years much has been achieved in Software Engineering research and still more is to be done. Here are some examples given by Manfred Broy at ICSE'08 [2]: in *software engineering foundation*

ACM Computing Classification System (1998): D.2.0.

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we have comprehensive system modelling theories, but they have to be reflected in powerful modelling languages; in *software process* we have adequate process models with tailoring abilities but we have to broaden them to professional use; in *software structuring* we have understanding software architectures but their broad exploitation in practical projects is still a challenge; in software quality we have structured quality models that have to be made a state of practice, also the reliability of safety-critical systems is impressive but there are still areas that want improvement; in software tools we have a rich set of tools but they have to be integrated.

The Service-Oriented Architecture (SOA) [4, 5] paradigm has been having a substantial impact of late on the way software systems are developed. Although significant progress is being made on several fronts, there is still no set of clear, central themes to focus research activity on. As a result, there is a danger that important research needs will be overlooked, while other efforts will focus on issues of peripheral long-term significance in practice.

1.1. Aim and task. This paper aims to present a view on the future of the research agenda in Software and Services (*S&S*), primarily focused on the Faculty of Mathematics and Informatics (FMI), Sofia University. This view derives from a systematic analysis of the current state and future trends in Bulgaria and worldwide and could be applied to other institutions in Bulgaria.

This investigation was performed within the work package WP2A, a part of the FP7 SISTER project, and aims at strengthening the research capacity of FMI in Software and Services. The first WP2A task 2a.1, named *Determining joint research agenda in S&S*, is dedicated to the subject of this paper. The main purpose of this task is to enable the FMI research group in S&S to capitalize on existing research capacities, while providing a strategy for harmonization of research focus. It has to identify topics of S&S research that (i) constitute research urgencies at European levels from the NESSI technology platform initiative roadmap as well as other emerging working groups' roadmaps and FP7 priorities, (ii) map on local and regional interests and capacities, and (iii) are in the research focus of the FMI research group. Another target is to propose and apply a research approach that will bring most benefits to the group.

Within this task we aim at providing a shared view about current efforts in Bulgaria in Software and Services and shared strategic vision about future priorities.

1.2. S&S in general—introduction of terms and notions. As in many other fields there is no consensus about numerous terms and notions in

software engineering. We observe a substantial variety in the emerging so-called Services Sciences, Software as a Service, Service oriented software development. We assume that “Software services” are distributed software components and integrated open software packages offering their functionality through a network. “Software” and “Software engineering” have the standard and well-known meaning defined by IEEE. In this sense as a working hypothesis S&S is considered as a superset of software engineering (SE). This is because (among other arguments) some problems of software services have a purely business character.

The rest of the paper is organised as follows: Section 2, “Methodology”, introduces the classification frame of the research topics, the methodology applied for identification of the appropriate ones, and the sources of information used. Section 3, named “Investigation findings”, summarises the data collected from conferences and journals, PhD theses defended and in progress, research projects, and the global trends. Section 4 presents the application of the methodology described in section 2 on the data gathered in Section 3. Section 5 concludes the paper with a discussion of open issues and possible ways to improve the methodology for identifying research priorities in Software and Services field.

2. Methodology.

2.1. Background. One very important question that had to be answered at the very beginning was what classification frame would be the most appropriate for the needs of the task. The “candidates” were the following:

2.1.1. The ACM computing classification system. The ACM computing classification system [1] has been permanently updated since 1998 and the state we are using is valid through 2009, as stated in the website quoted. The part relevant to our research is:

D. Software

D.0 GENERAL

D.1 PROGRAMMING TECHNIQUES (E)

D.2 SOFTWARE ENGINEERING (K.6.3)

D.2.0 General (K.5.1)

D.2.1 Requirements/Specifications (D.3.1)

D.2.2 Design Tools and Techniques

D.2.3 Coding Tools and Techniques

D.2.4 Software/Program Verification (F.3.1)

D.2.5 Testing and Debugging

D.2.6 Programming Environments

- D.2.7 Distribution, Maintenance, and Enhancement
- D.2.8 Metrics (D.4.8)
- D.2.9 Management (K.6.3, K.6.4)
- D.2.10 Design (D.2.2)
- D.2.11 Software Architectures
- D.2.12 Interoperability
- D.2.13 Reusable Software
- D.2.m Miscellaneous
- D.3 PROGRAMMING LANGUAGES
- D.4 OPERATING SYSTEMS (C)
- D.m MISCELLANEOUS

H. Information Systems

H.3 INFORMATION STORAGE AND RETRIEVAL

H.3.5 Online Information Services

- Commercial services

- Data sharing

- Web-based services

H.4 INFORMATION SYSTEMS APPLICATIONS

H.5 INFORMATION INTERFACES AND PRESENTATION

- (e.g., HCI) (I.7)

H.m MISCELLANEOUS

2.1.2. *SWEBOK*. The purpose of the Guide to the Software Engineering Body of Knowledge (SWEBOK) [13] is to provide a consensually validated characterization of the bounds of the software engineering discipline.

The SWEBOK **Knowledge Areas** are ten on the higher level. One lower level is available.

2.1.3. *Standards*. Areas of knowledge/research, respectively of research, are closely related to various **standards**. The most widely used ones are those produced by **IEEE** and **ISO/IEC JTC1/SC7**. However, we could not find any classification of subject areas relevant to our aims.

2.1.4. *Decision*. After having analysed ACM CCS 1998 and SWEBOK we decided that the former would be more appropriate for us, mostly because of the degree of its granularity, as well as its relatively higher popularity (it has a substantially longer life and is still in wider use).

2.2. Methodology proposed. As already stated above, our main goal is to **select areas of research priority** in S&S. We believe that the main determining factors are:

- current state and trends of the research in the world,
- capabilities, traditions and trends in Bulgaria in S&S research,
- needs of the employers in Bulgaria,
- needs of the Sofia University, respectively FMI.

One possible approach to solving the problem of the recognition of development trends in scientific fields may consist in analysing the dynamics of various sources of information. This is a modification of the basic idea of [9] who investigates the vocabulary dynamics in documentary databases. The theoretical basis of the latter was provided by elements of the theory of non-equilibrium thermodynamics in open systems [10, 11], the main points of which were projected on the field of information science and the science of science. The method is based on the principle of isolating monotonous and fluctuating sections in the dynamics of information sources under investigation.

Hence, first we have to gather the appropriate information. More specifically this is:

- on the level of FMI—areas and numbers of scientific publications, as well as research projects, authored by or with the participation of FMI members/PhDs, number of PhDs and theses defended;
- on the national level—areas and numbers of scientific publications, PhDs and theses defended;
- on the global level—areas and numbers of scientific publications, trends, particularly taking into account the research priorities of relevant EU bodies;
- the foreign partners' opinion on priorities and more generally on the proposed methodology. They are asked through a questionnaire to provide their views on the current state and current trends according to their institutions' experience;
- the opinion of representatives of the Bulgarian software industry and trade.

The number and importance of citations would also be a valuable source of information, but our efforts proved it to be quite difficult and expensive to obtain full and reliable data.

A very tempting instrument is to consider and compare the number of ap-

pearances of the candidate areas when searching with Google (or another engine). However such an approach would contain a high degree of noise.

Another possibility is to compare the number of queries made in Google within a given period. Unfortunately this is difficult to implement for the moment.

2.3. Sources of information. As a consequence of the considerations above (2.1, 2.2), the following particular sources of information were processed in relation to the **FMI and national level**:

- Publications of BG authors in BG (conferences + journals)
- Publications of BG authors in the world (conferences + journals)
- PhD theses defended in BG
- PhD students in BG
- Research projects with Bulgarian teams involvement (national + international)
- Partners' opinion

Bulgarian authors are those working for research organizations established on Bulgarian territory, regardless of their actual nationality.

Our focus was on the following **conferences** and their respective **proceedings**:

- CompSysTech, 2004–2008
- SAER and later InfoTech, 2004–2008
- i.TECH, 2004–2008 in Varna
- Balkan Conference in Informatics (BCI), 2007 in Sofia
- Computer Science Conference, 2005–2006
- SAI Automatics and Informatics Conference — 2005–2008
- Conference John Atanasoff Days — 2006 Challenges in Higher Education (CHER) in Sozopol
- International Scientific Conference on Information, Communication and Energy (ICEST)

and on the following **journals**:

- International Journal “Information Theories & Applications”, volumes 14/2007 and 15/2008, published by the Institute of Information Theories and Applications FOI ITHEA, Bulgaria

- Journal of Information Technologies and Control, published by the Union of Automatics and Informatics in Bulgaria
- Computer Engineering — 2006, 2007
- Serdica Journal of Computing, published by the Institute of Mathematics and Informatics, Bulgarian Academy of Sciences
- Cybernetics and Information Technologies, published by the Institute of Information Technologies, Bulgarian Academy of Sciences

For the **global level** we considered the following very representative events:

- European Software Engineering Conference (ESEC)
- European Joint Conferences on Theory and Practice of Software (ETAPS)
- IEEE Software Engineering Workshop

3. Investigation findings.

3.1. Publications of BG authors in Bulgaria (conferences + journals). In this section of the report, we present the results of research on publications made by *Bulgarian authors* in the area of S&S in the last five years (from 2004 to 2008). The relevant publications are categorized according to the aforesaid ACM classification. The term *Bulgarian author* is defined as follows: authors who are working for a research organization established on Bulgarian territory, regardless of their actual nationality. Additionally we focus only on events held and journals published by Bulgarian organizations. We have identified the following main conferences with reviewed papers, published in the corresponding conference proceedings:

- International Conference on Computer Systems and Technologies CompSysTech (CompSysTech), <http://www.compsystech.org/>.
- International Conference on Information Research and Applications (i.TECH), proceedings from 2004 to 2007, <http://www.foibg.com/conf/proceedings/index.htm>.
- 3rd Balkan Conference in Informatics (BCI), held in Sofia in 2007.
- International Conference on Systems for Automation of Engineering and Research (SAER), proceedings from 2004 to 2006. In the last two years this conference was succeeded by the International Conference on Information Technologies (InfoTech), <http://www.tu-sofia.bg/saer>.

- The International Bulgarian-Greek Conference—Computer Science, held in 2005, 2006 and 2008, <http://www.csconf.org>.
- International Conference on Automatics and Informatics.
- International Conference UNITECH '08, held in Gabrovo.

The following journals also took place in the investigation:

- International Journal “Information Theories and Applications”, volumes 11/2004 to 15/2008, published by the Institute of Information Theories and Applications FOI ITHEA, Bulgaria, <http://www.foibg.com/ijita/ijita-finfo.htm>.
- Serdica Journal of Computing, published by the Institute of Mathematics and Informatics, Bulgarian Academy of Sciences, volumes 1/2007 and 2/2008, <http://www.math.bas.bg/serdicajcomputing/>.
- Cybernetics and Information Technologies, published by the Institute of Information Technologies, volumes 4/2004 to 8/2008, <http://www.cit.iit.bas.bg/>
- Computer Engineering, published by the Technical University of Sofia, volume 1/2007.

Next in the document we present the papers published by Bulgarian authors in the publications listed above. Research papers are analysed according to the place of publication. The results are presented in Table 3.1:

The results of the investigation are summarized in Table 3.2.

As seen from the results, 65 percent of the publications are on Design Tools and Techniques, Online Information Services and Systems. Most concern different practical applications such as database development, management and optimization, development of software tools and web service-based applications for intelligent search, assessment and e-learning.

As can be seen, about half of the papers are presented at a total of thirteen conferences (see Table 3.1). Most of the conferences, for example MENSURA, RE and CONQUEST, cover specialized areas in Software and Services. About one third of the publications have been published in journals.

More specifically, the topics cover some of the most contemporary programming platforms for web-development as PHP, OSGI and Spring. Their simplicity, the simplicity of usage and learning encourage many beginners to concentrate their efforts mainly on them. However, in order for them to be applied in a wide range of systems, more research is needed and the authors acknowledge

Table 3.1. Distribution of research papers according to place of publication

| No | Place of Publication | Papers count |
|----|---|--------------|
| | Conferences | |
| 1 | International Conference on Information Research and Applications — i.Tech (2004–2007) | 12 |
| 2 | SECOND IEEE INTERNATIONAL CONFERENCE ON INTELLIGENT SYSTEMS, JUNE 2004 | 4 |
| 3 | International Conference AUTOMATICS AND INFORMATICS (2005 and 2006) | 12 |
| 4 | International Conference on Computer Systems and Technologies — CompSysTech (2004–2008) | 36 |
| 5 | International Conference on Information Technologies (InfoTech), 2007–2008, successor of the International Conference on Systems for Automation of Engineering and Research, SAER (2004–2006) | 29 |
| 6 | 3 rd Balkan Conference in Informatics (2007) | 3 |
| 7 | IEEE John Vincent Atanasoff 2006 International Symposium on Modern Computing | 2 |
| 8 | International Scientific Conference UNITECH (2008) | 3 |
| 9 | International Scientific Conference Computer Science (2005 and 2006) | 7 |
| | Total | 108 |
| | Journals | |
| 1 | CYBERNETICS AND INFORMATION TECHNOLOGIES | 12 |
| 2 | International Journal “Information Theories & Applications” | 23 |
| 3 | Serdica Journal of Computing | 3 |
| 4 | Journal of Computer Engineering (2007 and 2007) | 4 |
| | Total | 42 |

this fact.

The most envisaged research area in Software and Services is the so-called Service Oriented Architecture (SOA). This is one of the topical questions for research in order to build Information Technology Society and establish the concept of Pervasive Computing. However these areas should be additionally supported by adequate research in the area of embedded systems. Bulgarian authors have focused their research in the areas of business process modelling and SOA for GRID environments. Additionally some aspects of Quality of Service in distributed systems have been discussed.

Other topics in SOA include the challenges and problems that test soft-

Table 3.2. Distribution of research papers according to the ACM classification index

| No | Classifiers | Papers count |
|----|-------------------------------------|--------------|
| 1 | D.1.3 Concurrent Programming | 3 |
| 2 | D.1.5 Object-oriented Programming | 1 |
| 3 | D.2.1 Requirements/Specifications | 1 |
| 4 | D.2.2 Design Tools and Techniques | 29 |
| 5 | D.2.4 Software/Program Verification | 1 |
| 6 | D.2.5 Testing and Debugging | 5 |
| 7 | D.2.9 Management | 10 |
| 8 | D.2.11 Software Architectures | 15 |
| 9 | D.2.13 Reusable Software | 4 |
| 10 | D.3.4 (Software) Processors | 1 |
| 11 | D.4.6 Security and Protection | 12 |
| 12 | H.2.4 Systems | 22 |
| 13 | H.3.5 Online Information Services | 46 |

ware development teams' experience when testing SOA applications. There is also an analysis of how the testing of SOA is carried out now and how it can be improved. Also interesting are the efforts to improve the currently existing technologies for implementation of SOA. More specifically some improvements of the Universal Discovery and Description Interface (UDDI) have been proposed.

More theoretically oriented is the research in the area of information systems. A model of Distributed Database Management Systems and an approach for Distributed Database Systems modelling has been created and the effectiveness of Algorithms for Concurrency Control of Transactions in Distributed Database Management Systems has been discussed. An interesting paper deals also with the problem of development and distribution of software. No less important is the problem of user interface usability and a new model has been proposed in this area.

There exist also purely practical elaborations like concrete architectures and frameworks or web-services, implemented to solve particular problems in IT. Some authors also deal with purely information theory problems such as access methods for databases and devices, storing information and surveys of the basic structure of General Information Theory with its main divisions outlined.

As a conclusion it may be stated that most of the research in Bulgaria is focused on study and practical applications of technologies for general-purpose

Table 3.3. Distribution of publications of BG authors in the world, according to the ACM classification index

| No | Classifiers | Number |
|----|-------------------------------------|--------|
| 1 | D.1.3 Concurrent Programming | 1 |
| 2 | D.2.1 Requirements/Specifications | 7 |
| 3 | D.2.2 Design Tools and Techniques | 11 |
| 4 | D.2.4 Software/Program Verification | 0 |
| 5 | D.2.5 Testing and Debugging | 2 |
| 6 | D.2.9 Management | 4 |
| 7 | D.2.11 Software Architectures | 2 |
| 8 | D.2.13 Reusable Software | 0 |
| 9 | D.4.6 Security and Protection | 0 |
| 10 | H.2.4 Information Systems | 1 |
| 11 | H.3.5 Online Information Services | 7 |

and desktop software systems. This is also seen from the large number of publications that fall under the D2.2 (Design Tools and Techniques) classifier. Efforts lack in the area of dependable systems and embedded systems in particular.

3.2. Publications of BG authors in the world (conferences + journals). The publications of Bulgarian scientists are also classified according to the ACM Computing Classification System.

The results are summarized in Table 3.3:

Since there are no publications in some scientific areas, the ACM classifiers D.2.4 Software/Program Verification, D.2.13 Reusable Software and D.4.6 Security and Protection are missing in the diagram. About 70 percent of the publications concern Design Tools and Techniques, Online Information Services and Requirements and Specifications. Most of them are relevant to the development of software tools and web service-based applications for intelligent search, assessment and e-learning. The publications concerning Requirements and Specifications are focused on ERP solutions.

The publications are analysed according to the place of publication. The results are presented in Table 3.4:

Table 3.4. Distribution of publications of BG authors in the world, according to the place of publication

| No | Place of Publication | Number |
|----|--|-----------|
| | Workshops | |
| 1 | TENCompetence Open Workshop | 3 |
| 2 | International Workshop on Software Measurement, IWSM, Potsdam | 1 |
| 3 | International Workshop on “Computer Science and Education in Computer Science”, Borovetz, Sofia | 1 |
| 4 | International Workshop on Trust and Reputation Management in Massively Distributed Computing Systems, TRAM | 1 |
| 5 | APSO “Scrutinizing Agile Practices: Or Shootout at the Agile Corral” Workshop | 1 |
| 6 | International Workshop on Software Measurement | 1 |
| 7 | Workshop on Requirements Engineering, WER | 1 |
| | Total | 9 |
| | Conferences | |
| 1 | Computer Science Conference | 3 |
| 2 | Conference on Knowledge Management in Organizations, KMO | 1 |
| 3 | International Conference on Electronic Publishing, ELPUB | 1 |
| 4 | American Society for Engineering Education Annual Conference, ASEE | 1 |
| 5 | SEEDI Conference “Digitization of cultural and scientific heritage” | 1 |
| 6 | International Conference on Web-Based Education | 1 |
| 7 | Informatics Education – The Bridge between Using and Understanding Computers, ISSEP | 1 |
| 8 | International Conference on Software & Systems Engineering and their Applications, ICSSEA | 1 |
| 9 | International Conference on Software Process and Product Measurement, MENSURA | 2 |
| 10 | International Conference on Requirements Engineering, RE | 2 |
| 11 | International Conference on Interactive Computer-aided Learning ICL | 1 |
| 12 | International Conference On Product Focused Software Process Improvement, PROFES | 1 |
| 13 | International Conference On Quality Engineering in Software Technology, CONQUEST | 1 |
| | Total | 17 |
| | Journals | |
| 1 | Requirements Engineering Journal, Springer | 1 |
| 2 | Journal of Information Technologies and Control | 1 |

| | | |
|---|---|----------|
| 3 | Review of the National Center for Digitization | 1 |
| 4 | Communication and Cognition | 1 |
| 5 | International Transactions on Systems Science and Applications (ITSSA), Special issue on WS-MAS | 1 |
| 6 | eService Journal | 1 |
| 7 | Applied Soft Computing, Special Issue on Dynamic Data Mining | 1 |
| 8 | IEEE Software | 1 |
| | Total | 8 |
| | Symposiums | |
| 1 | IEEE International Symposium on Empirical Software Engineering and Measurement | 1 |
| | Total | 1 |

About half of the papers have been presented at a total of thirteen conferences (see the table above). Most of the conferences, for example MENSURA, RE and CONQUEST, cover specialized areas in Software and Services. 23 percent of the papers have been published in journals and 26 percent presented at international workshops. All the papers are uniformly distributed, i.e., there are no preferred conferences or journals.

In the next two subsections we continue with the presentation of research conducted by PhD students working in Bulgarian research organizations.

3.3. PhD Theses Defended in Bulgaria. According to Bulgarian law PhD theses are defended in front of committees divided into problem areas. Of all areas relevant to the topic of Software and Services, the areas with following codes are considered here:

01.01.12 Informatics

02.21.04 Computer System Complexes and Networks

02.21.07 Automated Systems for Information Processing and Control

They cover most aspects of Software Engineering, Computer Science, etc. In the period from 2004 to 2008, the following numbers of theses were successfully defended, categorized according to problem areas (Table 3.5):

3.4. Analysis of the ongoing research by PhD students in Bulgaria. Investigations reflected here include only the ongoing research of PhD students currently supervised at the computer science departments of St. Kliment Ohridski University of Sofia and the Technical University of Sofia.

Table 3.5. Distribution of PhD theses according to problem areas

| No | Problem area | Number of PhD theses |
|----|--|----------------------|
| 1 | Informatics | 6 |
| 2 | Computer System Complexes and Networks | 1 |
| 3 | Automated Systems for Information Processing and Control | 3 |

Table 3.6. Distribution of PhD theses according to the ACM classification index

| No | Classifiers | Number |
|----|-----------------------------------|--------|
| 1 | D.2.2 Design Tools and Techniques | 2 |
| 2 | D.2.5 Testing and Debugging | 1 |
| 3 | D.2.9 Management | 1 |
| 4 | D.2.11 Software Architectures | 2 |
| 5 | D.4.6 Security and Protection | 4 |

The list of PhD thesis topics matching the area of “Software and Services” covers the areas of analysis and development techniques in the area of Object-Oriented Programming (OOP), some application aspects like the software approach to search and transformation of combinatorial configurations and operational compatibility of business systems. Issues such as adaptive software systems, agile methodologies and testing are also considered. A summary of the investigation of ongoing research by PhD students in Bulgaria is shown in Table 3.7.

Table 3.7. Approximate distribution of research areas of current Bulgarian PhD students

| No | Classifiers | Papers count |
|----|-----------------------------------|--------------|
| 1 | C.2.4 Distributed Systems | 2 |
| 2 | D.1.5 Object-oriented Programming | 2 |
| 4 | D.2.2 Design Tools and Techniques | 4 |
| 6 | D.2.5 Testing and Debugging | 1 |
| 7 | D.2.9 Management | 1 |
| 11 | D.4.6 Security and Protection | 1 |
| 12 | H.2.4 Information Systems | 2 |

As a result of the last two subsections it is of interest to state that Online Information Systems (and more specifically Services) are almost missing in the research of PhD students. The reasons for this may be various: on one hand, we have taken into account only two research organizations (although they are the most important ones in the field), and on the other hand the topics are usually defined very broadly in order for the young researchers to have enough freedom to choose the actual direction to work in during their PhD study.

3.5. Research projects with the involvement of Bulgarian teams.

There is limited public information about research projects with involvement of Bulgarian teams from the academic community and industry. In this section we present the results from the Bulgarian participation within European Framework Programmes during last 5 years.

Software and services are the area in which Bulgaria has shown the best performance with participation in 54 out of 82 ICT related research projects in total within FP6 and FP7 [3].

The Bulgarian research community and software companies participated very actively in the FP6 IST priority calls, showing good presence in all instruments. The distribution of participants by type of organisation shows that not only academia and the universities were successful, but also the SMEs, whose average share in retained proposals is about 21%. 72 IST projects with Bulgarian participation were funded, of which 47 were in the area of software and services. The distribution in sub-areas as defined by the IST work programme and presented in Figure 1 is as follows: 30% Support action, 13% Strengthening the integration effort in an enlarged Europe, 11% Software and services, 9% Networked business and government, 9% Future international cooperation, 6% Towards a global dependability framework, 4% Manufacturing enterprise, eHealth and Cross media content, 2% Embedded systems, Grid based systems, Open software.

Bulgarian researchers have actively participated in the first call of FP7 ICT priority. Again software and services were the most successful area—7 out of 10 ICT projects were funded. The distribution of research areas presented in Figure 2 is as follows: 30% The network of the future, 14% Software and services, ICT for aging, Secure and trusted infrastructures, ICT for risk assessment, Networked media.

Recently the Bulgarian Ministry of Education, Youth and Science started, through the National Science fund, to stimulate national research projects in ICT with grants similar to the accepted European practice. In the near future we

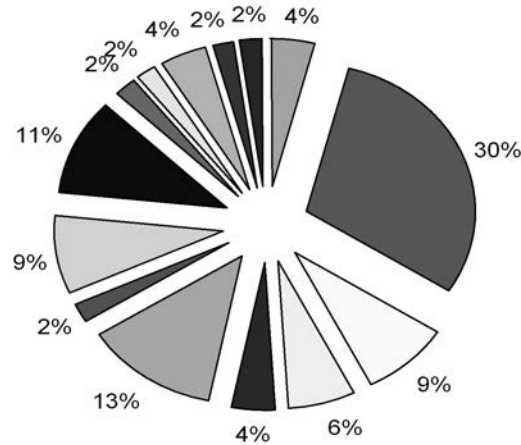


Fig. 3.1. Software and Services Research projects with Bulgarian participation in FP6

plan to investigate those projects and their results, as currently they are at their earliest stage.

3.6. Global trends. During the first year of the SISTER project we followed the intensive efforts of different groups and organizations to define the roadmap of future research in Software and Services. Here we will summarize the outcome of several respective ones:

3.6.1. European FP7. European FP7, Challenge 1, objective 1.2 “Internet of Services, Software and Virtualisation” [14] announced in the working programme 2009–2010 the following two main research priorities: *Service Platforms for the Future Internet* and *Highly Innovative Service/Software engineering*.

The main expected outcome from those two areas is the following:

Service Architectures and Platforms for the Future Internet

- Service front ends
- Open, scalable, dependable service platforms, architectures, and specific platform components
- Virtualised infrastructures
- Highly Innovative Service/Software Engineering
- Service/Software engineering methods and tools
- Verification and validation methods, tools and techniques

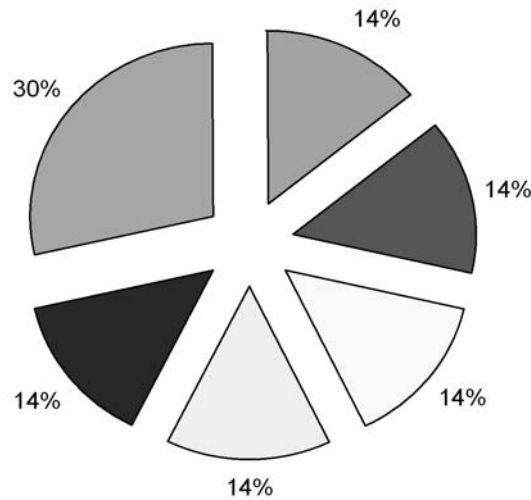


Fig. 3.2. Software and Services Research projects with Bulgarian participation in FP7

- Methods, tools and approaches specifically supporting the development, deployment and evolution of open source software.

3.6.2. NESSI roadmap. NESSI [7] is the European Technology Platform dedicated to Software and Services. Its name stands for **Networked European Software and Services Initiative**. NESSI is coordinated by industry and academia and aims at uniting all ICT stakeholders through active contributions and involvements in the elaboration and evolution of its *Strategic Research Agenda* and definition, implementations and delivery of NEXOF, the NESSI Open Service Framework. The last version of NESSI roadmap version 3.2 dated May 2009 [8] identifies the following challenges:

Service-oriented utility: from adaptation of ICT infrastructures as a whole to differentiating specific aspects for Hardware, Middleware and new programming models ranging from flexible allocation to energy efficiency, and from new composite system designs to harmonised virtualisation;

- *Service and System Engineering:* extending the notion of systems to hybrid systems and their modelling, construction and management; mapping embedding in Service Engineering advanced practices to non-functional properties of components; Refining semantics to become appropriate across hybrid service-based systems;
- *Adaptive interactions:* from service adaptation to embedding intelligence;

situational-driven personalisation of user interfaces and services; and embodiment of educating principles into hybrid service-based systems;

- *Business process*: from modelling to building business processes composing IT services;
- *Trust, security and dependability*: from trust and confidence through policies, QoS, security, etc., to embedding persuasive tactics and intuitive security;
- *Services in society*: from the definition of the research area to building systemic foundations for a Service Economy.

Currently the NESSI roadmap version 3.3 is work in progress and the directions in Software and Service Engineering are:

- Change of the software-service landscape from packaged software to software as a service, e.g., new methodologies, new business models (under consideration of legal issues) and migration strategies;
- Research in the way intelligence is embedded in different layers (for example, service messaging may be included in low level protocols ...);
- Focus on automation and consumers' empowerment.

3.6.3. Report on Longer term research challenges in Software & Services.

The research priorities identified in this report are an outcome from two workshops held on the European Commission's premises on the 8th of November 2007 and 28th and 29th of January 2008 by a respectable expert group. A summary of the research challenges follows:

- *High-level Service Description Languages* which rely on powerful abstraction constructs to enable stakeholders to describe service-based applications in terms of what they require, thus allowing all kinds of parties to develop provisions and compose complex service-based applications.
- *Service Design Theories* that gravitate towards having to deal with large scale, dynamic, global reach and open service-enabled applications and systems and provide suitable interfaces to allow runtime testability and debuggability.
- *Service Domains* to understand dynamic problem domains and to acquire, reason about and incorporate domain knowledge expressed in different forms and in a wide range of sources into domain-specific service technologies and methodologies.

- *Service Platforms* that will virtualise vast numbers of heterogeneous computing systems and resources and will have the flexibility to adapt to application-specific and contextual needs and to optimize themselves accordingly while preserving agreed-upon QoS and SLAs.
- *Service Quality* techniques and theories to guarantee that appropriate end-to-end quality of service levels are attained for service-based applications that will run in highly volatile execution contexts, which cannot be anticipated when the service-based application is being designed and deployed.
- *Software Service Life Cycle* for novel service-based applications based upon extremely large, open service networks which will rely on improvisational, and often ad-hoc, procedures supporting resource discovery, self-deployability and self-adaptability of service-based applications.

Obviously it is difficult to have clearly defined priorities in this dynamic research environment. Also, the abovementioned examples show that different groups at the European level concentrate their efforts in order to synchronize and direct research in Software and Services. In this way the expected outcomes will be more valuable. Our efforts are similar to those activities. We will continue to follow the work in this direction and use it as an important input for adjusting our national priorities in the S&S field. Other factors (see section 2.2) specific for the Bulgarian environment will be taken into account too.

4. Applying the methodology on the gathered information—FMI/national level.

4.1. Criteria weights—processing and results. As already mentioned above (2.3), a group of experts were asked to fill in the table below (Table 4.1). The aim was to determine the weights of importance of each of the criteria selected.

As is well known, various proven methods are available to this aim. After some analysis we decided to use AHP [12].

The experts were asked to use the scale table contained in Table 4.2 (with A in the row and B in the column):

Ten experts (nine Bulgarians and one partner) submitted their opinions. One, possibly due to a misunderstanding, delivered answers dramatically differing from the rest. Another one changed to some extent the meaning of the criteria. These two sets of answers were removed and only 8 were taken into account. (Just for verification, the AHP procedure was applied to the set of nine, incl.

Table 4.1. Criteria table

| Criteria | Number of publications of BG authors in BG (journals+conferences) | Number of publications of BG authors in the world (journals+conferences) | Number of PhD theses defended in BG | Number of PhD Students in BG | Research projects – national and international | Number of citations of BG authors | Project Partners' opinion |
|--|---|--|-------------------------------------|------------------------------|--|-----------------------------------|---------------------------|
| Number of publications of BG authors in BG (journals + conferences) | 1 | | | | | | |
| Number of publications of BG authors in the world (journals + conferences) | | 1 | | | | | |
| Number of PhD theses defended in BG | | | 1 | | | | |
| Number of PhD students in BG | | | | 1 | | | |
| Research projects – national and international | | | | | 1 | | |
| Number of citations of BG authors | | | | | | 1 | |
| Project Partners' opinion | | | | | | | 1 |

Table 4.2. Scale table

| Value | Meaning |
|-------|---|
| 1/6 | A is substantially less important than B |
| 1/4 | A is moderately less important than B |
| 1/2 | A is slightly less important than B |
| 1 | A is equally important as B |
| 2 | A is slightly more important than B |
| 4 | A is moderately more important than B |
| 6 | A is substantially more important than B |

the deviating opinion, but, as expected, the results obtained were quite different from the ones quoted below.)

Table 4.3 gives an overview of these opinions. The first number in each cell indicates the highest submitted value; the second one, the lowest. In addition a grey colouring scheme was applied in order to give an impression of how the individual opinions differ from each other (the darker the shade of grey, the bigger the difference). As can be seen,

- on no pair of criteria have all eight experts chosen the same value,
- however, on some of them they have demonstrated the lowest difference possible,
- it seems that the hardest criterion to evaluate was “Number of PhD theses defended”: it participates in three pairs of criteria (viz. “Research projects”, “Number of citations” and “Partners’ opinion”), and the difference is formidable ($6-1/4$ or $6-1/2$).

Our general conclusion is that it was worthwhile asking for the experts’ estimates and then aggregating them by using AHP.

As the next step of AHP the values in each cell were accumulated.

After that, the following procedure was carried out:

- replacing each value by its average (divided by 8);
- filling in each cell below the diagonal with the value $1/a$, where a is the value in its symmetric cell;
- creating an additional row below with the sums of the respective columns.

As a next step a normalization procedure was applied—each value was divided by the sum of its column.

Table 4.3. Experts' opinions

| | | | | | | |
|------|-----------|------|---------|---------|-----------|---------|
| 1,00 | 1/2 - 1/6 | | 6 - 1/4 | | 1/2 - 1/6 | 1+1/4 |
| | 1,00 | | 6 - 1/2 | | | 6 - 1/2 |
| | | 1,00 | | 6 - 1/4 | 6 - 1/4 | 6 - 1/2 |
| | | | 1,00 | | | |
| | | | | 1,00 | | 6 - 1/2 |
| | | | | | 1,00 | |
| | | | | | | 1,00 |

The last step was to add up the numbers of each row and to enter the sum obtained in a new rightmost column (Table 4.4). Then a final normalization was performed by dividing these sums by 7 (the number of criteria) and by putting the final weights so obtained in a new leftmost column.

Table 4.4. Final criteria weights

| | | | | | | | | |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|------|
| 0,07 | 0,06 | 0,10 | 0,12 | 0,08 | 0,04 | 0,06 | 0,53 | 0,08 |
| 0,28 | 0,25 | 0,42 | 0,28 | 0,21 | 0,15 | 0,20 | 1,79 | 0,26 |
| 0,11 | 0,10 | 0,16 | 0,25 | 0,26 | 0,23 | 0,20 | 1,31 | 0,19 |
| 0,04 | 0,06 | 0,04 | 0,07 | 0,09 | 0,12 | 0,09 | 0,51 | 0,07 |
| 0,16 | 0,23 | 0,12 | 0,15 | 0,19 | 0,27 | 0,18 | 1,30 | 0,19 |
| 0,25 | 0,22 | 0,10 | 0,08 | 0,10 | 0,14 | 0,20 | 1,08 | 0,15 |
| 0,08 | 0,08 | 0,06 | 0,06 | 0,07 | 0,05 | 0,07 | 0,47 | 0,07 |
| 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 7,00 | 1,00 |

The same weights are given in descending order in Table 4.5:

4.2. Application of the weights to the data gathered. Now we summarise in a single table all the data gathered, as described in section 3, and the weights obtained in 4.1.

Taking into account the quantity of the data gathered it would be wise to ignore the last four or even five rows.

As it might also be noticed, two of the criteria chosen and processed – “Number of citations of BG authors” and “Project Partners’ opinion” – are not in the table. The reason is that for the first one not enough data has been collected up until now, and as for the second one, it is still not quite clear how to quantify

Table 4.5. Final criteria weights—sorted

| | |
|--|------|
| Number of publications of BG authors in the world (journals + conferences) | 0,26 |
| Research projects—national and international | 0,19 |
| Number of PhD theses defended in BG | 0,19 |
| Number of citations of BG authors | 0,15 |
| Number of publications of BG authors in BG (journals + conferences) | 0,08 |
| Number of PhD Students in BG | 0,07 |
| Project Partners' opinion | 0,07 |

this opinion.

In the chart (Figure 4.1) we have multiplied the weighted values by 10 in order to enable a clearer comparison.

The conclusion is that the weights do not dramatically change the ranking of the subject areas. This could be explained, but we believe it is beyond the aim of our work.

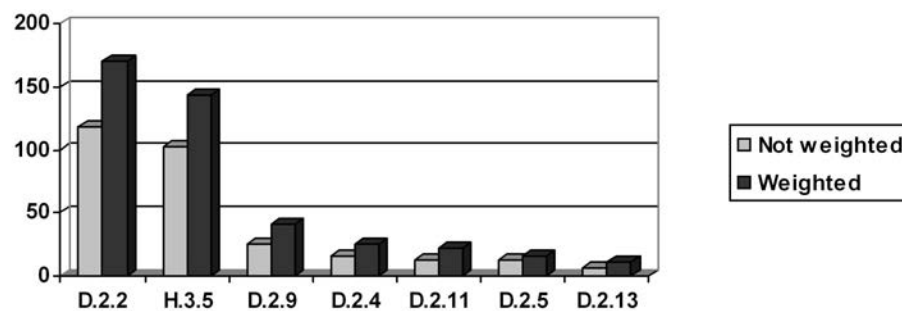


Fig. 4.1. Graph representation of the data aggregated

5. Conclusion. The paper presented the methodology and its application for identifying the priorities for future research in the Software and Services field at FMI. It can be considered as a first step which sets the priorities at a higher level. Further refinement and concrete formulation of research topics is our next step. The current results are fully in line with the priorities defined

Table 4.6. Aggregated data

| Weights | 0,08 | 0,26 | 0,19 | 0,07 | 0,19 | | |
|---|--|---|--|------------------------------|----------------------|-----------------------------------|---------------------------|
| Criteria | Number of publica- tions in BG (journals+ confer- ences) | Number of publica- tions of bg scientists in the world (journals+ conferences) | Number of PhD theses defended | Number of PhD students | Research projects | TOTAL not weighted | TOTAL weighted |
| D.2.2 Design Tools and Techniques | 66 | 45 | 1 | 5 | 1 | 118 | 17,71 |
| H.3.5 Online Information Services, incl. Commercial services and Web services | 53 | 22 | 2 | 2 | 24 | 103 | 15,04 |
| D.2.9 Management [of soft- ware development] | 9 | 13 | 1 | 2 | 0 | 25 | 4,43 |
| D.2.4 Software/Program Verification | 4 | 8 | 1 | 2 | 0 | 15 | 2,73 |
| D.2.11 Software Architec- tures | 0 | 1 | 1 | 1 | 10 | 13 | 2,42 |
| D.2.5 Testing and Debug- ging | 6 | 3 | 1 | 1 | 1 | 12 | 1,71 |
| D.2.13 Reusable Software | 2 | 3 | | 0 | 1 | 6 | 1,13 |
| D.4.6 Security and Protec- tion | 0 | 0 | 2 | 1 | 0 | 3 | 0,45 |
| D.2.1 Requirements/Speci- fications | 0 | 0 | 0 | 4 | 0 | 4 | 0,28 |
| H.2.4 Information Systems | 0 | 0 | 0 | 3 | 0 | 3 | 0,21 |
| D.1.3 Concurrent Program- ming | 0 | 0 | 0 | 1 | 0 | 1 | 0,07 |

on a European level. For example the first priority in our list, Design tools and Techniques, after further refinement could be related with the Service-oriented utility challenge of the NESSI roadmap and Service Platform and Service Design Theories challenges from the report on longer-term research challenges in S&S.

We consider the results obtained up by now (as shown in Table 4.6) as ready for application by FMI, but also as a sound basis for some future refining of the forecast of S&S research priorities in Bulgaria in general.

We believe that this refinement should be based on the following:

- Distinguish between national and international projects;
- Consider partners' opinion and take it into account in a more detailed and objective way;
- Consider more carefully and take into account Bulgarian industry opinions;
- Resolve the problem with publications/theses covering more than one area;
- Break down H.3.5 "Online information services" into at least two sub-areas.

Work on some of those directions has already started. The same methodology could be applied by other research groups and also on a national level helping the identification of priorities for further research.

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