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UNESP GRADUATE PROGRAM ON CARTOGRAPHIC SCIENCES

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ABSTRACT:

Cartographic Sciences play an important role in the progress of developing countries like Brazil. For historical and costs reasons, most of the teaching and research in this area is carried out by public universities. In general, the number of professionals in this area with a university degree (Cartographic or Surveying Engineers) is not enough for providing the required human resources by the community. Graduate studies are growing up, with several universities offering Master and Doctoral courses. The status of Unesp Graduate Programme on Cartographic Sciences, will be presented. The programme is an umbrella over several Geomatic fields, including GIS, Geodetic positioning and Image Computing. The structure of the Programme, the research projects being carried out and the perspectives for the near future will be presented.

RESUMO

As Ciências Cartográficas desempenham um papel importante no progresso de países emergentes, como o Brasil. Por razões históricas e de custos, a maior parte do ensino e pesquisa nessa área está concentrada em universidades públicas. Em geral, o número de profissionais com grau universitário nessa área (Engenheiro Cartógrafo e Agrimensor) não é suficiente para atender à crescente procura por recursos humanos qualificados. Os programas de pós-graduação estão crescendo em número e qualidade em diferentes localidades, oferecendo tanto o Mestrado quanto o Doutorado. Será mostrado, neste trabalho, o *status* atual do ensino e pesquisa no Programa de pós-graduação em Ciências Cartográficas da Unesp. O programa é amplo o suficiente para conter as várias áreas da Geomática, incluindo SIG (Sistema de Informação Geográfica), Posicionamento Geodésico e Computação de Imagens. Serão apresentados a estrutura do programa, os projetos em desenvolvimento e as perspectivas futuras.

1. INTRODUCTION

Cartographic Sciences play an important role in the progress of developing countries like Brazil. The products provided by this science compose the basic infra-structure for development. Nowadays, with the crescent needs for providing high quality services within different sector of activities, like energy, telecommunication, transport, etc., the cartographic information is the primary product for reaching such aim. For historical and costs reasons, most of the teaching and research in this area is carried out by public universities. In general, the number of professionals in this area with a university degree (Cartographic or Surveying Engineers) is not enough for providing the required human resources by the community. By other hand, graduate studies are growing up, with several universities offering Master and Doctoral courses.

In Brazil, the three main graduate programs related to Geomatic sciences are the Geodetic Science from UFPR (Paraná Federal University), the Cartographic Science from UNESP (São Paulo State University) and the Geodetic Science and Geo-information Technology, from UFPE (Pernanbuco Federal University). The first one, with more than three decades of experience, is the most traditional and the first one to be established in this area in Brazil. UNESP program started its activities in the beginning of 1997, and the UFPE one in the beginning of 2001. There are also programs of other areas offering opportunities for developing research in the Geomatic area. We can make mention to the two graduate programs in Transportation Engineering from USP (São Paulo University); one located at São Paulo city and the other at São Carlos, with concentration areas in Spatial Information and Transport Infra-Structure respectively. The Civil Engineering Program from UFSC (Federal University of Santa Catarina) has a concentration area of research in Land Information System (Cadastre). UERF (Rio de Janeiro State University) started recently a graduate program in Geomatics with two main research areas: Computation System and Geo-information technology. Finally, but not last, one also has to mention the Remote Sensing Program (RS) from INPE (National Institute of Spatial Researches), with a great tradition in the development of researches related to GIS and applications and development of RS, and from UFRGS (Federal University of Rio Grande do Sul).

The aim of this paper is to briefly describe the graduate programme on Cartographic Sciences offered by the Faculty of Science and Technology (FCT) of São Paulo Sate University (Unesp), at Presidente Prudente, SP.

2. SÃO PAULO STATE UNIVERSITY - UNESP

UNESP - Universidade Estadual Paulista (São Paulo State University) - is the most successful experiment of a multi-

campus university in Brazil, maintaining intense and diversified activities in the most developed state of the Federation: the state of São Paulo. In 1923, the School of Pharmacy and Dentistry of Araraquara was founded. In the fifties and sixties the government founded the Isolated Institutes of Higher Education in many towns in the central region of the state of São Paulo. These institutes were joined to form a university in 1976. Henceforth, the former Isolated Institutes have been Academic Units of UNESP, having common goals: production, preservation and transmission of knowledge in all fields: arts and sciences, humanities and technology, offering high quality, tuition-free, public education both at the undergraduate and graduate levels, setting up research units and rendering services to the community. Unesp has one campus in the capital and 14 in the central region, besides two advanced campuses and several complementary units.

UNESP is an independent self-governing institution with autonomy concerning pedagogical, scientific, administrative, disciplinary, patrimonial and financial management issues. It is ruled by its own charter and its internal regulations. The budget, almost in its totality, is composed of grants from the São Paulo state government based on a fixed percentage of the revenues from the Tax on Goods and Services (ICMS).

The undergraduate programme offers a bachelor's degree (training for a profession in a specific field of study) and a teaching certificate. A prerequisite to enter the programme is to have finished high school and passed the entrance examinations ("Vestibular"). At this level, UNESP covers all fields of study.

Graduate programmes are highly specialised academic activities at the masters and doctorate levels awarding the degrees of Master of Arts or Science (MA or MS) and Doctor of Philosophy (PhD). The aim is to form researchers and specialised human resources in a wide range of fields. They comprise advanced studies and research regarding specific fields of knowledge.

Besides graduate and undergraduate studies, the Academic Units organise university extension programmes with the purpose of disseminating new developments in technique and knowledge to professionals and to the community at large.

Additionally to teach, an essential part of the university mission is to promote basic and applied technological research, contributing to scientific advancement and improving the quality of human life.

A significant factor for the effective development of collective or individual research projects is the predominance (93%) of the full-time work contract of faculty members, which assume that they will also be involved in research activities. Another factor is the nature of the academic career - it is structured in a way that encourages the constant professional development of faculty members.

To face the ever-increasing demands to be met as an entity dedicated to teaching, research and academic extension, UNESP has strengthened its links with various types of Brazilians and foreigners institutions. Thus, a wide range of agreements with distinct objectives have been signed: financial co-operation with the private sector or with governmental organisations providing grants for research development; others concerned exclusively with the rendering of university extension services; technical and scientific co-operation; all promoting the exchange of experience.

The first step of the academic career, that of teaching monitor, occurs when the scholar has graduated but still does not hold any other degree yet, although developing a research project. The second step is that of Assistant Professor when his master's dissertation has been approved; the third is the Senior Assistant Professor, upon approval of his doctorate thesis. The defence of another thesis, now at the post-doctorate level, awards the scholar the title of Adjunct Professor and the highest rank is achieved with the title of Full Professor. There is also the career devoted exclusively to research, bringing together qualified scholars for the realisation of specific projects. Most of the 3104 faculty members are full time, in order to do teaching and research for the 23603 undergraduate students and 6263 graduate students.

3. UNESP CAMPUS OF PRESIDENTE PRUDENTE - SCHOOL OF SCIENCES AND TECHNOLOGY

Presidente Prudente is located approximately 600 km far from São Paulo with 200.000 inhabitants. It is a regional centre for commerce and services, serving the neighbours regions of north of Paraná State and Mato Grosso State.

At Unesp campus in Presidente Prudente there is the Faculty (School) of Sciences and Technology (FCT), with approximately 200 faculty members, most of them with full time contracts, more than 2000 undergraduate students, around of 200 graduate students (Msc and Phd), more than 250 students undertaking specialisation courses and about 230 administrative civil servants.

FCT was originally created as a Philosophy School in 1958. The fusion with Unesp forced to change its characteristics, from dedicated Human Sciences to a broad range of Sciences. Nowadays, FCT offers 10 undergraduate programmes: Geography, Mathematics, Cartographic Engineering, Statistics, Physiotherapy, Physical Education, Pedagogy; Environmental Engineering, Computer Sciences and Physics.

Graduate programmes are offered in three main fields: Geography (MSc and PhD), Cartographic Sciences (MSc and PhD) and Pedagogy (MSc). The PhD Programme in Cartographic Sciences is the newest one; it started in 2002. Besides these academic programmes, other opportunities of graduate studies are being offered. Nowadays, following an international education policy, there is a trend in offering continued education courses in several fields of knowledge. It is expected that formal continued educational program should be offered regularly very soon.

4. CARTOGRAPHIC ENGINEERING AND CARTOGRAPHIC SCIENCES

Cartography in Brazil is understood as a broad field that covers all the sciences that contribute to the Mapping process, e.g., Geodesy, Photogrammetry, Surveying, Remote Sensing. Therefore, in this sense, it is a synonym for Geomatics. The professional who is qualified to manage all the phases of the mapping process is called Cartographer Engineer. The UNESP Cartographic Engineering programme started in 1977, with 30 student posts each year. Recently this number was increased to 40, in order to attend the high demand of the private sector, which is requiring specialists with good knowledge in GIS (Geographical Information System) and GNSS (Global Navigation Satellite System).

At UNESP, as well as in other public universities, students are stimulated in various ways to get out the most of their academic experience. To reach such aim, the Scientific Initiation Programme (IC) is one of the most successful initiatives. In the IC programme students start with the development of research projects in various fields. The orientation is undertaken by a staff member with at least MSc degree. Undergraduate students present the results of their investigations at a conference held annually, besides writing reports and papers on the related topic. This encourages early research activities and contributes to the higher level of education attained by the professionals educated at UNESP.

The Graduate programme on Cartographic Sciences started its activities in 1997 with the Master of Science course. Around 10 students are accepted each year. The students must attend courses and seminars besides performing some preliminary research during the first year. The second year is mainly dedicated to the development of the proposed research and to write the dissertation. Before the VIVA (final examination), the MSc candidate has to submit a paper to a scientific journal. The PhD course started at the beginning of 2002. Four students were selected among the candidates. Two years are reserved to obtain the compulsory credits (courses, papers, training) and to submit to the qualify examination. Then, within two years from that the research has to be finished as well as the writing of the PhD thesis. It is worth to mention, although such procedure was not used still, that a MSc student with a very good performance can be upgraded to be a PhD student.

The Cartographic Sciences program has a very tight link with the other FCT research fields, specially Geography and Maths. Some staff members from the departments of Geography and Maths were enrolled in the program as lecturers and supervisors. By other hand, students from Maths and Geography undergraduate courses were selected to become graduate students. Based on such experience it is expected that with the maturation of the new undergraduate courses (Computer Sciences and Environmental Engineering) a broad range of research should take place at FCT.

There are three main research fields at the graduate programme in Cartographic Sciences:

- Geodetic Positioning (GP);
- Digital Cartography and Geographic Information System (DCGIS);
- Image Computing (IC).

Besides theses main fields, several researchers are engaged in related fields (RF), e.g., maths, statistics, soil sciences, computer graphics, etc. Table 1 presents the staff members of the Master programme, with their main field of interest (IC= Image Computing; GP= Geodetic Positioning; DC = Digital Cartography and GIS = Geographical Information System).

Aluir Porfirio Dal Poz	IC
Antonio Maria Garcia Tommaselli	IC.
Erivaldo Antonio da Silva	IC
João Fernando Custódio da Silva	IC
João Francisco Galera Monico	GP / DC
João Carlos Chaves	GP
Júlio Kiyoshi Hasegawa	IC / DC
Luiz Augusto Toledo Machado	RF
Luiz Roberto Almeida Gabriel	RF
Maria de Lourdes B. Trindade Galo	IC /GIS
Marco Antonio Piteri	IC
Messias Meneguette Junior	IC / GIS
Monica Modesta dos Santos Decanini	DC / GIS
Nilton Nobuhiro Imai	DC /GIS
Nelsi Cogo de Sá	GP
Paulo de Oliveira Camargo	GP / IC
Suetônio de Almeida Meira	RF
Vilma Mayumi Tashibana	RF

Table 1: Faculty members enrolled in Cartographic Sciences programme.

Geodetic Positioning is concerned with researches related to new technologies in this area, specially GPS, GLONASS, besides other systems, as well as the integration of positioning systems. Development and improvement of models and algorithms are the main subjects, besides applications in a wide range of sciences, like environment, meteorology and geophysics. Realisation and implementation of new reference system, including densification of frames, are also topics of investigation in this research field.

The fields of **Digital Cartography and Geographic Information Systems** are concerned with the use of computers for mapping, spatial data representation and spatial analysis. The main topics of interest are: Spatial data modelling; spatial data representation; cartographic generalisation; processing and analysis of spatial data; cartographic visualisation and spatial data quality control.

Image Computing is an umbrella embracing topics related to measurement, analysis or synthesis of digital images. The topics of interest are: development and implementation of mathematical models for Photogrammetry, special techniques and algorithms for image processing and the application of these techniques in Remote Sensing, surface reconstruction, reconstruction with structured light, Mobile Mapping Systems, road extraction, mapping with digital cameras, camera calibration, etc.

The core curriculum of the program (MSc and PhD courses) was designed to provide several different tracks, according to the student field of interest connected to one of the three main fields. The courses to be attended are selected by the student and the advisor considering the project to be developed. Most of the courses presented in Table 2 are offered every year, depending on the number of students and availability of the lecturer. For a MSc student a minimum of 38 credits must be filled by courses and complementary research. For a PhD student with a MSc degree in this field, a minimum of 30 credits must be attended (one credit = 15 hours).

Course	Credits
Linear Algebra and Applications	05
Multispectral Image Analysis	06
Multivariate Statistics	06
Thematic Cartography	05
Computer Graphics	04
Quality Control in Geodetic Positioning	06
Elements of Computer Graphics	04
Elements of Photogrammetry	04
Elements of Geometric and Physical Geodesy	06
Spatial Data Structure	06
Analytical Photogrammetry	06
Digital Photogrammetry	06
Fundamentals of Spatial Analysis	06

Introduction to the Cartographic Sciences	04
Introduction to the Estimation Theory	03
Numerical Methods for Linear Systems	04
Scientific Methodology	04
Satellite Positioning	06
Digital Image Processing	06
Quality of Geographic Data Bases	06
Geodetic Reference Frames	04
Remote Sensing in the acquisition of Spatial Information	05
Geographic Information System	06
Estimation Theory	06
Advanced Topics in Differential Geometry	06
Advanced Topics in Photogrammetry	06
Advanced Topics Digital Image Processing	06
Seminar	--

Table 2: Courses available.

The following laboratories are available for teaching and research during the development of the activities in the program:

- Astronomy, Topography, and Geodesy
- Space Geodesy
- Computer Graphics and Image Processing (two rooms: research and teaching)
- Digital Photogrammetry
- Analytical and Analogic Photogrammetry
- Remote Sensing and Image Analysis
- Photo interpretation

The students have access to modern hardware and software and analogic plotters as well. The main resources are the following:

- IBM Unix workstations with ArcInfo, Spring, and other software;
- IBM PC compatible microcomputers with standard software (compilers, editor, graphic tools, etc..);
- Digital cameras (Kodak DC40, DC210, DC240, Fujix DS300);
- Mutispectral Digital Camera (MS - DuncanTech);
- analog metric cameras (UMK 1318, Phototheodolite and Stereocameras from Zeiss Jena);
- analogic stereo plotters (Wild A10, B8, B8S, Topocart Zeiss Jena, Stecometer Zeiss Jena);
- scanners, digitising tables and plotters;
- Digital photogrammetric Workstation - Socet Set from LHSystems (2 units);
- Dual frequency GPS receivers with commercial and scientific softwares;
- Single frequency GPS receivers with integration to GIS software;
- In house developed software for camera calibration, triangulation, feature extraction, space resection, GPS data processing; Spatial data quality control.

Considering that the research fields are connected, students are working together and are stimulated to use other labs and equipment, including GPS receivers, theodolites, etc.

The program has now a total of 19 scholarships from the following agencies: Fapesp - 5 , Capes - 11 and CNPq - 3.

Several agreements have been signed in order to strengthen the co-operation with private companies, government agencies and international research centres:

- Geomatics Institut - Cataluña, (Spain) - IG;
- University of New Brunswick (Canada) - UNB;
- Technical University of Delft (Holand) - TUD;
- Jet Propulsion Laboratory (USA) – JPL;
- The University of Nottingham (UK) – IESSG;
- IBGE (Brazil - GPS Network);
- IME - (Brazil)
- Embrapa - (Brazil);
- Esteio (Private Company at Curitiba, Pr).

In the last few years, some international visitors have contributed to improve the quality of the program either with lectures and conferences or aiding to establish joint projects:

- Dr. Ismael Colomina (IG);
- Dr. Wolfang Kainz (ITC);
- Dr. M. Stewart (Curtin University of Technology - Austrália);
- Dr. Kees de Jonge (TUD);
- Dr. Ayman Habib (Ohio State University - OSU); and
- Dr. Marcelo Carvalho dos Santos (UNB).

The main projects being conducted in the program are listed in Table 3. Most of these projects are receiving or received grants from research agencies and as a result it is expected that they will generate publications and dissertations.

Project	**Grant**
Mobile Mapping System	Fapesp
Relational Matching	Fapesp
Photogrammetry applied to Archaeology	Cesp
Reconstruction with Structured Light	CNPq and Fundunesp
Semi-automatic feature extraction	CNPq
Mapping with low cost digital cameras	Fapesp
Automatic Road Extraction	Fapesp
GPS Meteorology and Ionosphere modelling	Fapesp
GIS for Precision Farming	Embrapa
Spatial Data Quality Control	Unesp
GPS Kinematic positioning	CNPq
Spatial Technologies for positioning	CNPq

Table 3: Main Projects and Grants on Image Computing

The following tables presents some data concerning the results of the program since its beginning. In table 4 the number of candidates that applied in the program, the number of selected students and the number of concluded dissertations are presented.

Year	Candidates	Selected Students	Concluded dissertations/ thesis
1997	20	11	9
1998	24	10	9
1999	28	10	9
2000	35	10	3
2001	35	12	0
2002	37	14	0

Table 4: Students in the program (July 2002).

Considering 1997, 1998 and 1999 we can see that 4 students did not completed the course. One of the 2000 selected students was transferred to the Geography program. All remaining students from this year are expected to obtain the degree during 2002.

Two students from 2001 did not attend the minimum requirement of the program and were dissociated. In the year 2002, the number of candidates and selected students increased because the first selection of PhD students, which occurred during February 2002, are also considered.

Table 5 shows the students distribution among the three research fields and Table 6 the number of concluded dissertations in the related field.

	1997	1998	1999	2000	2001	2002
GIS	4	4	2	2	3	2
GP	1	1	4	3	2	4
IC	6	5	4	5	7	8

Table 5: Students accepted in the program per area

	1999	2000	2001	2002
GIS	2	5	4	
PG	0	1	3	2
IC	2	2	5	4

Table 6: Number of dissertations per area

In table 7 the number of publications of both researchers and students over the last 3 years are presented. It can be seen that there is an improvement on the number of peer-reviewed papers, a trend that should increase in the forthcoming years.

	1998	1999	2000	2001
Peer reviewed papers	9	8	13	4
Full papers in Proceedings	35	31	42	40
Abstracts	73	55	11	12
Books/Chapters	2	2	5	3

Table 7: Publications of faculty and students.

5. PERSPECTIVES

After 5 years since the beginning, the Cartographic Sciences Graduate programme has increased its number of grants and scholarships and the PhD course started in the begin of 2002. A challenge for the staff involved is to improve the level of the research being conducted in order to publish their results in international peer reviewed journals and to strength links with private companies and other research organisations. An example of this profitable co-operation is the project of precision farming, that is being leading by Embrapa with several staff members and students involved in the project.

In the forthcoming years, with the new undergraduate programmes of Environmental Engineering and Computer Sciences it is expected to create new areas and opportunities of research due to the proximity of these fields with Cartography and Geomatics.

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