Some Aspects of Geospatial Education in Technological Universities

Eugene LEVIN, Alfred LEICK and Robert LIIMAKKA, United States

Key words: Surveying curricula developments, International knowledge exchange, e-Learning

SUMMARY

There is a large and growing societal need for scientists and engineers with advanced training in the geospatial technologies. In particular, there is a recognized need in different disciplines to gather, analyze and interpret geographically referenced spatial information data. Powerful new research and technological tools for addressing these problems require undergraduate and graduate-level training in the geospatial sciences for their effective use. This paper focuses on educational aspects and analysis of Michigan Technological University’s Geospatial Initiative. Developed by the Surveying Engineering program, the Geospatial Initiative has led to multiple educational collaborations at Michigan Tech University, resulting in new undergraduate and graduate educational programs promoting geospatial professions and skills campus-wide. Moreover, the Initiative includes collaboration by National (University of Maine) and International (Technical University of Israel, Siberian State Geodetic Academy, AVAProEDU Finland) institutions currently involved in geospatial education and research. Much of the educational curriculum is comprised of a developed online component. Coursework can be delivered worldwide in an effort to target and encourage students nationally and internationally. It also can be useful for continuing education of geospatial professionals worldwide. This paper describes the above mentioned activities in more detail.
Some Aspects of Geospatial Education in Technological Universities

Eugene LEVIN, Alfred LEICK and Robert LIIMAKKA, United States

1. INTRODUCTION
Sustainable development of the society greatly depends on availability and credibility of geospatial data. Terrabytes of geospatial data and metadata about the Earth are acquired using different sophisticated sensors and instruments such as global navigational satellite systems, aerial and satellite panchromatic and hyper-spectral remote sensors, hi-precision optical-electronic surveying instruments, laser scanning systems, radars, sonars, etc. This data help scientists from many different disciplines such as geology, volcanology, forestry, agriculture, social sciences, demography, history, political science, etc., to study diverse aspects of the Earth and human phenomena. All these disciplines use this data and technologies as a supplementary tool in their research, but geospatial data acquisition and processing is an applied science and technology by itself. The roots of these technologies are embedded in the geodetic sciences of photogrammetry, cartography, surveying and topographic and thematic mapping. Featured with new technological development in optics, electronics and computing, these roots emerge into a new blend of applied science – integrated geospatial technologies. Terrestrial and airborne laser scanning systems are widely used to get 3D models of object, high-resolution satellite imaging sensors provide multi- and hyper-spectral video data which allow the user to investigate spatio-temporal and physical properties of objects on the Earth, Ocean and Atmosphere; Global Navigation Satellite Systems provide real-time accurate geo-positioning and navigation data to define precise location of objects not only on the land surface, but any features on and under water, including man-made and wildlife creatures tracking. In many cases the same geospatial product such as a Digital Terrain Model, can be created by different techniques. To achieve desired results professionals need to predict and varify the spatial and semantic accuracy of the final product. They also compare different techniques and approaches, estimate technological and financial efforts as well as manpower. Planning data acquisition process, balancing errors and accuracies, combining and optimizing different technologies for data acquisition and adjustment require truly integrative, professional knowledge and skills in different areas of expertise in quantitative geospatial techniques and technologies. This paper describes an integrated approach to geospatial education to achieve the goal of expert training and professional knowledge.

2. MICHIGAN TECH GEOSPATIAL INITIATIVE AT GLANCE
Geospatial is a term widely used to describe the combination of spatial information software and analytical methods with terrestrial or geographic datasets. The term is often used in conjunction with geographic information systems, surveying engineering and geomatics. Sub-disciplines in geospatial sciences and technologies are: geodesy, land surveying, photogrammetry, cartography and GIS. Geospatial technologies employ Earth observation systems, global navigation satellite systems, laser and radar imaging sensors, optical-electronic measurement systems, computer geo-visualization and analysis systems, mathematical and statistical data processing, real-time data acquisition networks, wireless and
Internet technologies.

Fundamental Geospatial sciences include: theory of the Earth shape, geodynamics, global positioning systems, mathematical cartography and projections; planetary and outer space spatial sciences. The most important applied geospatial sciences from a surveying perspective cover: Earth observation systems, optical, laser and radar imaging sensors, GPS networks and systems, wireless and mobile data collection technologies, spatial data visualization, distributed geo-networks and data repository, geospatial data compilation, updating and fusion, automated image classification and feature extraction, geospatial data mining, knowledge and expertise in elicitation and transfer, industrial surveying, emergency response surveying, land surveying and land monitoring.

There is little question that the geospatial information enterprise is large and growing. Absent a standard industry definition, however, estimates of the size of the enterprise have varied. Technology market research firm Daratech [Daratech, 2009] estimated that worldwide sales of GIS software, services, data, and hardware totaled $1.84 billion in 2003. The American Society for Photogrammetry and Remote Sensing’s (ASPRS) survey of the “remote sensing and geospatial information industry” led it to estimate 2010 industry revenues at $2.4 billion, and to predict growth to more than $6 billion by 2012 [Mondello, Hepner, & Williamson, 2006]. The National Aeronautics and Space Administration (NASA), in consultation with the Geospatial Workforce Development Center at the University of Southern Mississippi, estimated that the U.S. “geospatial technology” market would generate $30 billion a year by 2005—$20 billion for remote sensing, $10 billion for geographic information services [Gaudet, Annulis, & Carr, 2003]. This most optimistic prediction, based on an expansive conception of the geospatial information industry that includes remote sensing, GIS, and global positioning system technologies, has since been adopted by the U.S. Department of Labor [U.S. Department of Labor, n.d.]. Environmental Systems Research Institute (ESRI), which along with Intergraph accounts for nearly half of the worldwide GIS software market, estimated in 2000 that 500,000 individuals in the U.S. use its software products as part of their jobs, and that some 50,000 individuals work as full-time GIS specialists (Phoenix, 2000). Longley and colleagues estimate that there are some four million GIS users worldwide, working at some two million sites [Longley, Goodchild, Maguire, & Rhind, 2005]. Whatever the actual size of the geospatial information workforce, it is clear that there is a great demand for individuals with a strong geospatial background to support the industry’s growth.

Because of the varied definitions, broad scope, and rapid evolution of the geospatial enterprise, reliable information about the size and composition of the geospatial workforce is difficult to obtain [Ohio State University, 2002]. A few telling estimates do exist, however. ASPRS estimates that about 175,000 people are employed in the “U.S. remote sensing and geospatial information industry” [Mondello, Hepner, and Williamson, 2004].

In 1998, Duane Marble published an influential critique of the “low-level, non-technical” character of GIS education in undergraduate degree programs [Marble, 1998, p. 28]. “Existing GIS education,” Marble claimed, “fails to provide the background in GIScience that is necessary to meet the needs either of the users of GIScience technology or of the scientific
community engaged in basic GIScience research and development” [Marble, 1999, p. 31]. Unlike students in the early days of GIS education, when the primitive state of the technology necessitated programming skills, Marble pointed out that latter day students and some instructors believe that all one has to do to become a GIS professional is to master the standard functions of commercial off-the-shelf (COTS) software. Thus, graduates are no longer prepared “to make substantial contributions to the ongoing development of GIS technology” [Marble, 1998, p. 1]. Advanced knowledge and skills in computer and information sciences are needed more than ever, he argued, to realize the full potential of GIS&T.

Very few higher education institutions in the United States offer baccalaureate degree programs focused specifically upon Geospatial technologies and GIScience per se. [Berdusco, 2003] identified about 425 higher education institutions worldwide (about 260 U.S.) that offer formal certificate, diploma, and degree programs in GIS and GIScience. Of the 28 U.S. universities listed as offering undergraduate degree programs in GIS, all but four in fact offer B.A. and B.S. degrees in geography (nineteen programs), Earth science, environmental science, natural resources, or forestry, with concentrations, specializations, tracks, or undergraduate certificates in GIS, GIScience, cartography, and related topics. For the same reasons that the geospatial workforce is diffused among many industries in every employment sector, geospatial activities tend to be widely dispersed and poorly coordinated on four-year college campuses. Within academic programs, courses involving geospatial technologies are often positioned as intermediate or advanced technical specialties with prerequisites and class size limits that pose barriers to enrollment.

Considering the need for an increased professional pool in the field of Geospatial Technologies, the department of Surveying Engineering envisions its **ultimate strategic goal by developing a highly skilled workforce, well educated and equipped to lead the development of Geospatial Information Technology on the cutting-edge scientific and technological level.**

The program’s long-term goal will be accomplished by integrating three essential features: expert-led, self-paced, and collaborative efforts through achievement of the following objectives:

1. Consolidate (integrate) geospatial capabilities throughout Michigan Tech institutions by establishing the Michigan Tech Geospatial Consortium
2. Reinforce research in Geospatial sciences, technologies and applications
3. Strengthen and expand undergraduate and graduate programs in Geospatial sciences and technologies

To address these goals and objectives the Surveying Engineering department in the School of Technology proposes to create an Inter-disciplinary Geospatial Task Force (IGTF) to develop a framework for the Michigan Tech Geospatial Initiative by **establishing an Integrated Geospatial Technology Center of Excellence (IGTCE)** at Michigan Tech.
The primary purpose for establishing this Interdisciplinary Geospatial Task Force is to facilitate an interactive dialog. Interested stakeholders throughout Michigan Tech subdivisions will promote and collaborate on future trends and issues in Geospatial sciences and technologies that address the Michigan Tech strategic development plan and also develop the work plan for implementation of IGTCE. The successful outcome of the Geospatial Task Force will be based upon a coalescence of the needs and directions of a diversified group of research, teaching and service subdivisions within Michigan Tech working together in their respective communities to develop a pragmatic approach for establishing and successive implementation of the Michigan Tech Geospatial Initiative for Sustainable Development and Environmental Stewardship. IGTCE structure is based on three integral components: research, education and consultancy.

Michigan Tech innovative Strategic Faculty Hiring Initiative makes it possible to attract world-class researchers and faculty to establish Michigan Tech Integrated Geospatial Technology Center of Excellence for research in applied geospatial sciences, technologies, emergency surveying and mobile mapping. The center will play the key role in development of the cutting edge geospatial sciences and technologies and will bring Michigan Tech at the leading position as the world-class excellence research institution. GIScientists lead research and development efforts at GIS software firms, government agencies, and in universities. Academic GIScientists are also responsible for recruiting, training, and mentoring the next generation of researchers who will advance the capabilities of geospatial technologies in the future. Research-based, multidisciplinary graduate education in GIScience prepares students to master the technical, analytical, business, and interpersonal competencies needed to play leading roles in research and development, system analysis and design, and application development [Saalfeld, 1997]. Graduate education can also promote adoption of spatial analysis and geographic modeling among the various disciplines that employ geospatial technologies.

Teaching at undergraduate, master and doctoral levels is an inherent part of the Michigan Tech Geospatial Initiative. Section 3 of the current paper comprises detailed description of the educational component.

Michigan Tech employs state of the art surveying measurement equipment and software applications for data acquisition. Professionally certified or licensed faculty and staff will provide consulting to Michigan Tech subdivisions and external entities in land surveying, industrial surveying, and emergency response, mobile mapping, GPS mapping, cartographic mapping, map design, geospatial data compilation and analysis.

The combination of all three initiative components will make it possible to provide education, training and ongoing research to an ever growing geospatial industry and practitioners.
3. INTEGRATED GEOSPATIAL TECHNOLOGY EDUCATION: IMPLEMENTATION ASPECTS

The general diagram of existing and forthcoming geospatial degrees is presented on Figure 1.

![Diagram](image-url)

**Figure 1.** Structure of Michigan Tech degrees in Geospatial Science, Technologies and Informatics

Such a degrees structure follows from multidisciplinary nature of educational effort described. Current status of degrees development for the time of current paper submission is following:

Undergraduate geospatial degrees -
1. BS in Surveying Engineering (existing)
2. BS in Geospatial Engineering for Engineering Students (existing)
3. Minor in Surveying Engineering for Natural Sciences Students (under development)

Graduate degrees -
1. MS and Certificate in Integrated Geospatial Technologies (under development)
2. MS in Geospatial Applications and GIS (to be developed)
3. PhD in Geospatial Sciences (to be developed)
4. PhD in Geoinformatics (to be developed)

Michigan Tech has already demonstrated success in its ability to put together interdisciplinary PhD programs that are housed within the Graduate School and allow faculty from multiple disciplines to work together, across traditional disciplinary boundaries and departmental structures. To develop the new PhD programs it is necessary to: 1) bring together a group of colleagues from multiple disciplines; 2) build bridges between traditional administrative units that will allow scientists and students from multiple disciplines to learn from one another; 3)
lay the framework that is necessary for new knowledge to develop at the intersections of the different disciplines. For the current initiative implementation we are collaborating with departments of electrical engineering, mechanical engineering, cognitive and learning sciences, civil engineering, forestry and geology. Moreover, collaborators from another U.S. and international universities are involved as it is described in the following sections.

3.1 GPS-GAP as e-learning and continued education tool

GPS-GAP (GPS, Geodesy and Application Program) consists of undergraduate and graduate courses covering the areas of adjustments, 3-dimensional geodetic model, conformal mapping, and geodetic-quality relative positioning and precise point positioning with GNSS (Global navigation Satellite Systems). The course material is mathematical in nature and algorithmically and geodetically correct and complete. Many computational laboratories use actual data, such as pseudoranges and carrier phases, and instructor-provided software which is fully available to students. The latter frees learners from the constraints of commercial software and offers the possibility of in-depth experimentation. Asynchronous and iterative learning strategies tightly integrate the textbook *GPS Satellite Surveying*, PowerPoint presentations with audio and Mathcad solutions with audio. The courses are available via the Internet using WebCT/Blackboard technology. Using Skype for free communication and Microsoft Shareview to share views of computer screens makes for a truly unique learning environment which is location-independent as to student and instructor and which lends itself naturally to individualized instruction.[GPS-GAP] Iterative learning is implied through the student’s ability to repeatedly view the lectures and other material, in particular the quiz questions. The quiz questions, indeed, are an important and integral part of the iterative learning strategy in GPS-GAP. The complete contents of the courses, i.e. mathematical derivations, final expressions, numerical values and considerations, theoretical concepts, figures, Mathcad source code, rules of thumb and so on, are subjects of quiz questions. The questions are presented in form of graphical images which make it possible to create powerful composites, e.g. combining equations and figures, equations and text, equations and Mathcad code, etc.

![Figure 2. GPS-GAP Interactive e-learning strategy](image-url)
Following the iterative learning strategy outlined in Figure 2, the student first listens to the lecture and the Mathcad implementation, perhaps even experiments with live Mathcad solutions available from the dedicated server or with his/her own solutions, and studies the quiz questions. If the student does not feel ready to take the quiz he/she can listen to the lecture again, study the quiz questions once more, and repeat this cycle until comfortable to take the quiz. This iterative approach assures that the student does not overlook the mathematical detail and the finer points presented in the lecture, because the quiz questions are a subtle reminder of what has been missed.

3.2 Practical steps towards geospatial research-based education
Integrated approach to geospatial education requires can be realized in optimal way when it is based at research-oriented multidisciplinary environments. Michigan Tech faculty team deploys various aerial and mobile research programs and platforms, as it is depicted on Figure 3

![Small UAV (SUAV) and CHrisler PT Cruiser based mobile research platforms at Surveying Engineering Program of Michigan Tech](image)

Michigan Technological University is implementing a number of remotely controlled aircraft platforms in its photogrammetry course. The Surveying Engineering Program is working on a SUAV suite configuration that will make the following hands-on labs possible: project planning and potential accuracy analysis, implementation of project waypoints into the SUAV operational control unit, auto-pilot flight control over calibration sites and test-objects, and processing of gathered UAV imagery on softcopy photogrammetric workstations. The initial SUAV is equipped with autopilot and can carry up from 1 to 11 pounds of payload, and is
currently fitted with a 7.1 and 12 MP non-metric cameras. Students use surveying grade GPS equipment to prepare calibration sites. Processing of the obtained datasets encompasses: bundle block adjustment, image co-registration, mosaicking, and finally feature extraction from UAV imagery. Comparison of the results obtained from the SUAV to respective results obtained from traditional aerial photogrammetry will provide an excellent opportunity for research investigation directed at accuracy and applicability of SUAV imagery for specific projects. Practical hands-on experience with SUAV control and imagery provides students a unique opportunity to participate in ongoing development and research activities in the geospatial science and industry.

The PT Cruiser based mobile research platform is a research project in progress equipped with a combination of GPS, LIDAR and imaging sensors. The mobile platform will be used as a mobile lab for anticipated research projects and as a tool for upper level field labs conducted off-campus. Preliminary results of the mobile platform research that was used for scanning of Winter Carnival snow statues are given on Figure 4

![Three dimensional presentation of snow statues scanning by means of Michigan Tech mobile research scanning platform.](image)

This research project was performed by Surveying Engineering students using a Trimble GX 3D Scanner platform. Work on a permanent sensor configuration for a mobile mapping research platform is in development.

We strongly believe that the most efficient educational output of multidisciplinary research approach is that geospatial students are learning to work with students of another engineering specialties as a team.
Strong emphasis is also placed on interdisciplinary research projects. Surveying engineering students are learning to work in teams with students from other engineering disciplines. For example, SUAV research is performed as a mutual project with mechanical engineering’s aerospace student enterprise. As a result, during interdisciplinary research projects described surveying engineering students are applying skills and knowledge of geodesy, GPS, photogrammetry and GIS. Project planning and management skills will serve also as useful assets in their future careers.

3.3 National and International collaborations

The surveying engineering program is a small entity at the moment. As such, one way of making the integrated geospatial technology educational approach grow to full fruition is collaboration with other universities. Dr. Alfred Leick of the University of Maine contributed to the program with GPS-GAP and other high level geodesy courses. Dr. Yerach Doitsher of Technical University of Israel (Technion) also contributed three geospatial courses to support integrated geospatial technology educational initiative.

Michigan Tech University also recently signed an agreement of academic cooperation with the Siberian State Geodetic Academy in Russia. This academic agreement assumes the following activities:

- Exchange of scholars
- Facilitating joint research projects
- Creating joint research networks
- Co-sponsoring of/participation in workshops and/or conference days
- Facilitating joint preparation and publication of articles on topics of mutual interest
- Exchange of students.

National and international collaborations appear to be a reasonable solution for the geospatial programs which do not have the internal resources to deliver graduate education. This collaboration is considered a core vehicle in implementing integrated geospatial technology education and research.

4. CONCLUSION AND FUTURE ACTIVITIES

Future developments, research and curricula will be devoted to the finalization of the mobile mapping and SUAV data acquisition processes within GIS and 3D visualization environments. Moreover, applying various spectral filters may develop a valuable potential for remote sensing studies. For instance, infrared filters may be used for wildfire detection and prevention, etc. Fusion of the UAV imagery with aerial and satellite data opens another opportunity for graduate and post-graduate research.

Increased support for programs like IGTCE is needed to increase the capacity of research-based graduate education, which in turn is needed to “rebuild the top of the pyramid” – effective and cutting edge research in geospatial sciences and technologies. Michigan Tech

TS 9G - Quality in Surveying Education
Eugene Levin, Alfred Leick and Robert Liimakka
Some Aspects of Geospatial Education in Technological Universities

FIG Congress 2010
Facing the Challenges – Building the Capacity
Sydney, Australia, 11-16 April 2010
experience in integrated geospatial technologies research-based curricula development can be applied by many technological universities worldwide.

REFERENCES


GPS GAP: http://www.gnss.umaine.edu/e-material.htm


Ohio State University (2002). Geographic information science and technology in a changing society: A research definition workshop. Columbus, OH: Center for Mapping and School of Natural Resources.


BIOGRAPHICAL NOTES
Eugene Levin is Surveying Engineering program Chair and Assistant Professor at School of Technology of Michigan Technological University. He received M.S. degree in astrogeodesy from Siberian State Geodetic Academy in 1982 and Ph.D in photogrammetry from Moscow State Land Organization University in 1989. Dr. Levin is ASPRS and SPIE member, ASPRS Certified Photogrammetrist. He is regional ASPRS director for Michigan UP. Dr. Levin held multiple research and managing positions for both academy and geospatial industry in Russia, Israel and United States. He served as principal investigator in multiple award-winning government programs. Eugene Levin is author of many peer-reviewed papers and conference presentations.

Alfred Leick Alfred Leick (Ph.D. - Ohio State University, Department of Geodetic Science) is the author of the book GPS Satellite Surveying (J. Wiley, 1990, 1995, 2004), Editor-in-Chief of the peer-reviewed journal GPS Solutions (Springer Verlag), and author of numerous technical publications. He has been teaching at the University of Maine in the area of GPS (Global Positioning System), Geodesy, and Estimation since 1979, and is the program coordinator of GPS-GAP (www.gnss.umaine.edu). Dr. Leick launched his GPS research in 1982 when he tested the prototype Macrometer satellite receiver at M.I.T. He carried out GPS research the Air Force Geophysics Laboratory (Cambridge, Massachusetts) in 1984/85 (1 year), the University of Stuttgart in 1985/86 (1 year), 3S Navigation (Los Angeles, California) in 1996, and the Jet Propulsion Laboratory in 2002 (6 months each). He is a Fellow of ACSM (American Congress on Surveying and Mapping).

Robert Liimakka is Assistant Professor and Co-Chair of the Surveying Engineering program at Technology of Michigan Technological University. He received his BS in Land Surveying from Michigan Technological University, M.S. in Spatial Information Science and Engineering from the University of Maine and is currently writing his dissertation for a PhD in Civil Engineering from the University of Maine. He is also a licensed professional surveyor in multiple states.

CONTACTS

Eugene Levin
Michigan Technological University
4216 EERC Building, 1400 Townsend drive
Houghton, MI 49931
USA
Tel. +1-906-487-2446
Fax + 1-906-487-2583
Email: elevin@mtu.edu
Web site: http://www.tech.mtu.edu/Faculty_Pages/Eugene_Levin.html

Alfred Leick
University of Maine

TS 9G - Quality in Surveying Education
Eugene Levin, Alfred Leick and Robert Liimakka
Some Aspects of Geospatial Education in Technological Universities

FIG Congress 2010
Facing the Challenges – Building the Capacity
Sydney, Australia, 11-16 April 2010