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COMPUTER GRAPHICS - ENGINEERING ANIMATION STUDY PROGRAM AT THE FACULTY OF TECHNICAL SCIENCES IN NOVI SAD

Abstract: *Computer Graphics - Engineering Animation study program got certified at the Faculty of Technical Sciences in Novi Sad, University of Novi Sad, Serbia in December 2010. The study program consists of Undergraduate Academic Studies (UAS) that last 4 years (8 semesters), Master Academic Studies (MAS) that last a year and Doctoral Academic Studies (DAS) that last 3 years. The first generation of students enrolled in 2011 and this generation finished their UAS and graduated with an engineering degree in Computer Graphics. Now they are studying at MAS and the first student received a master degree in September 2018. UAS comprise 48 subjects, 37 compulsory subjects and 11 elective positions with a choice of several subjects, while MAS comprise 11 subjects with three elective positions. This article shows the curriculum of UAS, MAS and DAS, with the list of subjects, the number of classes for each subject and European Credit Transfer and Accumulation System (ECTS) for these Curricula.*
A general division of our study program would be into two parts: one in which students learn all the techniques and software needed for digital production of animated films and visual effects and the other which is primarily focused on the processing or manipulation with pictures. In this paper, we will present our study program Computer Graphics - Engineering Animation which is prepared for the third accreditation cycle in 2019 in the Republic of Serbia.

Key words: *Computer Graphics, Animation, Undergraduate Academic Studies, Master Academic Studies, Doctoral Academic Studies, Higher Education*

1. INTRODUCTION

Computer Graphics - Engineering Animation study program was founded in 2010 and started in 2011 [1] and [2], at the *Faculty of Technical Sciences*, *University of Novi Sad*, *Serbia*. Broadly speaking, the program can be divided into two main areas. The first is the creation of computer-animated films, such as the animated film *Alea Iacta Est* [3], or animated film *Head is not dead* [4]. The second area is concerned with various types of programming related to image creation and analysis. These studies are interdisciplinary, positioned between Computer Graphics, various technical disciplines (Electrical Engineering and Computer Science, Architecture, Mechanical Engineering, Civil Engineering...) and Mathematics. The program is enriched with a relatively small percentage of art education courses (three artistic subjects out of 60) [5], [6] and [7]. We can say, based on the past experience and relatively quick employment of our graduate students, that the study program responded well to the demands of the present day economy in our environment [8].

Study program Computer Graphics - Engineering Animation got certified for the first time in 2010, the second accreditation cycle was in 2013, and now in 2019, is the third accreditation cycle.

The study program has undergone significant qualitative and quantitative changes over the past ten years [9]. The process of university education of students is a fairly inert process and the evaluation of a study program's results and the assessments of its success are made after one generation completes a five-year program, i.e. undergraduate and master studies. After that, it is possible to determine relatively precisely the good qualities of these studies, as well as the shortcomings. Of course, during this five-year cycle, the shortcomings of the program are observed but the complete picture is obtained only at the end of the cycle. All comments and suggestions are then entered into a new accreditation cycle and with each new accreditation, we are approaching some kind of ideal, yet imaginary model. In technical disciplines, we are faced with a relatively big problem, which also presents a challenge, because technology changes very fast. We are constantly confronted with new application software, programming languages and the need for new skills. It is true that there are topics that are standardized and where the changes are small, but this refers primarily to the topics that are studied within fundamental disciplines and subjects. In the studies described in this paper, however, such cases are in a considerable minority.

This fact is the source of the key issues we have to address and the challenges we encounter in creating, monitoring and modifying the curriculum of the studies. This is a study program based on subjects that are either completely new or introduced only recently in the higher education system. Unlike, for example, mathematics and mechanics, which can build on the literature and experience of the previous centuries, most of the courses in *Computer Graphics - Engineering Animation* were created in the first or second decade of the 21st century and, due to technological advancement, they will have to be permanently modified, year after year. The task of the educational staff, specific for our study program, is to successfully predict the directions of further development of computer graphics and animation and accordingly, align existing and create new, future plans and programs.

In addition to the assessments of the quality of studies made by the professors, it is also important to consider the

assessment of the other side, or, to be more precise, the reaction of the students. The third party, whose opinion is also important, is actually the economy, that is, businesses that operate in our environment and employ our graduates. In this aspect, we can even say that we have a problem since the students leave our study program before graduation to get a job and they can find a job relatively easily in the Republic of Serbia. So now, in the school year 2018/2019, about two-thirds of the fourth year students are those who are employed and thus do not have enough time to complete their studies. We think that it is important for them to complete their studies and that these students should try to find time to pass the remaining exams and get their degrees.

Also, at master level studies, we enrolled the third generation of students, but so far we have not had more than 10 students each year despite the enrollment quota of 32 students. This is again conditioned by the fact that these students can easily find employment and most of them do not want to continue education. We can hope that we will have more students enrolled in the master level program when the demand for our students in these companies drops, due to possible saturation with the staff. Time will show whether this will happen, the truth is that the demand for IT professionals working in the creative industry is constant and large.

If we return to the students' assessment of the quality of their studies, we can examine the information collected during each school year at the *Faculty of Technical Sciences* (FTS) when students assess the teaching process on two occasions: at the end of winter semester, usually in December, and before the end of the summer semester, in late May. The average grade of the professors working at our study program during the previous school year (2017/2018) was 9.38 (out of 10) and the grade of the teaching assistants was 9.39. We can say that we have reached such a high average after eight years of hard work with students. However, at the beginning we did not have that high average grade; with the first generations of students it was about 8.5 which is considered to be an acceptable grade by the students at FTS, but that is not an excellent grade. We, have now reached, according to the students' assessment, the quality of teaching of other study programs at our Faculty, which were previously better rated than us.

In the first accreditation in 2010, our UAS had 40 subjects and now in the third accreditation, there are 48 positions (subjects). The number of weekly classes has now been raised from 25 to 30, which is the maximum number of hours allowed under the accreditation rules. Also, the rules require that there is a certain percent of subjects belonging to the appropriate groups. Thus, the division into groups of subjects at UAS is as follows:

1. Elective subjects ≥ 20%
2. Academic general education, about 15%
3. Theoretical methodological, about 20%
4. Scientific-professional, about 35%
5. Professional applicative, about 30%

Regardless of the fact that the number of 30 hours of instruction looks like a large number, in our opinion it is not so. Each class is actually 45 minutes, so 30 school classes last for 22.5 hours or almost 3 working days, if the

working day is 8 hours. The whole Bologna system was designed to reduce the number of hours compared to the time 25 years ago, (when the authors of this paper were students), when the weekly number of classes at engineering programs was about 45 (or 33.75h). The assumption was probably that students will now use "excess" of free time to work at home, revising the topics covered in classes, as well as for self-exploration. However, we have considerable problems, because students often expect to get absolutely all the information in classes and, to a large extent, they are not used to work independently on their own. Of course, the role of university is also to change students' habits, but work with relatively large groups, and with relatively few hours of work at the Faculty during a week, is an aggravating circumstance that we fight every day.

When we talk about the companies that operate in our environment, primarily in Novi Sad and Belgrade, we note that our students are employed in the companies that are part of IT or are engaged in creative industries. Basically, those are the companies that deal with creating 2D games (HOPA - *Hidden Object Puzzle Adventure Games*), some parts of 3D games, such as 3D scans, Motion Capture, creating 3D commercials, creating special effects, compositing etc. These companies probably employ our students for two reasons: the first is that they are hungry for IT personnel, because the situation is such that no matter how many IT students we educate, this number is not sufficient. The other reason is that we probably train our students well, and they can easily fit into any environment in which they are employed for a relatively short period of time.

2. COMPUTER GRAPHICS - ENGINEERING ANIMATION STUDY PROGRAM

2.1 Undergraduate Academic Studies

Tables 1-4 show the subjects offered during four years of study at the UAS, with 12 subjects each year. The letter *S* stands for *Semester*, the teaching format differs: *Lec* (*Lecture*) represent lectures held by the subject professor, *Pra* means *Practical work*, *SRW* means *Study Research Work*, and *OTT* means *Other Teaching Types*. The abbreviation ECTS refers to *European Credit Transfer System* and it is an important element of the Bologna process, meant to help international students make the most of their study abroad experience. Course ID represents *Identifier* which serves to facilitate the search of objects within the software used for the accreditation process. The contents of all subjects can be found on the page of the Computer Graphics - Engineering Animation program, which is presented on the website of the Faculty of Technical Sciences [10].

In the introduction we said that general division of our study program would be into two parts: one in which students learn all the techniques and software needed for digital production of animated films and visual effects and another is primarily focused on the processing or manipulation with pictures.

To create computer animations, we use a variety of 2D and 3D drawing software (Photoshop, 3DS Max, Solid Works), software for Motion Capture (VICON MC System,

Motion Builder), for Compositing (After Effects), 2D and 3D Tracking (Boujou), Digital Sculpting (Z Brush), Photogrammetry (Photo Modeler Scanner) etc. In the field of programming, our students learn C, C ++, Open GL, Open CV, Java, VTK (Visulization ToolKit) etc.

We have created our studies according to similar programs abroad, such as American universities Brown University [13], Computer Graphics at the University of Washington [14], Animation study at Purdue University [15]. In Europe, similar programs are Computer Games Programming, at Kingston University London [16], Computer Games, at University of Essex [17], Computer Animation and Visual Effects, at the University of Portsmouth [18], 2D / 3D Animation and Videogames at L'Idem Barcelona [19], Computer Graphics at the University of Bonn [20].

Table 1

First year at Undergraduate Academic Studies

No.	Course ID	Course name	S	Active lessons				ECTS
				Lec	Pra	SRW	OTT	
1	17.IA001	Algebra	1	3	3	0	0	6
2	17.IA006	Spatial Shape Design	1	3	0	0	3	6
3	17.RG018	Basics of Information Technology for Computer Animation	1	2	0	0	2	4
4	17.IA007	Geometry and Visualization of 3D Space	1	3	3	0	0	6
5	17.IGA003	Digital photo editing	1	2	0	0	2	4
6	17.RG017	Fundamentals of Drawing for Animation and Visual Effects	1	2	2	0	0	4
7	17.IA008	Drawing for animation and visual effects	2	3	2	0	0	5
8	17.IA002	Mathematical analysis	2	3	3	0	0	6
9	17.RG001	Textures and Lights Design	2	3	0	0	4	7
10	17.RG002	History of Digital Animation	2	2	0	0	0	2
11	17.RG009	An Introduction to Procedural Animations	2	3	0	0	3	6
12	17.RG014	Physics	2	2	0	0	2	4

Table 2

Second year at Undergraduate Academic Studie

No.	Course ID	Course name	S	Active lessons				ECTS
				Lec	Pra	SRW	OTT	
13	17.RG003	Rendering Techniques	3	3	0	0	3	6
14	17.RG011	Procedural generation of texture	3	2	0	0	2	4
15	17.RG016	Computer graphics for 3D animation	3	3	0	0	2	5
16	17.RG018	Elected position - 1 (select 1 out of 4)	3	2	0	0	0	3
		English language - Elementary		2	0	0	0	3
		English language - intermediate		2	0	0	0	3
		English language - Advanced		2	0	0	0	3
		Engineering Animation and Creative Industries		2	0	0	0	3
17	17.IAI004	Elected position - 2 (select 1 out of 2)	3	2	2	0	0	4
		Mathematical Shape modeling for Computer Animation		2	2	0	0	4
		Discrete and Combinatorial methods for Computer Graphics		2	2	0	0	4
18	17. IAI002	Elected position - 3 (select 1 out of 3)	3	2	2	0	0	4
		Mechanics		2	2	0	0	4
		Classical Animation		2	0	0	2	4
19	17.IA003	Perspective	3	2	2	0	0	4
20	17.IGA008	Mathematics for Engineering Graphics	4	3	3	0	0	6
21	17.EK312L	Acoustics and Audio Engineering in Multimedia	4	3	0	0	4	7
22	17.IGB340	Fundamentals of Engineering Animation	4	2	0	0	0	2
23	17.RG004	Spatial design and 3D environments	4	3	0	0	3	6
24	17.E21I1	Elected Language (select 1 out of 3)	4	2	0	0	0	3
		English in Engineering 1		2	0	0	0	3
		English in Engineering 2		2	0	0	0	3
		German - basic		2	0	0	0	3

Table 3

Computer Graphics - Engineering Animation Study Program at the Faculty of Technical Sciences in Novi Sad

Third year at Undergraduate Academic Studies

No.	Course ID	Course name	S	Active lessons				ECTS
				Lec	Pra	SRW	OTT	
25	17.IGA013	Character Animation	5	3	0	0	3	6
26	17.EK421Z	Digital image processing in animations	5	3	0	0	2	5
27	17.IA012	Storyboard	5	2	0	0	3	5
28	17.RG008	Simulation in animation	5	3	0	0	2	5
29	17.IAI031	Elected position - 5 (select 1 out of 2)	5	2	0	0	2	4
		Web design		2	0	0	2	4
		Kinematics		2	2	0	0	4
30	17.IRG006	Elected position - C (select 1 out of 2)	5	2	0	0	3	5
		Digital Sculpting		2	0	0	3	5
		Introduction to the technology of augmented and virtual reality		2	0	0	3	5
31	17.IGA031	Aesthetics of Visual Communications	6	3	0	0	3	5
32	17.IGB052	Engineering animation and other media	6	2	0	0	3	5
33	17.IGA055	Special Visual Effects	6	2	0	0	4	6
34	17.IGB034	Video Processing in Computer Animations	6	3	0	0	3	6
35	17.IAI033	Elected position - 6 (select 1 out of 2)	6	2	0	0	0	2
		Sociology of Engineering		2	0	0	0	2
		Career management and development		2	0	0	0	2
36	17.IAIN33	Elected position - D (select 1 out of 2)	6	3	0	0	2	6
		Introduction to Software Engineering		3	0	0	2	6
		Object oriented programming		3	0	0	2	6

Table 4

Fourth year at Undergraduate Academic Studies

No.	Course ID	Course name	S	Active lessons				ECTS
				Lec	Pra	SRW	OTT	
37	17.IA013	Interactive Engineering Graphics	7	2	0	0	3	5
38	17.IA020	Advanced Visualization Technologies	7	2	0	0	2	5
39	17.RG012	Techniques of writing and presenting theoretical work	7	2	0	0	0	2
40	17.IA015	Application of Engineering Animation	7	2	0	0	2	5
41	17.IA018	3D digitization methods	7	3	0	0	2	5
42	17.IAI04	Elected position - 7 (select 1 out of 2)	7	2	0	0	2	5
		Software patterns and components		2	0	0	2	5
		Image-based modeling		2	0	0	2	5
43	17.IASP01	Professional Practice	8	6 classes				3
44	17.RG007	Post-production for Animation	8	2	0	0	3	5
45	17.KPRN01	Visual programming for animation	8	3	0	0	3	6
46	17.IAI05	Elected position - 8 (select 1 out of 3)	8	2	0-2	0	0-2	4
		Formal mathematical models		2	2	0	0	4
		Geometry of Discrete Spaces		2	2	0	0	4
		Motion capture and analysis		2	0	0	2	4
47	17.IAIM04	Elected position - E (select 1 out of 2)	8	3	0-2	0	0-2	5
		The Color and illuminance		3	2	0	0	5
		Cloud Computing		3	0	0	2	5
48	17.IAZR01	Bachelor Thesis	8	10 classes				10

2.2 Master Academic Studies

The contents of all the subjects can be found on the Computer Graphics - Engineering Animation MAS web page of the Faculty of Technical Sciences [11].

Table 5 shows all the subjects at Master level studies.

2.2 Doctoral Academic Studies

The contents of all the subjects can be found on the Computer Graphics - Engineering Animation DAS web page of the Faculty of Technical Sciences [12]. Tables 6, 7 and 8 show all three years of doctoral studies.

Table 5

Master Academic Studies

No.	Course ID	Course name	S	Active lessons				ECTS
				Lec	Pra	SRW	OTT	
1	17.IA017A	Interdisciplinary Scientific Visualization	1	2	0	0	2	4
2	17.RGM1	Advanced simulations in animation	1	2	0	0	2	5
3	17.RG015	Augmented and virtual reality	1	2	0	0	2	5
4	17.IAI06	Elected position - 1 (select 1 out of 5)	1	2-3	0-2	0	0-3	4-6
		Digital audio signal processing		2	1	0	1	5
		Rendering Algorithms		3	0	0	3	5
		Computer vision		3	0	0	2	6
		Numerical optimization		2	2	0	0	4
		Advanced methods for motion capturing and analysis		2	0	0	3	5
5	17.IAI07	Elected position - 2 (select 1 out of 4)	1	2	2	0	0	4
		Digital audio signal processing		2	1	0	1	5
		Computer vision		3	0	0	2	6
		Rendering Algorithms		3	0	0	3	5
		Advanced methods for motion capturing and analysis		2	0	0	3	5
6	17.IGASP0	Professional Practice	1	6 classes				4
7	17.IA018A	Computer Geometry	2	2	0	0	2	4
8	17.E2528	Game Development Process	2	3	0	0	3	6
9	17.IAI09	Elected position - 2 (select 1 out of 2)	2	2	0-2	0	0-2	4-5
		Artificial Intelligence in Computer Animations	2	2	0	0	2	4
		Mathematical game theory	2	2	2	0	0	5
10	17.IGASI0	Study Research on Theoretical Background of the Master Thesis	2	0	0	7	0	10
11	17.IGA0ZR	Writing and Defense of the Master Thesis	2	5 classes				9
Active lessons in total				41-45				
						Total ECTS		60-64

Computer Graphics - Engineering Animation Study Program at the Faculty of Technical Sciences in Novi Sad

First year at Doctoral Academic Studies

No.	Course ID	Course name	S	Lec	Pra	SRW	OTT	ECTS
1	17.DZ001	Methods of scientific investigations	1	1	0	6	0	8
2	17.DZ0I1	Elected position 1 (select 2 out of 5)	1	4	0	2	0	10
	17.DZ01M	Selected Chapters 1 in Mathematics		2	0	1	0	5
	17.DZ02M	Selected Chapters 2 in Mathematics						5
	17.DZ01F	Selected topics in physics						5
	17.DZ01H	Selected chapters in chemistry						5
	17.DZ01T	Selected chapters from the theory of engineering experiment						5
3	17.AIDI02	Elected position 2 (select 1 out of 3)	1	5	0	2	0	10
	17.AID02	Advanced technologies for modeling and perception of video and 3D signal in computer graphics						10
	17.AID04	Haptic devices usage in the virtual environment						10
	17.AID08	Selected sections of applied computer graphics and visualization in medicine						10
4	17.AIDI03	Elected position - 3 (select 1 out of 6)	2	5	0	2	0	10
	17.AID03	3D representation of the real-world environment						
	17.DOM54	Computational Geometry						
	17.DOM55	Pattern Recognition						
	17.DRNI12	Advanced Software Development Methodology						
	17.DRNI15	Selected Topics in Advanced Computer Graphics						
	17.DRNI05	Software Standardization and Quality - Selected Topics						
5	17.IAI07	Elected position - 4 (select 1 out of 6)	2	5	0	2	0	10
	17.AID03	3D representation of the real-world environment						10
	17.DOM54	Computational Geometry						10
	17.DOM55	Pattern Recognition						10
	17.DRNI12	Advanced Software Development Methodology						10
	17.DRNI15	Selected Topics in Advanced Computer Graphics						10
	17.DRNI05	Software Standardization and Quality - Selected Topics						10
6	17.DZ002	Introduction to Scientific Research Method	2	0	0	6	0	12
		Active lessons in total		40				
		Total ECTS						60

Second year at Doctoral Academic Studies

No.	Course ID	Course name	S	Lec	Pra	SRW	OTT	ECTS
7	17.AIDI05	Elected position 5 (select 1 out of 4)	3	5	0	2	0	10
	17.AIDO8	Advanced Interdisciplinary Scientific Visualization						
	17.DRNI18	Selected Topics in Distributed/Mobile computing						
	17.RG021	Advanced Methods in Computer animation & simulation						
	17.DRNI09	Selected Topics in Human Centered Computing						
8	17.AIDI06	Elected position 6 (select 1 out of 4)	3	5	0	2	0	10
	17.AIDO8	Advanced Interdisciplinary Scientific Visualization						
	17.DRNI18	Selected Topics in Distributed/Mobile computing						
	17.RG021	Advanced Methods in Computer animation&simulation						
	17.DRNI09	Selected Topics in Human Centered Computing						
9	17.RGD01	Doctoral thesis - Research and publication of results 1	3	0	0	6	0	10
10	17.DZ02M	Doctoral thesis - Research and publication of results 2	4	0	0	15	0	18
11	17.RGD03	Doctoral thesis - Theoretical foundations	4	0	0	5	0	12
		Active lessons in total		40				
		Total ECTS						60

Table 8

Second year at Doctoral Academic Studies

No.	Course ID	Course name	S	Active lessons				ECTS
				Lec	Pra	SRW	OTT	
12	17.RGD04	Doctoral thesis - Research and publication of results 3	5	0	0	20	0	30
13	17.RGD05	Doctoral thesis - Study and research	6	0	0	20	0	20
14	17.RGD06	Doctoral thesis - writing and defending a thesis	6	0	0	0	0	10
Active lessons in total				40				
						Total ECTS		60

8. CONCLUSION

The Computer Graphics - Engineering Animation study program was established in 2010 when the first accreditation was completed. By the end of 2018, 60 students completed UAS and 2 students completed MAS. At the doctoral studies, which were established in 2013 in the second accreditation, we have 5 students. This year, the third accreditation is in progress and this paper presented the latest study program which includes all our experience from the previous 10 years. We believe that we have used the best of all possibilities from the accreditation system that is in line with the Bologna system. Students have six subjects per semester, with a weekly load of 30 school hours. The subjects are interestingly incorporated so as to develop two parallel basic paths of our studies: the first, which relates to all the software and skills needed to create 3D animation and the second part, relating to various programming techniques that relate either to image generation or image analysis.

Although our students have had no problems so far with employment, we believe that this new version of the study program will create personnel that will be even better and more attractive for companies in a wider environment and especially for the times ahead, in view of the great dynamics in the field of computer graphics and various new challenges. It is our job to try to anticipate the direction in which Computer graphics will develop and the potential new jobs for which we also want to educate our students. Some of the topics that we did not deal with previously are Augmented Reality and Virtual Reality which are now added through newly introduced subjects. These are the areas that are dynamically developing in the world, although we do not yet have companies that are significantly involved in these areas.

There is another problem that we have encountered and which we have not yet resolved. The problem was created because we were visionaries regarding this type of studies in our country and it can be said in the region as well. We were the first. We see only now a shy appearance of the subjects that deal with 3D animation, programming related to graphics, AR and VR at some faculties and departments in our environment. Such a position is pleasant to us, but it also carries with it certain problems.

One of the most important problems which directly stems from this position/situation is the development of the adequate teaching staff for our study program. Although we have 60 graduates at UAS and two at MAS, this year we have enrolled the first DAS student who has completed our UAS and MAS study programs.

It is realistic to expect our first doctors of science in the next 4-5 years. At the moment, the situation is such that our teachers are assisted by professors from other departments within the FTS. We also have 10 professors from other faculties from the University of Novi Sad and the University of Belgrade. It is certain that such a large base from which professors are engaged provides adequate high quality of studies and at this moment, without their help, the teachers employed at our department would not be able to successfully organize the entire teaching process.

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