Harmonization of Engineering Education in Europe as a Prerequisite for Student Mobility: a Case Study Based on Curricula Modularity

ALLA ANOHINA, JANIS GRUNDSPENKIS
Department of Systems Theory and Design
Riga Technical University
1 Kalku street, Riga, LV-1658
LATVIA
alla.anohina@rtu.lv, janis.grundspenkis@rtu.lv http://www.rtu.lv

Abstract: - The paper presents the case study of the curriculum "Computer Systems" which is taught at the master level in the Institute of Applied Computer Systems of Riga Technical University. The study is carried out with the goal to evaluate opportunities for the short-time mobility of students. The main problems related to the provision of student mobility are discussed in brief. Positive impact of curricula modularity on mobility is pointed out. The curriculum "Computer Systems" is analyzed using a concept of two-dimensional modularity. Results of the comparison of the curriculum "Computer Systems" with similar curricula of other countries of the European Union at levels of courses, their groups and modules are presented.

Key-Words: - higher engineering education, curricula modularity, short-term mobility of students

1 Introduction

On 25 May 1998 in Paris, ministers responsible for the higher education in France, Germany, Italy and the United Kingdom signed the Sorbonne Declaration [1] which emphasized that Europe should become the Europe of Knowledge. This document was a predecessor of the Bologna Declaration [2] that was accepted by 29 states on 19 June 1999. The declaration promotes the improvement of the higher education system, recognizing education as a cornerstone in the consolidation of a stable, peaceful and democratic society. Almost a year later the new strategic goal of the European Union (EU) for the next decade was established in the Lisbon Strategy [3]: Europe should become the most competitive and dynamic knowledge-based economy in the world. In turn, in 2005 the Council of the European Union stressed that the Lisbon goals of competitiveness and economic growth can only be achieved if young people coming onto the labor market are properly equipped through qualitative education and training in line with the evolution of society [4].

In the context of the mentioned documents it is important to harmonize curricula of universities of the EU due to the fact that in near future most probably all restrictions which exist today in connection with labor force flows among EU countries will be canceled. In situation when the number of freshmen who are interested in engineering studies decreases practically in all so called "old" European Union countries, e.g., Sweden, Germany, the United Kingdom, etc., shortage of educated people in engineering will be possible to diminish at least partly by attracting universities' graduates from "new" European Union countries, for instance, from Baltic countries, Czech Republic and Poland. It is worth to point out that easy adaptation of new specialists in different labor markets depends not only on the quality of curricula but also on wide opportunities for student mobility. According to [5] student mobility and accompanying academic recognition are assumed to be necessary prerequisites for an open and dynamic European educational area that will aid European integration and labor market mobility. It is quite obvious that the terms "student mobility" and "curricula harmonization" are closely coupled, that is, student mobility between universities will be more prolific if their curricula are harmonized till the certain degree.

The paper presents the case study of the master level curriculum "Computer Systems" which is compared with other curricula from perspectives of student mobility and curricula contents. The paper is organized as follows. Section 2 focuses on the problem of student mobility. Section 3 describes the curriculum "Computer Systems". The methodology for the selection of higher education institutions of the EU is discussed in Section 4. Results of the research on academic mobility of higher engineering education students are given in Section 5. Section 6 reflects results of the comparison of the curriculum "Computer Systems" with the similar curricula within the EU. In Section 7 the comparison of content of the course modules of the curriculum "Computer Systems" with similar courses of other institutions of higher education of the EU is given. The last section presents conclusions.

2 Student Mobility

In [5] mobile students are defined as those who study abroad for either a degree or for a certain period of time. This definition clearly points out two kinds of student mobility: long-term and short-term mobility. Thus, the former is related to a complete study programme abroad leading to a diploma, but the latter refers to a maximum of one year of studies in a foreign institution during student's overall studies [6]. Research presented in this paper focuses on the short-term mobility of students.

The short-term mobility of students within the EU has been widely supported already for 20 years since the first Erasmus mobility programme was established in 1987. Erasmus is the European Commission's educational programme for higher education students, teachers and institutions introduced with the aim to support and increase student and staff mobility within Europe. Erasmus forms a part of the EU Lifelong Learning Programme [7]. Regarding Erasmus European Commissioner in charge of Education, Training, Culture and Multilingualism, Ján Figel' postulated that "encouraging mobility will remain a priority for the Commission in the coming years, as we expect to reach the target of 3-million Erasmus students by 2011 with almost 300.000 students per year" [8].

In [9] it is emphasized that such elements of the strategy of Europe as world recognition of the quality of education and development of knowledge-based economy could be realized through three objectives – competitiveness of higher education, mobility of students and employability. This also is the reason why new curricula are designed in compliance with the principles of the Bologna declaration. For example, a consortium of four universities from different European countries has developed an interdisciplinary Master's curriculum in Environmental Process Control Engineering taking into account not only European credit transfer system and mixture of classical (frontal teaching) and modern (e-learning and web-based) teaching and learning methods, but also including student mobility as an integral part of the curriculum [10].

However, despite of all above told there are still many problems related to the provision of student mobility. According to the survey given in [11] despite the fact that mobility is considered to be one of the core goals of the Bologna Process it is far from being reached. Three problems are mentioned: the portability of loans and grants, additional financial support for mobile students and the removal of administrative obstacles for student mobility. The survey points out that loans and grants are not portable to all EU countries regardless the fact that Ministers responsible for higher education made a clear commitment to facilitate the portability of grants and loans in the Berlin communiqué in 2003 and confirmed their commitment in the Bergen communiqué in 2005. Only one third of the member states of the EU do not have problems with the portability of loans and grants for the study period up to one year. Other member countries have different restrictions from the minor obstacles for the portability of loans and grants even up to unavailability of grants and loans at all. Even when loans and grants are portable they rarely suffice to cover all the costs (tuition fees, travel costs, higher living costs) which a student is faced with during the mobility period. The results of the survey show that only Estonia, Italy, Lithuania and Sweden provide the possibility for financial support to mobile students on all of the above mentioned issues.

Other researchers consider the problem related to the insufficient provision of information on student mobility by universities. They offer software solutions aimed to support different kinds of information about available mobility programs as well as to share experience of studies in foreign institutions among students. Examples of such software can be found in [12, 13, 14].

Other problems affect institutions of higher education which curricula are not a part of such mobility programmes as Erasmus, so they are forced to establish their own procedures for the implementation of student mobility. An example of a good practice demonstrates the Faculty of Electronic Engineering of the University of Nis (Serbia) that within the framework of TEMPUS Project CD JEP-16160-2001 "Innovation of Computer Science Curriculum in Higher Education" organized a short-term student mobility program during which seven students visited University of Dortmund (Germany), four were at Technological Education Institute of Athens (Greece), while three had a professional placement at Institute for Informatics of The Faculty of Science and Mathematics of Skopje (Macedonia). The special organizing procedure was developed and used for the organization and implementation of student mobility program [15].

The Institute of Applied Computer Systems of Riga Technical University (RTU) faces the same abovementioned problems of student mobility regardless of participation in Erasmus mobility programme during several decades. The desire to find a solution is the main driving force for the research presented in this paper. The curriculum

"Computer Systems" is compared with similar curricula of other countries of the EU on the basis of the concept of two-dimensional modularity. The concept of modularity is highlighted because modularization is expected to have a positive impact on incoming and outgoing mobility [16].

3 The Curriculum "Computer Systems"

The curriculum „Computer Systems" has been implemented by the Institute of Applied Computer Systems of RTU since the middle of the 1990s. Today it has the 3+2+3 scheme, i.e. 3 year bachelor, 2 year master and 3 year doctoral studies. The curriculum objective is to provide academic education in computer science and to prepare highly qualified professionals in the fields of system analysis, software engineering and design of computer systems (databases, information systems and intelligent systems) with fundamental knowledge based on engineering science, which includes mathematics, physics, chemistry, electrical engineering and electronics. In 2001 the international evaluation commission accredited the curriculum "Computer Systems" for six years. The curriculum was reaccredited in 2007 till the year 2013.

The objective of the academic master level curriculum "Computer Systems" is to give students extended knowledge in computer science, software engineering and design of computer systems with intent that graduates could start working in the university, scientific-research computer companies and organizations, as well as to continue studies at the doctoral level. Studying at the master level students can choose the set of courses that are the most suitable for their interests and further career. They must decide on one of the 3 modules. The module "Computer Systems Design" is directed towards design of information systems, databases, intelligent systems and other software systems. The module "Applied Computer Systems Software" is related to general models, methods and algorithms for the development of applied computer systems. The module "Applied Computer Science" is directed towards modelling of computer systems and problem analysis. The total amount of credit points of the master's level studies is 121.5 ECTS. After the completion of the curriculum students receive the degree of Master of Engineering Science.

The curriculum "Computer Systems" at the master level includes the following courses (Fig.1):

- First semester (30 ECTS):
  - *Compulsory courses* (18 ECTS): Models for Software Planning and Metrology (6 ECTS), Large Databases (6 ECTS), Object-oriented System Analysis (6 ECTS);
  - *Restricted electives* (9 ECTS): System and Process Theory (6 ECTS), Software Quality (6 ECTS), Computer Networks Software (6 ECTS), Scientific Seminar on Computer Systems Design (3 ECTS), Applied Computer Science Seminar (3 ECTS), Scientific Seminar on Applied Software (3 ECTS);
  - *Humanitarian/social science, economics and management* (3 ECTS);

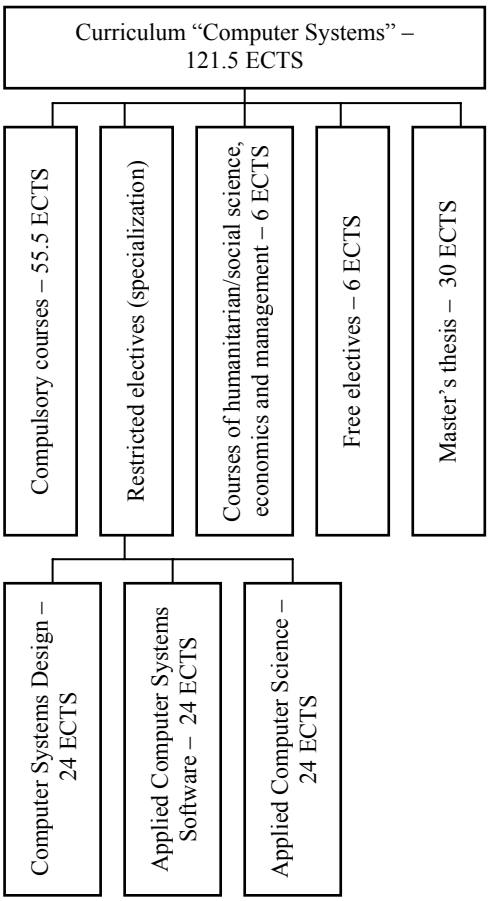

Fig.1. Structure of the curriculum „Computer Systems" of the master level

- Second semester (31.5 ECTS):
  - *Compulsory courses* (19.5 ECTS): Artificial Intelligence (6 ECTS), Process Programming (6 ECTS), Computer Aided Solution Processing (6 ECTS), Fundamentals of Labour Protection (1.5 ECTS);
  - *Free electives* (3 ECTS);
  - *Humanitarian/social science, economics and management* (3 ECTS);
  - *Master's thesis* (6 ECTS);
- Third semester (30 ECTS):

- *Compulsory courses* (18 ECTS): Specialized Data Processing Technologies (6 ECTS), Requirement Engineering (6 ECTS), Object-oriented Software Development (6 ECTS);
- *Restricted electives* (9 ECTS): Information Systems and CASE Tools (6 ECTS), Tools for Object-oriented System Development (6 ECTS), Methods of Engineering of Intelligent Applied Computer Systems (6 ECTS), Scientific Seminar on Methods of Computer Systems Design (3 ECTS), Applied Computer Science Seminar (3 ECTS), Scientific Seminar on Progressive Software Technologies (3 ECTS);
- *Free electives* (3 ECTS);

- Fourth semester (30 ECTS):
  - *Restricted electives* (6 ECTS): Knowledge Management (6 ECTS), Methods and Development Trends of Applied Computer Science (6 ECTS), Software Reliability Theory (6 ECTS);
  - *State examination: Master's thesis* (24 ECTS).

In 2005 the Institute of Applied Computer Systems of RTU started several ESF projects directed toward the improvement of the curriculum "Computer Systems" at all levels for bachelor, master and doctoral studies. The main objective of the projects is to align the curriculum with the European Educational Space promoting economical and competitive growth both of Latvia and Europe.

The projects are based on the methodological framework which principal concept is two-dimensional modularity of the curriculum. The horizontal dimension corresponds to the decomposition of the study programme into subsets of courses which have related topics and are taught concurrently. The vertical dimension presents subsets of courses which have related topics and are taught in different semesters or different study levels. Starting point for the definition of modules was the investigation of the existing "Computer Systems" academic study programme and profession standards for a software engineer and a system analyst where general and specific knowledge and skills are defined. This activity resulted in the form of so called "course profiles" which are filled up by experts of the corresponding courses. The essence of the course profile is identification of input/output knowledge. In fact, it is an extended course description with clear focus on prerequisite knowledge and strict formulation of outcomes, i.e. knowledge and skills obtained after finishing the course. In addition the course profile contains expert's opinion about the module in which the course should be included, as well as the statement about the current situation where such indicators as "right semester", "correct volume", "conflict courses", "student training level", "teaching materials" and "improvement proposals" are fixed. The gathered information allowed the definition of eleven modules where each of them includes 2-4 courses:

- Artificial Intelligence: Fundamentals of Artificial Intelligence (4.5 ECTS, bachelor level, third year, spring semester) and Artificial Intelligence (6 ECTS, master level, first year, spring semester);
- Systems Theory: Methods of Systems Theory (3 ECTS, bachelor level, third year, autumn semester) and System and Process Theory (6 ECTS, master level, first year, autumn semester);
- Databases: Technology of Large Databases (3 ECTS, bachelor level, third year, autumn semester) and Large Databases (6 ECTS, master level, first year, autumn semester);
- Knowledge Engineering: System Analysis and Knowledge Acquisition (3 ECTS, bachelor level, third year, autumn semester) and Knowledge Management (6 ECTS, master level, second year, spring semester);
- Services of Operating Systems: Computer Organization and Assemblers (4.5 ECTS, bachelor level, third year, autumn semester) and Process Programming (6 ECTS, master level, first year, spring semester);
- Object-oriented System Analysis: Object-oriented System Analysis and Design (4.5 ECTS, bachelor level, third year, autumn semester) and Object-oriented System Analysis (6 ECTS, master level, first year, autumn semester);
- Software Development: Software Development Technologies (4.5 ECTS, bachelor level, third year, autumn semester) and Object-oriented Software Development (6 ECTS, master level, second year, autumn semester);
- Applied Intelligent Systems: Interactive Intelligent Systems (7.5 ECTS, doctoral level, first year, spring semester) and Methods of Engineering of Intelligent Applied Computer Systems (6 ECTS, master level, second year, autumn semester);
- Data Processing Methodologies: Specialized Data Processing Technologies (6 ECTS, master level, second year, autumn semester) and Computer Aided Solution Processing (6 ECTS, master level, first year, spring semester);

- Requirement Engineering: Requirement Engineering (6 ECTS, master level, second year, autumn semester), Models for Software Planning and Metrology (6 ECTS, master level, first year, autumn semester) and Tools for Project Management Maintenance (3 ECTS, bachelor level, third year, autumn semester);
- Implementation of Algorithms: Algorithms and Programming Methods (3 ECTS, bachelor level, third year, spring semester), Functional Programming (3 ECTS, bachelor level, third year, autumn semester) and Adaptive Data Processing Systems (3 ECTS, bachelor, third year, autumn semester).

Different investigations and activities have been carried out within the previously mentioned projects. The next sections describe results of the research which have two main goals:

- to identify possible curricula which can provide academic mobility of higher engineering education students studying at the master level;
- to determine the correspondence of the curriculum "Computer Systems" of the academic master level to a wide spectrum of curricula in the field of computer science of other institutions of higher education within the EU. For this purpose a comparison of the curriculum "Computer Systems" with the similar curricula at the level of courses and their groups is carried out.

4 Selection of Higher Education Institutions

The full list of institutions of higher education of the EU is obtained by using information from the following sources:

1. Web sites of institutions responsible for higher education in each country;
2. a portal on learning opportunities throughout the European Space [17];
3. an international education directory of colleges and universities [18];
4. a Web site of higher education in Europe from Graduateshotline.com [19];
5. a directory Colleges.com [20].

However, the following problems impeded acquiring of curricula:

1. Web sites of many higher education institutions support only local language, for example, Hungarian or French, or gives only general information about the institution in English without the description of the curricula;
2. there is a specificity regarding master level curricula in some countries, for example, in Spain there is an information about „official masters" and „neofficial masters", or in the United Kingdom there are „taught masters" and „research masters";
3. sometimes information about a curriculum does not contain the detailed description, i.e. courses, their credit points and semesters.

Taking into account the mentioned problems, the following selection criteria are used:

1. information about a curriculum is in English on the Web site of a corresponding institution of higher education;
2. information about a curriculum includes titles of study courses, credit points for each course, as well as semesters, when the course is taught (only for the identification of mobility opportunities);
3. the level of a curriculum is the academic master studies (the same as the level of the curriculum "Computer Systems");
4. the title of a curriculum contains some of the following words: Computer Science, Computer Systems, Software Engineering, Software Development, Information Systems, Information Technology, Computing;
5. the offered curriculum is not a distance learning programme;
6. the obtained degree is Master of Engineering Science.

5 Opportunities for Mobility

The criteria listed in Section 3 allow the identification of 29 curricula in 25 institutions of higher education from 15 countries of the EU for the research of providing academic mobility of higher engineering education students (Table 1). One part of the found institutions are the partners of RTU in Erasmus programme [21]; others were examined from the perspective of potential partners.

Results of the comparison of course titles and corresponding credit points show that it is very difficult to provide mobility of engineering students because there are essential differences among curricula. As a rule, credit points of only one course can be transferred for the greater part of students studying at foreign institutions of higher education. Moreover, usually these credit points are provided by free electives or such courses as Software Engineering, Artificial Intelligence or Databases. The greatest number of credit points which can be transferred is 2 or 3 credits, however in this case it is necessary to consider such factors as the

specialization chosen by the student at the foreign institution and courses passed by the student in his/her local institution.

Table 1.
Distribution of curricula and institutions by countries for the mobility research

Country	Number of curricula	Number of institutions
United Kingdom	8	6
Belgium	1	1
Czech Republic	1	1
Denmark	1	1
Greece	1	1
Ireland	3	2
Lithuania	1	1
Cyprus	2	2
Luxembourg	1	1
Malta	1	1
Portugal	1	1
Romania	3	2
Slovak Republic	1	1
Germany	2	2
Sweden	2	2
Totally	29	25

The conclusion is that there opportunities are very limited for master level engineering students of the curriculum “Computer Systems” to go abroad and to get credit points for full semester. The reason is that there is not any suitable curriculum either among universities with which RTU has agreements for student mobility, or among other EU universities. Practically the only possibility is the development of the master thesis in a foreign institution of higher education at the end of studies.

6 Comparison of Courses and Credit Points

The following tasks are identified for the comparison of the curriculum "Computer Systems" of the master level with the similar curricula of other countries of the EU at the level of courses:

1. to identify the most often included courses in computer science curricula;
2. to group the identified courses accordingly to the groups of courses of the curriculum "Computer Systems" and to compare the number of credit points of the groups.

Totally 55 curricula in 43 institutions of higher education from 18 countries are identified (Table 2) for this research because it is not necessary to know a semester when courses are taught.

The focus of the research is concentrated on compulsory courses. The analysis of curricula at the level of courses shows that there is an enormous diversity. Totally 262 different titles of courses are identified. The most often offered courses are displayed in Figure 3. Their minimal, maximal and average number of credit points are presented in Table 3. The other 7 courses (Artificial Intelligence, Data Mining, Formal Methods, Human-Computer Interface, Operating Systems, Programming Languages and Computer Security) are included in 3 curricula with very different number of credit points, starting from 2 ECTS and up to 7.5 ECTS. Thirty three courses are found in two curricula, and others only in one curriculum.

Table 2.
Distribution of curricula and institutions by countries for the comparison of curricula

Country	Number of curricula	Number of institutions
United Kingdom	17	11
Belgium	3	3
Czech Republic	1	1
Denmark	2	2
Greece	4	3
Estonia	3	2
Ireland	3	2
Lithuania	1	1
Italy	4	3
Cyprus	2	2
Luxembourg	1	1
Malta	1	1
Netherlands	2	1
Portugal	1	1
Romania	3	2
Slovak Republic	1	1
Germany	2	2
Sweden	4	4
Totally	55	43

The results of the research reveal general tendencies. The main attention is granted to software engineering, including object-oriented approach, project management, artificial intelligence (intelligent and distributed systems, data mining, etc.), databases, information systems, computer networks, compilers and research methods. All of the mentioned courses excluding compilers are incorporated in the curriculum “Computer Systems” as well. Moreover, credit points either are identical with the average number of credit points of other curricula in the EU, for example, in Artificial Intelligence, Modern Databases, Information Systems Analysis and Design, Scientific Research

Methods, or are even higher, for example, as for Object-oriented Approach.

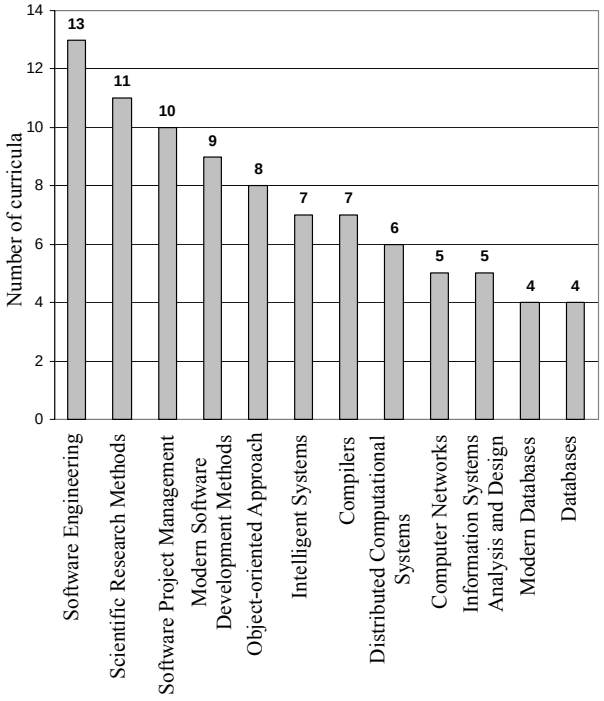

Fig.3. The most often offered courses

Table 3.

Distribution of courses by curricula

Course	Min. ECTS	Max. ECTS	Avr. ECTS
Software Engineering	3	7,5	5,46
Scientific Research Methods	3	7,5	5,91
Software Project Management	4	7,5	5,95
Modern Software Development Methods	4	7,5	6,11
Object-oriented Approach	6	7,5	7,31
Intelligent Systems	3,5	7,5	5
Compilers	3	7,5	5,21
Distributed Computational Systems	3	6	4,67
Information Systems Analysis and Design	4	7,5	5,8
Computer Networks	4	7,5	5,6
Modern Databases	4	7,5	5,63
Databases	3	7	4,5

To reduce the variety in the analyzed curricula the grouping of courses is made with respect to the curriculum "Computer Systems". As a result 32 groups of courses, as well as minimal, maximal and average number of credit points for each group are identified (Table 4).

Table 4

Groups of courses

Groups of courses	Number of curricula	Min. ECTS	Max. ECTS	Avr. ECTS
Software Engineering	62	2	7,5	5,31
Artificial Intelligence	33	3	7,5	4,98
Databases	24	2	7,5	5,01
Computer and Communication Networks	21	3	7,5	5
Information Systems	20	15	5	5,55
Computer Systems and their Different Kinds	20	2,5	7,5	4,83
Safety and Cryptography	14	3	7,5	5,43
Algorithms and Data Structures	13	3	7,5	5,88
Project Management	13	3,5	7,5	5,19
System Theory, Analysis and Design	12	3	7,5	5,21
Mathematics	11	2,5	7,5	4,45
Internet and Web Systems	11	4	7,5	6,2
Scientific Research Methods	11	3	7,5	5,91
Operating Systems	10	2	7,5	4,1
Compilers and Formal Languages	10	3	7,5	5,3
Object-oriented Approach	9	4	7,5	6,94
Theoretical and Social Aspects of Computer Science	9	3,5	7,5	5,06
Information Technology	8	1	7,5	3,56
Programming Languages	8	3	7,5	4,94
Computer Graphics and Image Processing	8	3	7,5	5,81
Computer Architecture	7	3	7,5	4,43
Modelling and Simulation	6	3	7,5	5,67

Table 4 (continued).
Groups of courses

Groups of courses	Number of curricula	Min. ECTS	Max. ECTS	Avr. ECTS
Human-Computer Interfaces and Interactive Systems	6	2	5	3,83
Informatics	5	4	7,5	6,5
Multimedia and Hypermedia Systems	4	3	7,5	6
Data, Information and Knowledge Management	4	4	7,5	5,75
Computer Hardware	3	3	5	4.33
Requirement Engineering	3	4	7,5	5,83
Information Theory	3	4	6	5
Data Communication and Processing	2	3	5	4
Signal Processing	2	5	5	5
E-Commerce	2	4	5	4,5

It is necessary to stress that the formed groups can be further merged into 3 large groups:
1. groups which correspond to the bachelor level of the curriculum "Computer Systems";
2. groups which correspond to the master level of the curriculum "Computer Systems";
3. groups which do not correspond to any level of the curriculum "Computer Systems".

The groups which correspond to the master level are the following:
1. Artificial Intelligence (RTU- 6-12 ECTS, depending on specialization; in EU countries, on average- 4,98 ECTS);
2. Databases (RTU- 6 ECTS; in EU countries, average- 5,01 ECTS);
3. Systems Theory, Analysis and Design (RTU- 6-12 ECTS, depending on specialization; in EU countries, on average- 5,21 ECTS);
4. Software Engineering (RTU- 6-24 ECTS, depending on specialization; in EU countries, on average- 5.31 ECTS);
5. Object-oriented Approach (RTU- 12-18 ECTS, depending on specialization; in EU countries, on average- 6,94 ECTS);
6. Information Systems (RTU- 0-6 ECTS, depending on specialization; in EU countries, on average- 5,55 ECTS);
7. Data, Information and Knowledge Management (RTU- 0-6 ECTS, depending on specialization; in EU countries, on average- 5,75 ECTS);
8. Computer Systems and their Different Kinds (RTU- 6 ECTS; in EU countries, on average- 4,83 ECTS);
9. Requirement Engineering (RTU- 6 ECTS; in EU countries, on average- 5,83 ECTS);
10. Data Communication and Processing (RTU- 6 ECTS; in EU countries, on average- 4 ECTS);
11. Human-Computer Interfaces and Interactive Systems (RTU- 0-6 ECTS, depending on specialization; in EU countries, on average- 3,83 ECTS);
12. Scientific Research Methods (RTU- 6 ECTS; in EU countries, on average- 5,91 ECTS).

The groups which correspond to the bachelor level are the following: Computer Architecture, Computer Hardware, Mathematics, Operating Systems, Algorithms and Data Structures, Computer and Communication Networks, Computer Graphics and Image Processing, Modelling and Simulation, Programming Languages, Project Management, Information Technology and Informatics. The groups of courses which do not correspond to any level of the curriculum "Computer Systems" are: Compilers and Formal Languages, Multimedia and Hypermedia Systems, Internet and Web Systems, Safety and Cryptography, Signal Processing, E-Commerce, Information Theory and Theoretical and Social Aspects of Computer Science. Number of credit points for both described categories of course groups are not compared because the research focuses on master level studies.

7 Comparison of Courses on the Level of Modules

Table 5 presents results of the comparison of courses included in the course modules of the curriculum “Computer Systems” with courses of other curricula in the field on computer science within the EU. Considering the table the following conclusions can be made. Firstly, courses of the modules “Artificial Intelligence”, “Databases”, “Object-oriented System Analysis”, “Software Development” and “Implementation of Algorithms” are widely supported by other higher education institutions of the EU and the good correspondence can be observed between them and courses included in the mentioned modules of the curriculum “Computer Systems”. Secondly, courses of the modules “Systems Theory”, “Knowledge Engineering”, “Applied Intelligent Systems” and

"Services of Operating Systems" are specific both for the curriculum "Computer Systems" and other computer curricula within the EU, so the number of matching courses is very small. Thirdly, it is difficult to find direct analogy with the courses included in the module "Data Processing Methodologies". Fourthly, particular topics taught in the courses of the module "Artificial Intelligence" form separate courses in other universities of the EU, for example, Artificial Intelligence Logics (5 ECTS) or Expert Systems (3 ECTS). Fifthly, topics of databases are presented is many forms. Besides, courses related to modern approaches have the greater number of credit points than traditional approaches while specific questions such as spatial and temporal databases have the smallest number of credit points.

Table 5
Comparison of courses on the level of modules

Module	Courses included in the module	Courses in other institutions of the EU
Artificial Intelligence	Fundamentals of Artificial Intelligence - 4.5 ECTS Artificial Intelligence - 6 ECTS	Agent-oriented Software Engineering - 6 ECTS Artificial Intelligence - 3 or 5 ECTS Applied Artificial Intelligence - 5 ECTS Intelligent Systems - from 3,5 up to 7,5 ECTS
Systems Theory	Methods of Systems Theory - 3 ECTS System and Process Theory - 6 ECTS	Systems Theory and Practice - 7,5 ECTS Methods of Systems Theory - 4 or 5 ECTS
Knowledge Engineering	System Analysis and Knowledge Acquisition - 3 ECTS Knowledge Management - 6 ECTS	Internet Knowledge Management- 4 ECTS Information and Knowledge Management - 7,5 ECTS
Data Processing Methodologies	Specialized Data Processing Technologies - 6 ECTS Computer Aided Solution Processing- 6 ECTS	Model Identification and Data Analysis - 5 ECTS Data Visualization - 3 ECTS

Table 5 (continued).
Comparison of courses on the level of modules

Module	Courses included in the module	Courses in other institutions of the EU
Databases	Technology of Large Databases - 3 ECTS Large Databases - 6 ECTS	Databases - from 3 up to 7 ECTS Relational Database Design - 7,5 ECTS Database Management Systems - 3 ECTS Topics on Database Systems: Models, Languages and Architectures - 3 ECTS Topics on Database Theory - 2 ECTS Modern Database Systems - 7,5 ECTS Database Administration, Theory and Practice - 7,5 ECTS Advanced Databases - from 4 up to 7,5 ECTS Topics on Spatial and Temporal Databases - 2 ECTS
Services of Operating Systems	Computer Organization and Assemblers - 4.5 ECTS Process Programming - 6 ECTS	Process Management Systems - 4 ECTS Advanced Operating Environments - 4 ECTS
Object-oriented System Analysis	Object-oriented System Analysis and Design - 4.5 ECTS Object-oriented System Analysis - 6 ECTS	Systems Analysis and Design with UML - 7,5 ECTS Software Systems Analysis and Modeling - 8 ECTS Methods of Systems Analysis - 4 ECTS Implementation of Object Oriented Design – 7,5 ECTS

Table 5 (continued).
Comparison of courses on the level of modules

Module	Courses included in the module	Courses in other institutions of the EU
Software Development	Software Development Technologies - 4.5 ECTS Object-oriented Software Development - 6 ECTS	Software Evolution - 5 ECTS Agile Software Development - 7,5 ECTS System Design - 5 ECTS System Development Workshop - 7,5 ECTS
Applied Intelligent Systems	Interactive Intelligent Systems - 7.5 ECTS Methods of Engineering of Intelligent Applied Computer Systems - 6 ECTS	Methodologies for Intelligent Systems - 5 ECTS Artificial Intelligence Logics - 5 ECTS Expert Systems - 3 ECTS
Requirement Engineering	Requirement Engineering - 6 ECTS Models for Software Planning and Metrology - 6 ECTS Tools for Project Management Maintenance - 3 ECTS	Requirements Engineering – from 4 up to 6 ECTS Requirements Analysis and Database Design - 7,5 ECTS Software Metrics - 4 ECTS Software Quality and Project Management - 7,5 ECTS
Implementation of Algorithms	Algorithms and Programming Languages- 3 ECTS Functional Programming- 3 ECTS Adaptive Data Processing Systems – 3 ECTS	Advanced Course of Algorithm Design and Analysis - 5 ECTS Analysis of Algorithms - 7,5 ECTS Advanced Algorithms - 5 or 6 ECTS Advanced Programming - 7,5 or 8 ECTS Functional Programming Techniques - 2 ECTS Parallel and Distributed Algorithms – 5 or 6 ECTS

8 Conclusions

On the basis of the analysis of curricula in the field of computer science within the European Union it is possible to conclude that regardless of the fact that there is a big diversity among curricula the curriculum "Computer Systems" at RTU falls within the European Educational Space because it includes the most popular courses. However, in order to provide good opportunities for student mobility it is necessary to harmonize study programmes within the European Educational Space. Harmonization of curricula demands extended and coordinated research in all countries of the EU.

It is necessary to stress that some factors limited the analysis presented in the paper. The main of them are inaccessibility of curricula of many higher education institutions or their availability only in a local language, not in English. In order to obtain more valid results the following activity can be accomplished in the future: comparison of content of courses and direct contacting of representatives of corresponding institutions with the purpose of translation of curricula given in a local language. In the latter case it can be possible to analyze a broader scope of curricula and to get more precise view about the effective ways how to achieve needed similarity between curricula of EU countries.

To summarize the results of the research we can conclude that perspectives of mobility for students of the curriculum “Computer Systems” are not very high if names of courses are taken as the main criterion. In this case there is not any suitable curriculum which allows easily transfer of courses and credit points. Practically the only possibility is the development of the master thesis regardless of the fact that the curriculum “Computer Systems” includes many courses with the same number of credit points as several other curricula. The picture changes if the results of the comparison of courses on the level of modules are analyzed. The lists of courses of modules offer a variety of courses which may be transferred for mobile students. This must be taken into account for mobility planning of master level students.

The results presented in this paper are outcomes of the ESF project 2005/0125/VPD1/ESF/PIAA/04/APK/3.2.3.2/0062/0007 “Improvement of courses of the academic study program “Computer Systems” at Riga Technical University”.

References:

[1] *Sorbonne Joint Declaration*. Joint declaration on harmonisation of the architecture of the European higher education system by the four Ministers in charge for France, Germany, Italy and the United Kingdom Paris, the Sorbonne, May 25, 1998, 3 p.

[2] *The European Higher Education Area*. Joint Declaration of the European Ministers of Education Convened in Bologna on the 19th of June 1999, 2 p.

[3] *Presidency conclusions.* Lisbon European Council. March 23-24, 2000, 17 p.

[4] Council Conclusions on Education and Training in the Framework of the Mid-Term Review of the Lisbon Strategy. Doc.6604/05 EDUC 29 SOC 76. Brussels, 21 February 2005. Council of the European Union, 9 p.

[5] *Student Mobility in Europe,* Briefing Paper 2. Online: http://www.pjb.co.uk/npl/bp2.htm

[6] J. Szarka, Student Mobility in the EU, *European Integration Studies*, Vol.2, No.2, 2003, pp. 123-138.

[7] *British Council-Erasmus*. Online: http://www.britishcouncil.org/erasmus

[8] *Another successful year for Erasmus,* Press Release, European Commission, Brussels, February 18, 2005. Online: http://europa.eu/rapid/pressReleasesAction.do?reference=IP/05/190&format=HTML&aged=0&language=EN&guiLanguage=en

[9] D.-M. Duse, C.S. Duse, Engineering Education in a Highly Globalised World, *Proceedings of the 5th WSEAS/IASME International Conference on Engineering Education (EE'08)*, Heraklion, Crete Island, Greece, July 22-24, 2008, pp.206-210.

[10] A. Capodaglio, R. Vilanova, R. Katebi, J. Vehi, Environmental Process Control Engineering: Interdisciplinary Approach for an International Master's Course Curriculum, *Proceedings of the 4th WSEAS/IASME International Conference on Engineering Education*, Agios Nikolaos, Crete Island, Greece, July 24-26, 2007, pp.71-75.

[11] *Bologna with Students Eyes*, Bologna Process Committee, London, UK, May 2007. Online: http://www.ond.vlaanderen.be/hogeronderwijs/bologna/documents/Bolognastudenteyes2007.pdf

[12] C. Devriendt, P. Vanhee, A.De Marco, A. Pescetti, *Enhancing Student Mobility by a Web 2.0 Platform*, The Erasmus Student Network Experience. Online: http://supernova.esn.org/files/ENHANCING%20STUDENT%20MOBILITY%20BY%20A%20WEB%202.0%20PLATFORM..pdf

[13] T. Walasek, J. Piatkowski, O. Stawska, D. Morawska-Walasek, On-line Support of Students Mobility, *Proceedings of the 2nd WSEAS/IASME International Conference on Educational Technologies,* Bucharest, Romania, October 16-17, 2006, pp.24-26.

[14] M. Ganzha, W. Kuranowski, M. Paprzycki, S. Rahimi, M. Szymczak, Designing an Agent-based Student Mobility Support System, *Proceedings of the International Symposium on Information and Communication Technologies*, Al Khalij Al Arabi, Tetuan, Morocco, 2005, pp. 44-50.

[15] T. Tokić, I. Milentijević, M. Stojčev, O. Vojinović, A. Vucetić, Implementation of Student Mobility Program within the Frame of TEMPUS Project CD-JEP 16160/2001, *Facta universitatis- series: Electronics and Energetics*, Vol. 18, No. 2, 2005, pp. 345-352.

[16] B. Kehm, F. Maiworm. Presentation of the Results of an International Study on Transnational Mobility in Bachelor and Master Programmes, *Bologna Conference on "Transnational Mobility in Bachelor and Master Programmes"*, May 29-30, 2006. Online: http://eu.daad.de/imperia/md/content/eu/bologna/kehm.pdf

[17] *Portal on Learning Opportunities Throughout the European Space*. Online: http://europa.eu.int/ploteus/portal/home.jsp

[18] *International Education Directory of Colleges and Universities*. Online: http://www.4icu.org

[19] *Higher Education in Europe*. Online: http://europe. graduateshotline.com

[20] *College and University List*. Online: http://www.colleges.com/index.html

[21] Erasmus studijas. Rīgas Tehniskā universitāte. Online: http://www.rtu.lv/studijas/sac/erasmus.php (in Latvian)