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DBBT
Digital Broadcasting & Broadband Technologies

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THE REPORT ON ANALYSIS OF MASTER STUDY PROGRAMMES IN THE FIELD OF DBBT IN EU COUNTRIES

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Table of content

INTRODUCTION

This document includes a report on the work and results of the WP1 activity No1. “Analysis consulting and training”. In the scope of this activity the existing study programmes of the EU partner countries were analysed from different perspectives such as the curriculum in covered subjects, teaching methodology and the equipment needed for the implementation of the study programmes. The following chapters address these questions

DBBT related study programmes of EU partners

This chapter includes presentation of the DBBT related study programmes in the EU partner countries – Slovenia, Estonia, Spain and Czech Republic. The specifics of each country are presented in individual subchapters in the following format:

1) The high-level structure of DBBT related study programmes
2) A description of teaching methodology
3) A description of equipment used.

Slovenia: University of Ljubljana

At the University of Ljubljana there are two study programmes highly related to the field of DBBT, implemented in recent years. These study programmes are **1st and 2nd level study programmes of Multimedia**, Interdisciplinary academic study programme (1st cycle) in Multimedia and Interdisciplinary postgraduate study programme (2nd cycle) in Multimedia. Both study programmes are provided in cooperation of two Faculties: By the Faculty of electrical engineering (**UL FEE**)and the Faculty of Computer and Information Science (**UL FRI**). Some DBBT related topics are also covered also by the Electrical engineering study programme, but as they represent only a subset of what is offered by the two Multimedia study programmes, they will be omitted from this document.

Structure of study programmes:

The Interdisciplinary academic study programme in Multimedia are composed of subjects from three domains:

1) Fundamentals, which covers mathematical and technology (electrotechnical/computers) basics, necessary for understanding other domains;

2) Technology, which covers telecommunications topics, information/software technology, digital signal processing, digital TV in terms of production and broadcasting aspects, digital signal processing for images and video, software development;

3) “Soft skills”, covering design basics, societal aspects of ICT, project work and management, user experience, legal issues, etc.

In this way the multimedia engineers will have knowledge of mostly engineering aspects of multimedia with additional soft skills necessary for interdisciplinary projects in the field of multimedia and DBBT.

The interdisciplinary postgraduate study programme (2nd cycle) in Multimedia is a natural continuation of the 1st cycle Multimedia programme, providing a deeper and more specialized insight into the field. If follows the logic of an interdisciplinary programme, designed to give students knowledge and skills from two complementing fields: new technologies in the field of multimedia, and methods, algorithms and programming skills, necessary for designing, implementing and maintaining modern multimedia systems. At the same time, the programme is structured so that through a choice of elective components in the programme each individual study track will profile the student into a specialist in a field that has been identified as central in the multimedia career spectrum and job market.

The most distinctive topics, distinguishing these study programmes from standard electrotechnical and ICT topics and related to the DBBT are:

- Introduction to multimedia systems
- Digital broadcasting systems
- Studio and multimedia production technology
- Editing and postproduction
- ICT technologies and society

- Transmitting of multimedia signals
- 3D sound in multimedia
- Design of visual communications

Other topics are DBBT related topics, but come from the telecommunication and digital signal processing domain and are as such more universally applicable.

Teaching methodology

The courses in both study programmes are generally divided into two parts: lectures and tutorials/laboratory work. The tutorials and laboratory work normally contain guided practical work and stand-alone seminars. In most cases, a course with 6 ECTS is comprised of 45 hours of lectures and 30 contact hours in the laboratory. The remaining time, dedicated to earning the credits allocated to a course (between a total of 75 and 100 according to European higher education guidelines) is devoted to self study including homework and project work outside the classroom.

Teaching at the UL FRI and UL FEE is strongly supported by virtual learning environments, eClassrom at UL FRI and e.FE at UL FEE which offer enough flexibility that the teaching staff is in most cases able to apply the didactical instruments and methods most ideal in their opinion. The eClassroom is an adaptation of the open source learning management system Moodle, which allows extensions and specific adaptations. All courses have their eClassroom space, where the learning material in various forms, class announcements, and other relevant information are published. The platform is also used for knowledge checking quizzes and submission of assignments. The system supports discussions and knowledge sharing debates, as well as group work. Some courses also use this platform for computer based examinations. At UL FEE the e.FE virtual learning environment allows for similar functionality as eClassroom in terms of access to and editing of learning material, exchange of class announcements, communication and knowledge checking. It allows for inclusion of interactive experiments and the solution is an in-house development and as such very flexible in terms of upgrades, adding of new functionality and integration with existing information systems at the University.

Besides a classical system of lectures and tutorials/laboratory work, supported by the eClassrom and e.FE learning platforms, a variety of other educational methods are also employed. The UL FRI supports the introduction of novel teaching and examination approaches. For example, individual courses introduce lectures with guided discussions where students read the prescribed literature ahead of the lectures and then discuss the contents with the lecturer during the lecture time. In this way the lecturer can focus his/her attention on more difficult parts of the curriculum. Due to strong demand for project work in the IT industry, several courses issue assignments appropriate for small groups. This promotes cooperation, social and managerial skills.

In 2015 a special student MakerLab laboratory was setup at UL FEE giving students the possibility to work on innovative interdisciplinary projects, where they have access to computer and electronics equipment, 3D printers, studio broadcasting equipment, etc. A number of mentors are supporting their activities including the mentors from industrial companies. The projects are promoted through the Faculty website while some of them are

presented on national TV and radio stations. One of the most popular projects was development of a digital TV receiver with HBBTV functionality and possibility of broadcasting of web pages through the DVB-T object carousel.

Every year a summer school is taking place at UL FEE and UL FRI promoting engineering in secondary and primary schools. The summer school covers a number of engineering domains from multimedia/DBBT to telecommunications, electronics, power engineering, programming, AI, etc. The students are participating in the role of mentors and tutors to children working on different multimedia related projects. The multimedia/DBBT domain has always been the most popular and has the most participants. In addition to summer schools the interested students can use the broadcasting and studio equipment for selected projects, often suggested by the industrial partners and sponsors of the Multimedia study programme.

Interested students are regularly invited to participate in industrial projects during their studies in order to improve their theoretical knowledge with practical work. The projects are offered either by the Faculty laboratories involved in such projects or by companies cooperating with UL FEE.

In addition to the above mentioned extracurricular activities the students are participating at lectures, demonstrations and laboratory work. Laboratory work in the form of laboratory exercises in the laboratory practicum is obligatory part of teaching methods in the sense of “hands -on” learning approach. It is performed in laboratories, which are used also for research activities of UL FEE. The teachers motivate students for the study work by acquainting them with the latest achievements in their research area.

An important part of laboratory work is coursework project, whose nature depends on the subject type (engineering subjects vs. social sciences/design subjects). Namely, for a particular teaching method to be appropriate and efficient it has to be in corresponding relation with the characteristics of the learner and the type of the course. The coursework projects are presented in the classroom where the debate is conducted by the teacher and strong/weak points of the projects are discussed.

A big part of the 2nd cycle students in all programmes participate in research work in the various labs.

A special emphasis in the 2nd cycle study programme Multimedia is devoted to writing skills. In addition to written seminars and reports that are an integral part of several courses, a major part of the second year with a workload of 24 credits is allocated to the master thesis and its defence. Students are guided through the process of completing the master thesis through a series of steps, including seminars and lectures on writing, copy-write rules, plagiarism and ethics.

Students are encouraged to complete their master thesis within the UL FEE and UL FRI labs with strong research tracks in multimedia-related fields. Both faculties have well equipped multimedia labs and additional multimedia equipment that is available, within reasonable limits, to the teaching staff. These are described in more detail in the next section. They also have strong connections to the national radio and TV (RTV Slovenija) and other multimedia-intensive companies and business which cooperate with teachers of specific courses In addition to the above mentioned extracurricular activities the students are participating at lectures, demonstrations and laboratory work. Laboratory work in the form of laboratory exercises in the laboratory practicum is obligatory part of teaching methods in the sense of “hands -on” learning approach. It is performed in laboratories, which are used also for research activities of UL FEE. The teachers motivate students for the study work by acquainting them with the latest achievements in their research area.

Equipment

For the purpose of practical (laboratory) work different types of equipment are used depending on the subject. Regardless of the fact that the equipment was bought in many different tenders and for different purposes, it is combined into a full working system ("glass-to-glass" chain). The system can be divided into the following parts:

- Studio equipment (walls, scenery, cameras, tripods, dollies, holders, lighting, microphones, cabling,…)
- editing rooms and corresponding equipment (video and audio mixers, servers, ingest, playout, storage, video wall, …)
- transcoders and transmission (DVB-T, DVB-C, IPTV, VOD) and corresponding equipment (multiplexers, modulators, transmitters, antennas, HBBTV servers, servers, transcoders)
- receivers (STB, TVs, computer with DVB-T receivers),
- Measurement equipment (RF and AV signal measurements, MUX analysers,…).
- A TV broadcasting truck, obtained as a donation from RTV Slovenija

The whole system of equipment allows for high quality level of study as well as for a comprehensive and deep analysis of all system elements. Some parts of the system are also reusable for different studies and subjects: e.g. Apple training room can be used for AATCe purposes (courses and certifications), learning NLE, animations, web development, application development, AV analyses of all kinds, and also many other purposes.

Cooperation with industry is another essential part of the study process and due to good collaboration and cooperation with different partners (national RTV stations, private RTV stations, vendors, sales offices and business support, distributors, developers, telco operators, …) a lot of laboratory work is based on support and collaboration with business partners. Technical excursions, practical work in companies, student practise and also presentations are additionally enriching the study process.

Spain: Universidad Politecnica de Madrid

At the Universidad Politecnica de Madrid (UPM), there are two study programs closely related to the focus of the DBBT project. These two study programs are carried out at Escuela Técnica Superior de Ingenieros de Telecomunicación (Superior Technical School for Telecommunication Engineers) of UPM, and they form part of Bachelor of Engineering in Telecommunication Technologies and Services, and of Master in Telecommunication Engineering, respectively. In the Bachelor programme, it is the subject "Specific Technology of Sound and Image" consisting of several courses having in total 48 ECTS credits in the 4th course, while in the Master programme, it is the subject Multimedia Systems and Services having 6 ECTS in the first year of Master, and the Optional major in Signals and Communications consisting of several subjects in the 2nd year.

Structure of study programmes:

In the Bachelor of Engineering in Telecommunication Technologies and Services, the subject "Specific Technology of Sound and Image" consists of the following courses in the 4th year having in total 48 ECTS credits: Digital Signal Processing, Speech and Audio Signal Processing, Audiovisual Communications, Digital Image and Video Processing, Audiovisual Equipment and Systems, Multimedia Production, Broadcasting and Network Services, Television.

In the Master in Telecommunication Engineering, the subject Multimedia Systems and Services having 6 ECTS, is carried out in both semesters of the first year of the Master. In the 2nd year the Optional Major in Signals and Communications consists of the following subjects each having 6 ECTS: High Frequency Circuits, Satellite Communications, Fiber Optics Communications, Radar Systems, Advanced Transmission/Reception Architectures.

Teaching methodology

Teaching methodology comprises lectures, problem solving sessions, collaborative actions, and laboratory sessions. For example, the Course of Speech and Audio Signal Processing in the 7th Semester of 4th year in the Program of Engineering in Telecommunication Technologies and Services, has 6 ECTS Credits and 60 Contact hours. The course provides fundamental concepts of signal processing techniques applied to speech and audio signals. Based on the analysis of the specific characteristics of speech and audio, the study of signal processing techniques is applied over four main areas: synthesis, coding, recognition and human-machine interaction. A major emphasis is put on speech and audio coding technologies.

The course covers the following topics: a) Speech and audio signals characterization. Production, perception and synthesis. b) Signal processing for speech and audio. c) Speech and audio coding. d) Recognition and human-machine interaction. The prerequisite for the course is a basic knowledge of signal and systems, digital signal processing and statistics. It is selective and elective course in the program.

Specific outcomes of the course are the following: Speech and audio signal processing for telecommunication services and applications: coding, synthesis, recognition and interactive systems; Speech and audio signals characterization based on production and perception mechanisms. Tools for speech and audio recording and reproduction. Basic synthesis procedures; Short-time analysis in time and frequency, and its use for synthesis, coding and recognition; Principles of source and perceptual coding. Main schemes and standards for speech and audio coding and their use in telecommunication networks and services. Standards for objective quality assessment; Basic speech

and audio recognition technologies (mainly speech and speaker recognition). Design of interactive systems and usability evaluation.

Bibliography and supplemental materials used in the course are the following:
"Speech and Audio Signal Processing", B. Gold, N. Morgan, and D. Ellis, 2nd edition, Wiley Press 2011.
"Spoken Language Processing", X. Huang, A. Acero, and H. Won , Prentice Hall, 2001.
"Introduction to Data Compression", Khalid Sayood, Fourth Edition, The Morgan Kaufmann Series in Multimedia Information and Systems, 2012.

Equipment

Through the agreement between RTVE (Radio Television Española) and the UPM, the Chair of RTVE at UPM is established with the aim to promote new audiovisual technologies like 4K/UHDTV, HEVC, DVB-T2, as well as Living lab of state-of-the-art technologies on digital TV around UHDTV, thus enhancing the lecturing quality in terms of state-of-the-art knowledge and equipment for UPM students. With the main aim to provide an immersive and improved experience for TV viewers, the other key companies like Dolby, Sapec and Cellnex are involved, integrating new features and technologies like e.g., HEVC encoding, DVB-T2 trials, subjective quality tests, participation in new productions like e.g. Parsifal, and through dissemination activities.

Thanks to the broadcast license granted by Spanish Secretary of State for Telecommunications, the broadcast trials are carried on as simultaneous transmission of 4K and other signals in the same mux for coverage area of University City in Madrid at 8 MHz with current allocated frequency of 658 MHz, with ~35 Mbps and based on DVB-T2.

The laboratory enables set and video content for subjective quality tests on EBU test sequences with 55"-screens lent by LG, improvement in the efficiency of HEVC (High efficiency video coding) vs. AVC, hidden reference tests where scores are obtained by HD sequences before and after knowing 4K. A real 4K transmission of contents produced by RTVE, using HEVC for encoding, DVB-T2 (channel coding), some sequences of Parsifal, live broadcast in 4K, HbbTV application, etc.

The laboratories are provided with professional equipment for transmission chain (Multiplexer, DVB-T2 modulator, Amplifier, Filter and Antenna on the roof), as well as the equipment lent by Dolby.

Czech Republic: VSB-Technical University of Ostrava

In the Faculty of Electrical Engineering (FEECS) and Computer Science of the VSB-Technical University of Ostrava, CZ, there are two study branches in a study programme *Information and Communication Technology*, which are related to the field of DBBT, the first one is the Telecommunication Technology and the second one the **Mobile Technology**. The second one is **highly related to the included topics** in the Erasmus DBBT project. Both of study branches are provided in Bachelor's and Follow-Up Master's degrees of study. In addition to the mentioned above, a post-gradual study branch **Communication Technology** is provided by FEECS in doctoral study programme *Computer Science, Communication Technology and Applied Mathematics* and guaranteed by Faculty of Electrical Engineering and Computer Science. All study branches in FEECS are provided and accredited in two languages; Czech and English.

Due to the content and intent of the DBBT project, only the Follow-up Master's level of study in study branch *Mobile Technology* will be described in next subchapters.

Structure of study programmes:

The Follow-up Master's type of study branch Mobile technology was submitted to the Czech Accreditation Authority in 2005 in for study in English and Czech language. The accreditation committee decided to provide accreditation for ten years and the re-accreditation was asked in beginning of 2015 and approved without any comment or notice. The Mobile Technology study has a unique code in CZ - 2612T059.

It is necessary to highlight the crucial role of Council of Study Programme (CSP) in the Faculty of Electrical Engineering and Computer Science and its control function. The CSP is responsible for approval all changes in the study branch which are submitted by guarantor of the study and based on request of guarantors of courses, so it brings practically permanent improvements in the study branch and its sustainability.

Courses in graduate study are generally focused on:

1) "Fundamental knowledge" of advanced engineering work, such as the compulsory course *Probability and Statistics mathematical* or *Selected parts of mathematical analysis*, these courses are important for understanding other advanced topics;

2) "Key technology knowledge" for a profession of high-educated experts, it covers basic topics of technologies such as the compulsory course *Radio Networks* or *Security in Communications*;

3) "Practical knowledge" expected and required by industry, it is based on feedback from companies and Industry Council of Faculty where mostly directors and other representatives of Industry are involved and it is necessary to focus on needs of the most often employers what is important for the study branch alumni. These courses are represented by subjects such as *Operating Systems of Mobile Devices* or *Practice in Communication Networks.*

The Follow-up Master's type of study in the study branch *Mobile Technology* covers important skills which are expected from students in the field of DBBT.

The graduate of Mobile Technology branch gains an experience in the field of information and communication technologies with a focus on the mobile networks. He can design, operate, modify and optimize mobile wireless networks, develop, and optimize applications to end mobile devices; he has knowledge of mobile networks, radio technology and software designing of applications for mobile devices. Practical laboratory training is carried out in coordination and cooperation with experts of leading telecommunications companies which focus on providing mobile services such as T-Mobile Czech Republic, Vodafone and O2 Czech Republic.

The graduates have added value in a particular ability to understand business needs and optimize its operation by the design of appropriate mobile applications, both in the sphere of labor-service and areas of administration and management. He has the potential to control the technical tasks related to the operation of mobile networks, the design and implementation of customized solutions. From that, it follows a preferred area for graduates in the form of mobile network engineers and developers of software for mobile devices.

The most distinctive topics in the study branch related to the DBBT are:

- Radio Networks
- Voice over IP
- Networks Modelling
- Measurement in Telecommunications
- Security in Communications
- Wave Propagation and Antennas
- Multimedia Technique
- Practice in Communication Networks
- Radio-communications Engineering

Other topics are DBBT related topics to the domain of Telecommunications, where DBBT belongs, and are applicable as well.

Teaching methodology

The courses in the study branch *Mobile Technology* are generally divided into two parts: lectures and seminars/laboratory work. Lectures are delivered mostly one per week and take 90 minutes, the same approach regards seminars/laboratories. Laboratory tasks are oriented on practical issues and seminars provide opportunity to demonstrate, repeat and explain applicability of topics from delivered lectures.

Students pass courses successfully if they obtain at least 51 points from 100 points. In practically oriented courses, semester projects are required which students solve mostly at home and higher demands in courses cases increasing number of ECTS credits assigned to the particular course.

The content of a subject is provided as an example, how courses are organized.

D - Study subject characterization

Study subject name: VoIP
Type of subject Choice: compulsory
Study subject extent: 28 + 42 , hours per week: 5 credits: 6
Different way of stating the content: 2 + 3
Way of completion: Credit and Examination Form of instr.: Lectures, Tutorials
Further demands on student : Knowledge of computer networks are required

Teacher

doc. Ing. Miroslav Vozňák, Ph.D., Ing. Filip Řezáč, Ph.D.;

Brief summary of the subject

This course is directed towards the students of study program Information and communication technology. The aim is to acquaint students with technologies and standards of voice transmission in IP network with communication protocols H.323, SIP, MGCP and with elements enabling an implementation of voice services in IP network. A significant part is focused on area of Quality of Service. Laboratory works are oriented on protocol analyzing and students can choose semestral project from three themes based on open source VoIP solution as Asterisk, GnuGK or OpenSER. Communication standards are been already formed with pursuit to network design with integrated service which are able to transfer a data, voice or video. The next generation networks are using in considerable amount these techniques which are called as Voice over IP and VoIP is the significant direction in next evolution of communications.

Lectures:

1. Real Time Protocol RTP, RTCP, SRTP, speech coding and decoding, speech bandwith requirements for RTP.
2. Standard H.323, protocol model, basic elements - GK, TE, GW, MCU, Signaling H.225.0 RAS, Q.931 and H.245.
3. Call models GRC and DRC, Fast Connect, H.245 tunelling, fax standard T.38.
4. H.323 open solution, GnuGK network design and configuration, GW for PSTN networking.

5. SIP/SDP protocol, description of elements - User Agent, Registrar, Redirect and Proxy server, SIP methods and answers, SDP protocol, transactions and dialogs, offer/answer model.
6. SIPp - SIP sessions generator, SIP/SDP grammar, practical SIP/SDP scenario with authentication.
7. Asterisk, SW PBX, applications, dial plan, extensions, practical using SIP and IAX.
8. SIP and IAX trunk, their application , security on SIP trunk, authorization of access on trunk, rules for modification of dialed umbers.
9. Asterisk - advances services, Presence and Instant Messaging, calendars, practial using presence with Jabber.
10. Asterisk billing - traffic tarification, CDR reports, practical implementation for Asterisk.
11. Kamailio, syntax, structure of configuration, modules, static routing, DB - interoperability, design and configuration, REGISTRAR modul, SIP NAT traversal, RTPPROXY, NATHELPER.
12. Quality of IP telephony - MOS, PESQ, E-model and R-factor, fragmentation, packet losses, delay and jitter, network requirements Intserv, Diffserv.
13. MGCP and Megaco/H.248, WebRTC and new trends in IP telephony.
14. Benchmarking and Penetration tests in VoIP infrastructure.

Seminars:

1. Codecs, RTP - introduction in the lab, software and hardware H.323 and SIP clients. W1
2. Introduction to H.323 - H.323 analysis using Wireshark. W2
3. Asterisk - installation, introduction, dialplan, extensions. W7
4. Asterisk - SIP Trunk configuration. W8
5. Asterisk - advanced services, IVR, Instant Messaging, Call Center. W9
6. Asterisk - billing, traffic accounting, CDR records, configuration, billing centers. W10
7. Quality of service in IP - MOS E-Model, R-factor. Project consulting. W12
8. Presentation of the semester project. W14

Labs:

1. GnuGK - introduction, analysis H.225 and H.245 - 4 points. W3
2. GnuGK - H.323 trunk configuration, DRC and GRC models - 2 points. W4
3. Analysis of SIP signaling and SIP headers - 6 points. W5
4. Introduction to Sipp + semestral project assignment 25p - 3 points. W6
5. Kamailio - Introduction to Kamailio, basic configuration, SIP proxy, database connection. W11
6. WebRTC, HTML5 - an introduction, configuration WebRTC client with Asterisk. W13

Projects:

Semestral project, design of VoIP network with one of the open source solutions as GnuGK, Kamailio or Asterisk.

Study literature and study aids

Compulsory literature:
M. Voznak, Voice over Internet Protocol, college book, VSB-TUO, 137 p., 2012.
Lectures in LMS – Moodle.

Recommended literature:

HARDY,W.: VoIP service quality, McGraw-Hill, 2003, New York, ISBN 0-07-141076-7.
Sinnreich, H.:Internet Communications Using SIP, Wiley Computer Publishing, New York, 2001, ISBN 0-471-41399-2

The Department guaranteeing the study branch organizes many open events – workshops, conferences and invited lectures, which are announced on web-page http://comtech.vsb.cz and several of them from year 2016 are listed below as an example. Events are important for keeping high-level of education and bring key-contributions such as internationalization and avoid of inbreeding and contribute to the ability to be competitive.

[1] September 2016, IoT EnvironHackathon supported by Vodafone

http://www.nadacevodafone.cz/programy/grantovy-program/aktualni-projekty/iot-environhackathon.html

[2] September 2016, International Conference – KTTO2016, http://ktto.vsb.cz

[3] July 2016, Invited lectures on M2m Communications and IoT LoRaWAN, delivered by prof. Cheng (IEEE Senior Member) from NTUST, Taiwan, http://homel.vsb.cz/%7Evoz29/files/2016_Ray.pdf

[4] April 2016, Special Session in International Conference ICCMIT 2016 in Italy in UNICAL,

http://www.iccmit.net/Mexico%20Special%20Session%20on%20ICCMIT%2716.docx

[5] February 2016, Workshop on Datamining in communication systems (visit from Harbin Institute of Technology, Shenzhen, China : prof. Lin and prof. Fournier).

Practical parts of courses are placed in laboratories of the department guaranteeing study branch Mobile technology. Cooperation with industry is highly recommended, industrial partners support laboratories and bring interesting practical problems which are solved within semester works and Master theses. Several companies support laboratories of study programme such as Huawei Technologies (research contract on 250,000 USD in 2014), Siemens (contract in development and training on 40, 000 EUR in 2013) or T-Mobile Czech (donated LTE e/NodeB in 2016).

Next information on study is provided on web-page:

https://comtech.vsb.cz/index.php/en/for-people-interested-in-studying

Equipment

Equipment, which is used in courses, is located in laboratories and it is necessary to keep all equipment up-to-date. For purpose of study DBBT, following laboratories are mentioned below.

Laboratory of Radio Networks and Mobile Communications is equipped with various types of antennas, DVB-T analyser, Vector analyser, RHS signal analyser up to 3GHz, finally

Laboratory of Voice over IP is equipped especially by video and audio terminals or Gateways interconnecting IP world with PSTN/ISDN/PLMN. Very important part of laboratory is IXIA Ixload solution for generation L2-L7 traffic including various applications and IxChariot providing an emulation of video and audio traffic and a quality assessment (MOS measurement).

Laboratory of Access Networks contains equipment for access measurement devices, signal generators and emulators of disturbance emulators.

Laboratory of Computer Networks is equipped with network elements such as routers, switches, wireless access points, firewalls, etc.

Laboratory of Digital Technology contains TIMS building models providing possibility to practice various tasks in courses focused on digital transmission technology.

Laboratory of Signal Processing is equipped with Matlab environment which is suitable for signal the processing practicing.

In addition to the described equipment as an example, other laboratories are used which can be connected to the DBBT study. The course *Multimedia Technique* is oriented on video processing in TV studios and its broadcasting and students are using devices such as audio mixers, professional video cameras, and various SW such as Pinnacle studio or open-source VLC for simple IP TV distribution.

In several course, an excursion is included as a part of education. As regards DBBT study programme, the excursion in regional TV company B Plus TV is highly related with content of study. Students get possibility to be closer to the real engineering life. Cooperating companies use very often an opportunity of submitting final theses.

Estonia: University of Tartu

Structure of study programmes:

The Interdisciplinary academic study programme in Robotics and Computer Engineering are composed of subjects from five domains:

1) Basic module, which covers fundamental knowledge of robotics and computer engineering and these modules are necessary for understanding other domains;

2) Seminar modules, which covers series of seminars conducted by students in order to keep them up-to-date regarding to the developments in the field as well as prepare them with their thesis defense;

3) Specialisation module, which covers three main specialisation, namely, robotics, computer engineering and space technology;

4) Narrow field module, which is aiming to develop management and economic skills of the students of this programme;

5) optional module, which is helping the students to learn more about topic or topics of their interests during their study.

In this way the robotic and computer engineers will have knowledge of mostly engineering aspects of robotics, computer engineering and space technology with additional skills necessary for interdisciplinary projects.

This programme is structured so that through a choice of aforementioned modules in the programme each individual study track will profile the student into a specialist in a field that has been identified as central in the multimedia career spectrum and job market.

The students in Robotics and Computer Engineering programme, need to take a master thesis of worth 30 ECTS in which they are working on a very special topic usually for over 6 months.

Teaching methodology

The courses in both study programmes are generally divided into two parts: theoretical and practical. The practical sessions normally students are conducting some mechanical and/or electrical work in order to increase their knowledge as well as sessions which are conducted for developing their programming skills. The evaluations are being done by considering the classwork as well as evaluation of assignment and sometimes practical exams at the end of the semesters are used in order to finalize the grade of students.

Teachings are conducted in classrooms by use of new technologies, including projectors and smart boards as well as using real-life demonstrations and conducting experiments during the teaching sessions. Some of the teaching materials are being backed with developed massive online open courses (MOOCs) which are being introduced by the university.

Evaluation of theoretical courses are usually done by assessing assignments, course projects and written final exams which is being hold at the end of the semester. Such evaluation will help students

to feel being involved in the whole semester and increase their ability of learning materials more in details.

Interested students are usually involved in projects which are being conducted in different relevant research groups within the university. These projects are usually offered by companies to the University and are having Research and Development Theme.

Usually students are finishing their study with a very strong theoretical background as well as clear awareness of the industrial opportunities that they can encounter in their upcoming future. Specially the involvement of students in projects is considered as a very strong point for their future steps.

Equipment

For the purpose of practical (laboratory) work different types of equipment are used depending on the subject. These facilities are:

- Advanced electronic laboratory equipped with state-of-the-art equipment such as spectrum analyser and oscilloscopes
- Robotic laboratory which is equipped with all required mechanical and electrical tools to build a robot
- RoboCup lab which is equipped with 9 NAO robots and a football field
- 3D Printing room which equipped with several new 3D printers enabling students to print their designs
- Measurement equipment used for extreme conditions for space technologies.

The whole system of equipment allows for high quality level of study as well as for a comprehensive and deep analysis of all system elements. Cooperation with industry is another essential part of the study process and due to good collaboration and cooperation with different national and international partners a lot of laboratory work is based on support and collaboration with business partners. Technical excursions, practical work in companies, student practise and also presentations are additionally enriching the study process.

6 REFERENCES

Website of the study programme Multimedia at UL FE: http://www.multimedija.info/eng/

Website of the Faculty – Education (in English): http://www.fe.uni-lj.si/en/

Virtual learning environments , e.FE at UL FEE: https://e.fe.uni-lj.si/login/

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Massive Online Open Course: http://www.ut.ee/en/current-students/moocs

Website of Intelligent Computer Vision Research group: http://icv.tuit.ut.ee

Web site of Robotics and Computer Engineering programme: http://rce.tuit.ut.ee

7 ANNEX

EU Universities Master Programs Analysis:

https://dbbt.pr.ac.rs/wp-content/uploads/2016/09/1-EU-universities-Master-programs-Analysis.pdf