CARTOGRAPHY AND GIS EDUCATION IN GEOMATIC ENGINEERING

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Abstract

Cartography and GIS education is largely undertaken by geomatic engineering (a.k.a. geodesy and geoinformatics, geospatial science or surveying and mapping/geoinformation) and geography departments of universities as part of their undergraduate and graduate programmes. Individual bachelor programmes on cartography are very few and in trend of decreasing while individual GIS or geoinformatics undergraduate programmes including some cartographic courses have been emerging. On the other hand, individual graduate programmes are increasing on these subjects apart from specialisations within geomatic engineering or geography programmes. The aim of this study is to examine different international higher education models of geomatic engineering with focus on cartography and GIS and show similarities and differences as well as make some proposals for possible curricula on cartography and GIS. As a result, the findings of this study may help improve the current curricula on cartography and GIS in geomatic engineering related departments.

1. INTRODUCTION

Cartography and GIS are the key disciplines for managing our earth and society. Boundaries between cartography and GIS are somewhat fuzzy and artificial at both scientific and educational level. Training on these areas is given by geomatic engineering (also known as geodesy and geoinformatics, geospatial science or surveying and mapping/geoinformation) and geography departments. Cartography and GIS education in geomatic engineering will be examined in this paper.

Geomatic engineering has emerged mainly from the integration of surveying and mapping with information science and technology. In addition, developments in computer science and electronics have been providing critical inputs. Hence this discipline has a dynamic nature.

In recent years, surveying and mapping related departments in some countries have experienced lack of interest from students to their university programmes. Hence, they have needed to transform their educational approaches by offering more modern, more specialised and technology-oriented programmes and courses. This has also affected cartographic education. Most of the traditional courses on cartography are being modernised under new titles or their topics are embedded in the courses entitled such as GIS, geoinformatics, mapping, GIS and cartography. Developments in information and communication (ICT) technologies particularly make this transition more rapidly because demands from industry and governments are changing in parallel.

Although such a dynamic environment exists in this domain, there is no comprehensive investigation of geomatic engineering programmes in view of cartography and GIS. Therefore, this paper aims at presenting a web-based investigation of undergraduate and graduate programmes of geomatic engineering departments towards cartography and GIS education and curricula worldwide as well as makes some propositions about a possible curriculum on these areas.

2. CARTOGRAPHY AND GIS IN THE GEOMATIC ENGINEERING EDUCATION

Geomatic engineering programmes take three or four years at the undergraduate level and two years at graduate level. There are few five-year programmes as well. Curriculum of these programmes mostly comprise from the courses on geodesy, surveying, photogrammetry, cartography and land management, either integrated with or embedded in

contemporary spatial information technology oriented contents or courses such as GNSS, remote sensing and/or GIS. Cartography and GIS related courses are examined in detail in the following sections.

2.1 Cartography and GIS in the Geomatic Engineering Undergraduate Curricula

There are many examples of geomatic engineering education worldwide. So cartography and GIS courses exhibit some varieties in these programmes. Table 1 presents some statistics on the numbers and the credits of the courses of some university programmes on geomatic engineering at undergraduate level.

Table 1. Some undergraduate geomatic engineering programmes and the percentage of the number of the courses and total credits on cartography and GIS in their curriculum.

Year	Country	University	Programme	Approximate percentage of the number of courses (GIS&Cartography)	Approximate percentage of the total credits (GIS&Cartography)
4	Australia	Curtin Univ. Of Tech.	Surveying	26	20
3	Australia	Curtin Univ. Of Tech.	GIScience	80	81
4	Australia	RMIT Univ.	Surveying	21	24
4	Australia	RMIT Univ.	Geospatial Science	29	29
3	Austria	Tech. Univ. of Wien Wien	Geodesy and Geoinformatics	21	15
4	Bulgaria	UACG	Geodesy	16	16
4	Canada	Univ. of New Brunswick	Geodesy and Geomatic Eng.	10	-
4	Canada	Univ. of Calgary	Geomatics Engineering	15	15
4	Canada	Univ. of Laval	Geomatic Sciences	7	9
3	Croatia	Univ. Of Zagrep	Geodesy and Geoinformatics	14	17
3	Germany	Hafen City Univ.	Geomatics	29	8
3	Germany	Tech. Univ. of Munich	Geodesy and Geoinformation	15	11
3	Germany	Univ. of Bonn	Geodesy and Geoinformation	15	12
3	Germany	Hannover Univ.	Geodesy and Geoinformatics	12	16
4	Ireland	Dublin Inst. of Tech.	Geomatics (Surveying & Mapping)	13	10
5	Kenya	Jomo Kenyatta Univ.	Geomatics Engineering	14	-
4	S.Africa	Univ. of KwaZulu-Natal	Land Surveying	9	-
4	S.Africa	Tshwane Univ. of Tech.	Geomatics	17	-
3	Slovenia	Univ. of Ljubliana	Geodesy and Geoinformation	7	10
4	Spain	P.Tech.Univ. of Valencia	Geomatic and Surveying Eng.	16	15
4	Spain	P.Tech.Univ. of Catalonia	Geomatic and Surveying Eng.	19	18
3	Sweden	Gavle Univ.	Geomatics	33	35
3	Switzerland	ETH Zurich	Geomatics Engineering & Planning	15	11
4	Turkey	Istanbul Tech. Univ.	Geomatics Engineering	12	14
4	Turkey	Karadeniz Tech. Univ.	Geomatics Engineering	11	7
4	Turkey	Selcuk Univ.	Geomatic Engineering	14	13
4	Turkey	Yildiz Tech. Univ.	Geomatic Engineering	11	11
4	USA	California State Univ.	Geomatics Engineering	18	20
4	USA	Oregon Inst. Of Tech.	Geomatics (Surveying)	10	8

Table 1. Some undergraduate geomatic engineering programmes and the percentage of the number of the courses and total credits on cartography and GIS in their curriculum (cont).

Year	Country	University	Programme	Approximate percentage of the number of courses (GIS&Cartography)	Approximate percentage of the total credits (GIS&Cartography)
4	USA	Oregon Inst. Of Tech.	Geomatics (GIS)	23	21
4	USA	Penn. State Univ.	Surveying Engineering	9	8

Average percentage of the number of the courses on cartography and GIS is about % 16 while average percentage of the credits is about % 15 except specialisation or specialist programmes. These values have been increasing if the programmes offer specialisations in last year or last two years or directly designed as specialist programme. For example these values are % 23 (the number of the courses) and % 21 (the total credits) in the Geomatics (GIS track) programme of Oregon Institute of Technology (USA) while % 80 (the number of the courses) and % 81 (the number of the courses) in the GIScience programme of Curtin University of Technology (Australia) respectively. The geomatics programme of Gavle University offers highest number and total credit for cartography and GIS courses, i.e. % 33 and % 35 respectively while they are % 9 and % 8 in the surveying programme of Pennsylvania State University (USA). These values are about average in the geodesy programme of University of Architecture, Civil Engineering and Geodesy (Bulgaria), the geodesy and cartography programme of Polytechnic University of Valencia (Spain), the geomatics engineering programme of University of Calgary (Canada), the geodesy and geoinformatics programme of University of Zagreb (Croatia), the geodesy and geoinformatics programme of University of Hannover (Germany). The geospatial science and the surveying programmes of RMIT University (Australia), the surveying programme of Curtin University of Technology (Australia), the geomatics engineering programme of California State University (USA), the geomatic and surveying engineering programme of Polytechnic University of Catalonia (BarcelonaTech) (Spain) offer more courses and credits than the average on cartography and GIS.

There are various cartography and GIS courses in geomatic engineering programmes. Some examples are given in Table 2.

Table 2. Cartography and GIS courses in the curricula of some undergraduate geomatic engineering programmes or their specialist programmes

University	Programme	Course Titles on Cartography&GIS
ETH Zurich (Switzerland)	Geomatics Engineering & Planning	Cartography I, GIS I, Thematic Cartography, GIS II, Cartography II, Spatial Data Analysis
Univ. of New Brunswick (Canada)	Geodesy and Geomatic Eng.	Introduction to Geographic Information Systems, Advanced Geographic Information Systems, Hydrographic Data Management, Web Mapping and Map Mashups, Special Studies in Digital Mapping
Wuhan University (China)	Geodesy and Geomatics Engineering	Principles of Geographic Information System, Principles and Methods of Digital Mapping, Cartography, Urban Spatial Information, GIS Project and Practice, Course Design and Practice of GIS
Curtin Univ. Of Tech. (Australia)	Surveying	Applied Cartography, Cartographic Statistics, Spatial Data Processing, Coordinate and Mapping Systems
Curtin Univ. Of Tech. (Australia)	GIScience	Spatial Data Representation, Applied Cartography, Geographic Information Systems Programming, Web Mapping, Coordinate and Mapping Systems, Spatial Project Management, Spatial Algorithms, Geospatial Analysis, Geovisualisation and Mapping, Spatial Modelling, Spatial Sciences Professional Practice, Spatial Sciences Project

Table 2. Cartography and GIS courses in the curricula of some undergraduate geomatic engineering programmes or their specialist programme (cont.)

University	Programme	Course Titles on Cartography&GIS
Hannover Univ. (Germany)	Geodesy and Geoinformatics	Introduction to Database Programming, Introduction to GIS and Cartography I, Introduction to GIS and Cartography II, Geographic Information Systems, GIS I (Data modeling), GIS II (Access structures and algorithms)
Poly. Tech. Univ. of Valencia (Spain)	Geodesy and Cartography	Cartographic Production, Cartographic Publishing, Cartography And Town Planning, Computerized Urban Cartography, GIS I, Geostatistics, Mathematical Cartography, GIS II, Thematic Cartography
California State Univ. (USA)	Geomatics Engineering	Computer-Aided Mapping, Geomatics, Digital Mapping, Introduction to GIS, GIS Applications, GIS Design
P.Tech.Univ. of Catalonia (Spain)	Geomatic and Surveying Engineering	Cartography, Mathematical Cartography, Databases, Cartographic Design and Production, 3D Data Processing, Geographical Information Systems, GIS Project Design and Management, Spatial Data Infrastructure, Spatial Data Infrastructure: Applications, Topographical Calculations and UTM Projection
RMIT University (Australia)	Geospatial Science	Cartography 1, Spatial Information Science 1, Applied Geospatial Techniques, Spatial Information Science 2, Cartography 2, Map Projections, Spatial Information Science 3, Database Concepts, Spatial Information Science 4, Database Concepts, Cartography 3
Istanbul Technical University (Turkey)	Geomatics Engineering	Introduction to Cartography, Computer Aided Graphics and Map Design, Databases in Engineering, History of Cartography, Digital Terrain Model, Cartographic Projections, Computer Aided Cartography, Cartographic Presentation of Spatial Data, Map Reproduction

2.2 Cartography and GIS in the Geomatic Engineering Graduate Curricula

Graduate programmes on geomatic engineering usually offer specialisations or specialty programmes. Such programmes offer more courses and credits than general programmes (Table 3). Courses vary based on the programmes (Table 4)

Table 3. Some graduate geomatic engineering programmes or their specialisation and specialist programmes and the percentage of the number of the courses and total credits on cartography and GIS in their curricula

Year	Country	University	Programme	Approximate percentage of the number of courses (Cartography&GIS)	Approximate percentage of the total credits (Cartography&GIS)
2	Australia	Curtin Univ. Of Tech.	Geospatial Science	81	81
2	Australia	RMIT Univ.	Geospatial Science	33.3	33.3
3	Australia	Univ. Of Melbourne	Geomatics	30.8	30.8
2	Canada	Calgary Univ.	Geomatics Engineering	14.3	14.6
2	Canada	Laval Univ.	Geomatic Sciences	23.1	23.1
2	Finland	Aalto Univ.	Geoinformatics	78.9	75.7
2	Netherlands	Delft Univ. Of Tech.	Geomatics	66.7	38.1
2	Slovenia	Univ. Ljubljana	Geodesy & Geoinformation	17.2	13.9
2	Turkey	Karadeniz Tech. Un.	Geomatic Engineering	14.3	15.4
2	Turkey	Selcuk Univ.	Geomatic Engineering	25	25
2	Turkey	Yildiz Tech. Univ.	Remote Sensing and GIS	76	76
2	USA	Ohio State Univ.	Geoinformation & Geodetic Eng.	15.4	23

Table 4. Cartography and GIS courses in the curricula of some graduate geomatic engineering programmes or their specialisation and specialist programmes

University	Programme	Course Titles on Cartography&GIS
Aalto Univ. (Finland)	Geoinformatics	GIS Analysis and Modelling, Visual Analysis in GIS, Principles of Geostatistics, GIS Application Development, Uncertainty in Geographic Information, Fuzzy Modelling of Geographic Information, Advanced Computational Methods in GIS, Spatial Data Mining, Visualisation of Geographic Information, Web Map Project, Topographic Data and Maps
Univ. of College London (UK)	Geographic Information Science	GIS Principles & Technology, Mapping Science, Principles of Spatial Analysis, Representation, Structures and Algorithms, Geographic Information System Design, Spatio-Temporal Analysis & Data Mining, Web & Mobile GIS, Spatial Decision Support
Univ. of Melbourne (Australia)	Spatial Information Science	Foundations of Spatial Information, Spatial Databases, Spatial Analysis, Spatial Visualisation, Spatial Data Infrastructure, Spatial Information Programming, Advanced Topics in GIScience
Univ. of Laval (Canada)	Geomatic Sciences (Geoinformatics Track)	Design of GIS Databases, Integration of Spatial data: Concepts and Practice, GIS and Spatial Analysis, Data Structures and Algorithms in GIS, Implementation of GIS Applications, Geomatics Software Development Frameworks, Digital Terrain Models and Applications, Advanced Spatial Data Publication on Internet, Geographic Information Society, Advanced Concepts of GIS Databases, Applications of 3D Geometric Modeling, Quality of Geospatial data, Geomatics, Decision and Cognition, Web Programming and Mobile Mapping Applications, Geographic Information Society

Table 4. Cartography and GIS courses in the curricula of some graduate geomatic engineering programmes or their specialisation and specialist programmes (cont).

University	Programme	Course Titles on Cartography&GIS
Delft Univ. of Technology (Netherlands)	Geomatics	3D Modelling, Geo Web Technology, GIS and Cartography, Decision Support, Geo Datasets, Geo-Info Law, Python Programming, Geo-DBMS
Istanbul Technical University (Turkey)	Geoinformation Technology	Spatial Data Analysis, Advanced GIS, Special Topics in GIS, Web GIS Technologies, GIS in Urban Planning, GIS for Disaster Management, Principles of Geo-Information Systems, Professionalism In GIS, Urban Information Systems, Spatial Mathematical Methods, Remote Sensing for GIS, Geo-database Development, Geo-Data Policy, Geo-Data Standards, interoperability in GIS, Temporal GIS and etc.

3. SOME PROPOSALS FOR CARTOGRAPHY AND GIS COURSES AND CONTENTS IN GEOMATIC ENGINEERING

Most of the departments have been updating their geomatic engineering curricula regularly depending on the scientific and technologic developments as well as demands from industry and governments. Some geomatic engineering departments offer specialist or specialisation programmes even at undergraduate level while most of them have one programme and curriculum including selective courses that is useful for specialisation at some degree.

Department of Geomatic Engineering of Yildiz Technical University (YTU), Istanbul, Turkey has just renewed their curricula of undergraduate and graduate programmes regarding programmes abroad and national demands. Four-year undergraduate programme includes following obligatory and selective courses on cartography and GIS in the new curriculum:

Obligatory Courses:

- Cartography 1 (Introduction to Cartography and Mathematical Cartography) 3+0 (4 ECTS) 2nd Year – Fall
- Topographic Mapping (Topographic DBs/Maps and Terrain Modeling) 2+2 (4 ECTS) 2nd Year – Spring
- GIS 1 (Geographic Database Management and Spatial Analysis) 3+0 (4 ECTS) 3rd Year – Fall
- Cartography 2 (Thematic Cartography and Geovisualization) 2+0 (3 ECTS) 3rd Year – Spring
- GIS 2 (GIS Implementation and Project Management) 3+0 (4 ECTS) 3rd Year – Spring

Elective Courses:

- Introduction to Geospatial Data Mining 2+0 (4 ECTS) 3rd Year - Fall
- Web GIS and Cartography 2+0 (3 ECTS) 4rd Year - Fall
- Decision Support Systems 2+0 (3 ECTS) 4rd Year – Fall
- GIS and Geocomputation 2+0 (3 ECTS) 4rd Year - Fall
- Land Information Management Systems 2+0 (3 ECTS) 4rd Year – Fall
- Web Based Geographic Information Systems 2+0 (4 ECTS) 4rd Year - Fall
- Programming in GIS 2+0 (3 ECTS) 4rd Year – Spring
- Mobile GIS and Cartography 2+0 (3 ECTS) 4rd Year – Spring
- Cartography and Geoinformatics Project 2+0 (4 ECTS) 4rd Year – Spring

If this curriculum is compared with other geomatic engineering programmes some more courses may be added to elective courses such as 3D GIS and SDI.

Updating of the curriculum of Geomatic Engineering Undergraduate Programme also started in Istanbul Technical University (ITU). In developing new curriculum, the number of Cartography and GIS courses is being increased and

contents of the courses are being improved by considering international programmes. Moreover, in addition to current Geomatic Engineering Graduate Programme, Geoinformation Technology Graduate Programme has started for more specialised multidisciplinary GIS education. Some courses of this program are presented in Table 4. Other interesting course examples on cartography in geomatics curriculum can be found in Cerba et al. (2012).

As for graduate level, course examples in Table 4 are quite comprehensive. These are usually offered by specialist or specialisation programmes of geomatic engineering departments. Some interesting courses beside fundamental ones are: Geo-Info Law, Uncertainty in Geographic Information, Fuzzy Modelling of Geographic Information, Advanced Computational Methods in GIS, Decision and Cognition, Geographic Information Society Data Structures and Algorithms in GIS.

One of the interesting issues is that some geomatic engineering programmes do not offer independent cartography courses in their curricula or do not use "cartography" term for their course titles but often "mapping" even these courses have directly related to cartographic topics.

4. CONCLUSIONS

Cartography and GIS education is an important part of geomatic engineering discipline. Both programmes and contents are changing due to the scientific and technological developments. These are also affected from national conditions and international trends. This paper has presented the current evaluation of curricula of some programmes and demonstrated some statistics and examples. In addition, some proposals are made for a possible curriculum at the undergraduate level based on the new curriculum in Department of Geomatic Engineering of Yildiz Technical University (YTU), Istanbul, Turkey. Some information on developing new curricula of geomatic engineering related undergraduate and graduate programmes in Istanbul Technical University (ITU) were given. Detailed information on these curricula will also be presented in future conferences when it is finalized. Besides, new and interesting courses at the graduate level are given apart from fundamentals one. Such studies may be carried out by international bodies such as ICA at a larger extent.

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