GIS EDUCATION TODAY:
FROM GI SCIENCE TO GI ENGINEERING

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ABSTRACT

Discussions about GIS Education should not only include methodological and technological aspects, they have to focus on content. Nowadays, there seems to be a trend from 'Big GIS', as built and used by large organizations, to 'Small GI' enterprises selling small pieces of information to individuals. GIS Education needs to adapt to this trend by extending its content to include legal and business aspects regarding geographic data. A GIS Education model based on three pillars, Geo, Info, and Business, is therefore proposed. It is further argued that curricula have to move from a GI Science perspective to a GI Engineering approach to satisfy industrial demands for the required skills of graduates.

INTRODUCTION

The educational programs and teaching methods must always be adapted to the current situation: The methods must use the best technology to help students learn and the content must cover what graduates need to know after graduation. There is an extensive debate on the best use of modern technology for education at all levels – for example, various methods from Virtual Field Trips (EUGISES 2000) to distance learning using the WWW (Johnson 2000) were discussed during the recent 2nd European GIS Education Seminar (EUGISES 2000) in Budapest. However, the technology discussion must not distract us from the primary concern in education: What should students learn?

The discussion about the content of GIS education is not new. Efforts include the development of the NCGIA core curriculum (Kemp 1990), a Delphi study to identify the expected knowledge and skills for GIS managers (Kemp *et al.* 1993), and a dialogue between potential employers from industry and major user organizations (Timpf 1998). Similar debates were held in other countries. It seems that based on these discussions a standard curriculum content, which is covered in most new textbooks on GIS such as DeMers (1999), Bernhardsen (1999), Burrough and McDonnell (1998), or Worboys (1995), has evolved.

Growth of standard GIS applications is slowly approaching saturation; convincing the state agencies of the need for new GIS installations is hitting empty state funds and a general trend towards lean governments. There is, however, a trend to GIS in commercial applications, which is rapidly gaining steam. This new use of commercial GI is – as most efforts in the 'new technology sector' – limited by the number of well-educated and competent professionals available.

The main argument in this article is that the commercial use of GIS has a different quality than the traditional uses we have seen in the past decades. We will contrast the traditional

'Big GIS' with the new commercial 'Small GI' and discuss the knowledge and skills of the professionals who will make this new trend a reality.

THE CHANGE IN THE GIS FIELD: FROM 'BIG GIS' TO 'SMALL GI'

In the past, GIS were mostly built for and used by large organizations, which needed spatial information on a regular basis to make decisions. These organizations collected the necessary data, managed them in their own databases, and produced reports and maps for various internal uses. The cost-benefit analysis is notoriously difficult within a single organization – it is difficult to assess how much a service contributes. The planning of systems was usually more influenced by internal politics than deep analyses of requirements or business reengineering (Hammer 1990). Numerous experiences show that the systems are beneficial to the organization, but often not for the reasons they were originally designed for. Typically, a cost-benefit analysis shows benefits in the form of a reduced workforce, but actual implementation later demonstrates that the major benefits lie, for example, in better and faster services to the customers.

We want to contrast such systems built for public utilities, towns and regions for planning purposes, highway departments etc., with GIS established by service providers, who build a GIS and collect the necessary data in order to sell the information produced with the system to many users in small quantities. We call this 'Small GI', because the amount of information sold in each particular case is very small. It is clear that the GIS are not necessarily smaller or require less data collection and management than 'Big GIS'. The difference lies in the separation between the organization that operates the GIS and the user who uses the Geographic Information (GI) produced.

'Small GI' is a commercial enterprise: the service provider is paid to operate the GIS. His income comes either from the users of the GI to which it is sold, or it is paid by some other organization, which benefits indirectly from the GI. For example, there are location-based services, where hotels, restaurants, etc. are willing to pay a fee if potential users are efficiently informed about their location and their offerings – this is advertising in a new, more direct form.

The trend to 'Small GI' service providers is advanced by people's increased need to acquire spatial information. In the past, most spatial information was found in the environment when needed, learned over the course of a lifetime and never paid for. In our world of high mobility we often find ourselves in unfamiliar environments. In order to plan our activities ahead we have to acquire the information before actual travel. Consider, for example, a business trip using different modes of transportation where the traveler needs to know in advance the connection times to meet an appointment in time. At the same time, our environment is transformed by new construction and transportation technology, which makes navigation more difficult: Common sense is not sufficient any more and counter-intuitive moves are often necessary to reach a goal.

Providing spatial information is becoming a business, which it not used to be. To estimate the size of the market for GI one can start with the well known statement that 80% of all decisions are in some way spatial (Albaredes 1992) and combine this with the observation that in all cases, where the benefits of GI can be assessed economically – for example, in the use of GI for routing – efficiency increases of about 20% are observed. This suggests that up to 16% of the Gross National Product is created from GI – an enormous market potential, which can only be realized over a long period of time.

'Small GI' produces Geographic Information for sale to others. The value of the information to the potential clients must be larger than the price charged (Krek and Frank 2000). Business with GI was very difficult in the past. If the only distribution channel for geographic data is in the form of paper maps, a 'just in time' delivery of information is not possible. Mobile phone technology creates the channel through which the required information can be transported to the user on demand and just in time. Mobile phones and Personal Digital Assistants are the first step to computer systems, which can be carried around all the time – see also wearable computers at MIT (2000).

There is a great number of possible application areas: services to inform potential clients of the locations of hotels, restaurants, cultural sites, etc., but also specialty stores, automatic teller machines, etc. (Kottman 1998). The combination of Yellow Page information with location based technology opens attractive opportunities for businesses. But there are also services for assisting people in the process of buying or renting a new home or apartment, and information providers for users of public transportation systems. This latter case will be used in the next section to give a concrete example for such an application, which is technically feasible today.

INFORMATION FOR USERS OF PUBLIC TRANSPORTATION SYSTEMS

The user of public transportation requires surprising amounts of information. Most people are habitual users and have acquired this information once and use it then on a daily basis. They are never aware of how much detailed knowledge they have. One is painfully aware of the information needs when arriving in a foreign country and trying to use the public transportation system – constantly asking for help, often to no avail, because of a lack of knowledge of the local language. Similarly, handicapped persons – especially blind people – have a difficult time using the public transportation system because they cannot acquire the necessary information about the spatial environment through visual perception (Golledge *et al.* 1998). We can state the following information needs for users of public transportation systems:

- Information must be collected to make a routing decision and to decide which transportation service is used for which part of the journey.
- Knowledge about tickets and reservations is necessary.
- Knowledge of exact location of departures points, but also about where to buy tickets and make reservations, is needed.

In the modern world we live in, the friendly and usually helpful person in the ticket office is being increasingly replaced by ticket vending machines, which pose interesting challenges to the user: instructions are often only in the local language; payment is accepted only with a restricted set of local currency tokens; etc.

More user-friendly and therefore better systems are feasible today: Let us assume that a traveler has booked an airplane ticket and a hotel through a travel agent. After arrival at the airport and claiming his baggage, he is informed through the Global System for Mobile communication (GSM) phone about the best route to his hotel and all necessary information to carry out this trip is provided step by step. It is not effective to deliver all the information ahead of time and in printed form, because this is not flexible enough: new instructions due to wrong actions of the user or changes in the environment (for example, air planes and trains being late) are not possible; also, the memory of the traveler is not sufficient to remember all of this information, which is only useful for a single decision at a particular moment in time. Only for trips we do often, we are willing to invest time and energy in the learning of the route – for all other trips we navigate as good as we can without learning.

Using GSM, we can also help the traveler with the necessary tickets – ticketing using mobile communication is working today with the Austrian Railway System (for further details in German see http://www.oebb.at/special/14.html) and it is expected that ticketing in all forms (for rail, public transportation in cities, movie theaters, etc.) will be an interesting business aspect of future mobile communication systems.

With Information Technology it is possible to guide a user continuously on his trip and provide all information just in time and accurately for the situation of the traveler (Figure 1, Figure 2), even if mistakes are made and parts of the transportation systems malfunction. We can save the traveler all efforts to collect the necessary information. For the short trip from Vienna International Airport to a hotel in the city, we observed that from a total time used of 70 minutes, 30 minutes were caused by information collection (Pontikakis *et al.* 2000). The value of the information is certainly a reasonable percentage of the cost of the ticket (in this case $ 6.50) – say $ 1.00 to $ 2.50. Every day about 16.400 visitors arrive at the airport and if only 10 percent use the information service, then the service provider's income will be approximately $ 600.000 to $ 1.500.000.

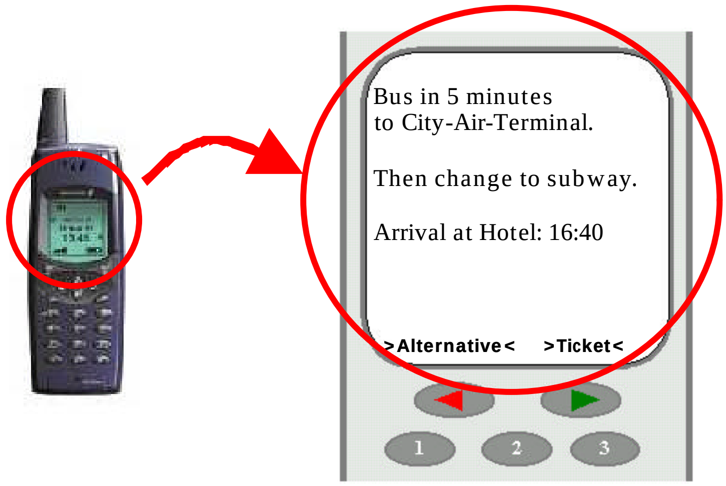

Figure 1: Information on modes of transport through WAP service.

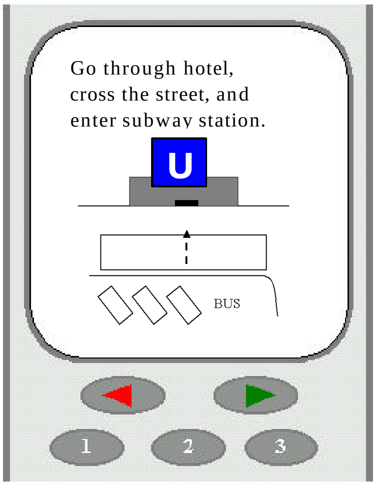

Figure 2: Information on how to go from the City-Air-Terminal to the subway station.

This is only an example – many other uses of GI are possible – all leading to the same business structure: A service provider collects data (often, most of the data is already collected or can be acquired from another GIS operator) and provides a pay-per-use service (Wenzl 2000), passing out small pieces of GI to users exactly when and where they need them. The fee must be less than the value of the GI for the user. To advance such business, competent GI specialists must set up the GIS, design the user interfaces, organize the business, and be aware of legal issues such as privacy and copyright of data. In the next section we look at the question of what knowledge and skills these professionals need to have.

EDUCATION NEEDS

Graduates must be equally prepared for 'Big GIS' and 'Small GI'. The content we have taught in the past enabled graduates to establish GIS, and to collect and manage data for organizations, which operate their own GIS. These skills continue to be important for the service providers in the 'Small GI' business. In addition to technical questions, the integration of data from different sources becomes more important and limits to meaningful combinations require attention. Data quality (Goodchild and Jeansoulin 1998) and how it translates to quality in the produced GI becomes a central issue in a business, where clients buy information for a fee and expect quality. Furthermore, customers may even have some liability claims (Perritt jr. 1996) if the information was grossly and negligently wrong.

For such demands a GI Science curriculum is not sufficient. In this section we show the content dimension and in the next section we discuss the difference between a science curriculum and an engineering approach. Discussion with industry has led to a curriculum design, which is based on three pillars (Figure 3):

Geo

The Geo pillar should give students a thorough feeling of how spatial situations can be observed, measured, analyzed, and represented. It therefore includes the fundamental concepts of physical and human geography – primarily the concept of processes in space – but also the understanding of spatial data collection, e.g., surveying, photogrammetry, and remote sensing. Not only do we have to model and analyze spatial processes, we also have to communicate the results. Digital Cartography, another component of the Geo pillar, deals with principles of spatial visualization.

Info

Graduates must be knowledgeable of modern information technology and have the necessary skills to use it. This includes knowledge of programming languages and database technology, principles of user interface design and the organization of information systems. Furthermore, students have to learn different aspects of networking and mobile technologies (see also section 3). The special problems of spatial information – spatial indexing, computational geometry, etc. – must be known. Graduates also need to understand information science – the logical structuring of information, the assessment of data quality, and the problems of integrating data from different sources and potentially different semantics.

Business

It is not sufficient that our graduates know how to technically build GIS. The GI professional must understand the principles of marketing, understand the user needs and see how they can be satisfied. Knowledge about the connection between technology and marketing is vital for the success of a 'Small GI' enterprise. Furthermore, we have to teach students the principles of e-commerce so that they know about mechanisms for collecting user fees, the organization of help desks and their costs, advertisement, etc.

Legal aspects concerning information systems and data are another major component of the Business pillar. Nowadays, the majority of data is transmitted electronically, collected by someone, distributed by somebody else, and used by yet another one. This procedure is very sensitive to legal aspects, such as privacy rights, copyright of data, or legal liability (Perritt jr. 1996). Graduates must not only know about the legal impacts on the use of databases and spatial datasets, but also about legal options to deal with conflicts (Onsrud and Rushton 1995).

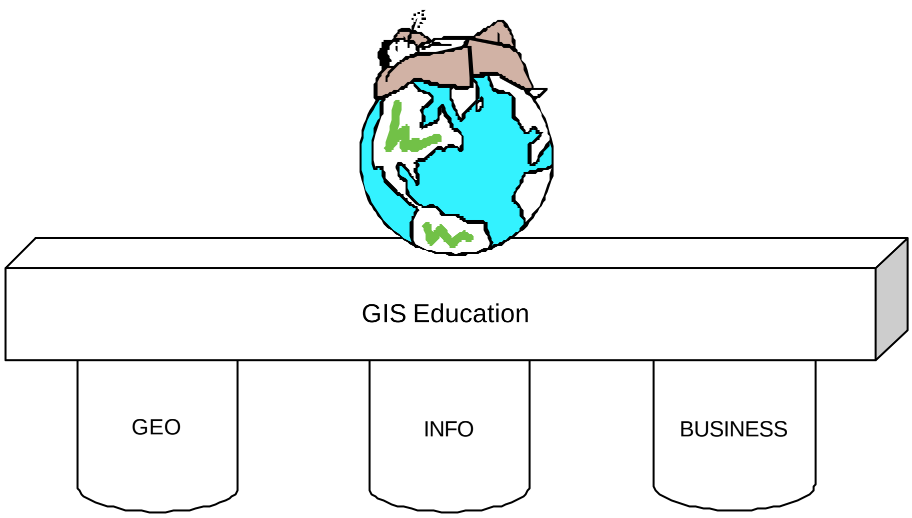

Figure 3: Education of a GI Professional is based on three pillars: Geo, Info, and Business.

Figure 4 shows our proposed curriculum in a generic form (details are available at http://www.cti.ac.at/fhk/geo/). It is a ‘German-style’ four-year program (after high school) and does therefore not contain any general knowledge areas such as in U.S. undergraduate programs. Students will acquire a practical degree – comparable to a non-thesis M.S. degree – leading them to professional practice. We propose this curriculum to add a sizeable chunk of business related teaching – from business law to marketing –, because industry leaders have assured us that successful engineers are more and more required to understand the business implications of technical solutions or find technical solutions for business opportunities. Integration is only achievable if one person can oversee the project – possibly asking specialists to contribute their individual pieces.

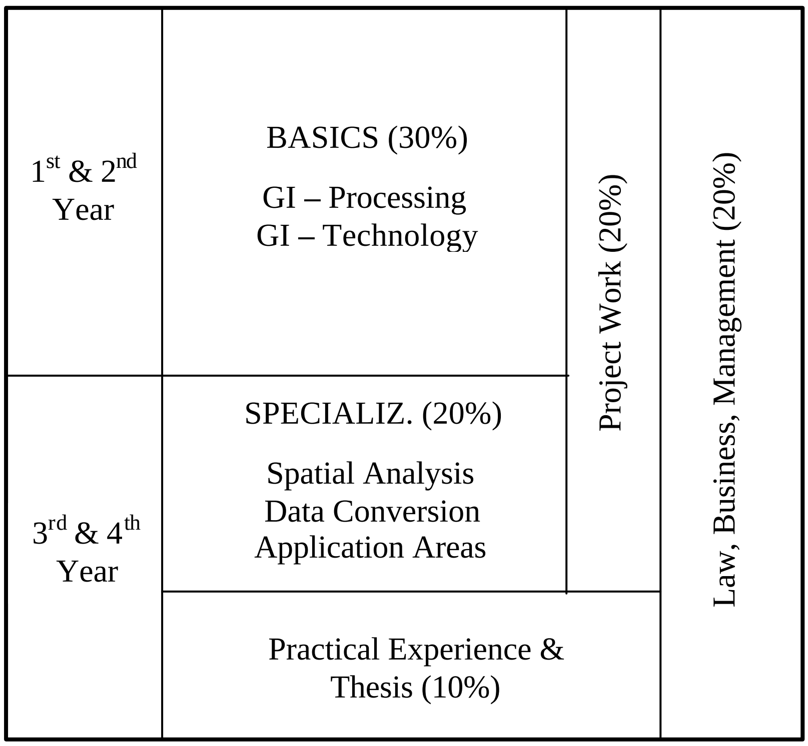

Figure 4: Generic model curriculum.

Education is a ‘zero sum game’: Adding content is only possible if we reduce content at a different front. Industry is clearly telling us that they want ‘young graduates’ and adding more years to the curriculum is not an option we should consider! In the next section, we will argue for an engineering approach and thus reduce the length of the study program compared to a scientifically oriented program.

FORM: ENGINEERING INSTEAD OF SCIENCE

Let us start with an explanation of how we understand engineering and science: Science is the search for knowledge – new knowledge, to be precise – and engineering is the systematic application of the results of scientific research to solve real-world problems in a predictably successful way. The outcome of a scientific experiment cannot be guaranteed. If we know for sure what the result will be, then it is not a meaningful scientific experiment. An experiment, which does not confirm the hypothesis, is as valid as one that does. The outcome of an engineering project must predictably work: Engineers build bridges and only very seldom a bridge fails. Failures are not acceptable and are definitely detrimental for the engineers' careers! Engineering 'reduces to practice' the results of scientific research. Scientific laws are combined with the results of long-term experience with useful guidelines, which codify the state of the art as standards, which engineers follow.

Many GIS courses are situated in scientific geography or computer science departments. The primarily declared goal of teaching in these departments – at least according to the theory – is oriented towards the student becoming a scientist. This is obviously not the wish of the majority of students and curricula have been adapted to provide better service to the students leaving the university after having obtained a B.S. or M.S. degree. We suggest here to push this movement to a conclusion: separating GI Science, i.e., the efforts to advance our understanding of Geoinformation in all forms, from GI Engineering, which is after science-based, predictive rules how to build working systems.

This not only changes somewhat the style of teaching GI, but it first requires an effort to establish a GI Engineering science – i.e., the scientific efforts to establish the rules and heuristics which engineers can use to build GI systems that predictably work. The scientific results we have produced over the past decades are substantial and cover most aspects of GI. But they are not yet 'reduced to practice' to be usable to design systems which predictably work.

CONCLUSIONS

A discussion of education must not only focus on the use of new technologies in the teaching environment, but must always and primarily consider the substantive issue of what is the appropriate content. Our teaching methods must be technically adequate and follow the development of technology, but content must as well track changes in the real world.

The GIS environment does not only change with respect to the technology, but technology change brings with it a change in the business organization. We have argued that in addition to the well known 'Big GIS' installations, which are operated by large organizations and provide various bits of Geoinformation to different parts of this organization, we see a 'Small GI' business emerge, where a service provider operates the GIS and sells small amounts of Geographic Information to various users. These users buy the information when they need it and get it delivered at the very instant they have to make a spatial decision. The example for 'Small GI' used in this article is a system for guiding users of a public transportation system, step by step on their way to the destination ('door to door'), combining spatial information about the location of service points, operational information like train schedules, and the business organization (ticketing, etc.).

A curriculum organized to equip students with the necessary knowledge and skills to design, develop, and manage 'Small GI' businesses, adds to the two classical pillars of GI Science – namely Geo (Geography, Surveying, Cartography, etc.) and Info (Computer Science, Information Technology, etc.) as a third, equally important part Business. Understanding concepts of marketing – from product design and user studies – to legal issues is indispensable in this realm. Well-designed systems, where technology and business logic fit together are only possible if a team leader can see the complete picture.

As we propose to add new content to a GI curriculum, we also have to indicate where reductions are possible. The professionals working with GIS are closer to engineers than to scientists: They must reliably solve real-world problems and therefore design systems that will work. They cannot take a scientific approach, where only novel problems are of interest and hypotheses that cannot be confirmed are as interesting as hypotheses that experiments confirm.

This means, the results of the past decades of GI Science research must be reduced to practice and simplified into useful engineering rules. Graduates must understand the rules and the scientific background that has led to them; they must understand the limitations and the built-in assumptions. They have to be GI Engineers but they need not be GI Scientists!

GI engineering is necessary to have GI achieve an important place in our world. A large part of the Gross National Product is produced with the help of Geoinformation and future economic growth is best achieved by making business processes more efficient. Geographic knowledge is often the key to this.

ABOUT THE AUTHORS

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