7-1-2005

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Internet-Based Cartographic Teaching and Learning: Atlases, Map Use and Visual Analytics. Joint ICA Commissions Seminar. Madrid, Spain, 6-8 July 2005.

FIELD-BASED GEOGRAPHIC EDUCATION USING MOBILE COMPUTERS

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Abstract: *Recent developments in mobile computing and wireless networking technology allow exciting new opportunities for geographic education. These technologies can provide the infrastructure for field-based laboratory exercises designed to teach principles of geographic information science. We believe that the placement of a student in the environment they are studying provides important feedback mechanisms which may increase their understanding of the natural environment and the methods by which we study that environment. This paper will demonstrate a field-based geographic education system currently in development in the Department of Geography at The University of Iowa. This mobile geographic education (MoGEO) system is comprised of a mesh of technologies including mobile computers (PDAs), global positioning devices (GPS), spatial databases, geographical information systems, and wireless network protocols. One of the most important features of the MoGEO system is the ability to determine the spatial, temporal and contextual situation of the students.*

INTRODUCTION

As educational institutions continue to benefit from advances in technology it becomes appropriate to explore educational methods that take advantage of these new capabilities. For example, mobile computing technologies allow educators to explore field-based teaching methods which link a person at a knowable point in space or time with networked computing resources. The combination of technology, domain-specific knowledge, curriculum, and spatio-temporal knowledge allow the development of the contextualized individual. By knowing the various contexts in which a student operates a mobile educational system can be developed which provides an individualized and adaptable experience for the student while maintaining the goals of the curriculum. Of particular importance are the properties of space, time, and context. Mobile computing is of particular importance today because of the rapid research and development of mobile geographically aware computing. Location-based services (LBS) can be seen as a particular instance of mobile geographically aware computing that offers contextually-aware information services such as network routing, sightseeing services, or proximity alerts detailing businesses near the user. Education, and particularly any discipline utilizing spatial information or field methods, can benefit from this research into mobile geographically aware computing.

This paper will demonstrate a framework for mobile geographically aware computing within the educational context. The subject of the paper is a mobile geographical education system (MoGEO) currently in development in the Department of Geography at The University of Iowa. The MoGEO system provides an in situ or field-based educational environment that allows network access using wireless networking, determination of student locations through space and time, individualization of the experience including adaptive feedback, and access to analytical tools such as geographical information systems. The MoGEO system attempts to enhance traditional geographic education by placing students in the environment they are studying. We believe that the digitally enhanced educational system [1] will improve the experience by assisting the creation of cognitive linkages between the physical environment, alternate views of the same environment, and the methods by which we study that environment. In addition to the field-based activities of the MoGEO system there are traditional computer laboratory methods which are designed to complement the outdoor activities. Considering that the system is being developed within a geographical information science curriculum it is interesting to note that students become involved in all aspects of a geographic information system (GIS) including data collection, storage, modification, analysis and output. Often traditional approaches exclude one or more of these activities and, therefore, limit the educational experience.

The system itself is a mesh of technologies, educational curriculum, and geographical methods. The technologies include mobile and desktop computers, computer networks (wired and wireless), global positioning systems (GPS), spatial databases, and GIS software. The usage of the MoGEO system falls under the domains of departmental and university curricula so it must operate within the constraints of these structures. The educational goals are an overriding factor in its usage and its effectiveness should be tested to determine if our educational hypotheses are correct. The role of context, as seen in the system constraints of educational curricula, proves to be one of the most important features of the project. The multiple levels of contextual dependence serve to provide a hierarchy of decision processes which shape the educational experience for the student. Operating within the hierarchy of contextual awareness and dependence are the roles of spatial and temporal properties so that these matter only within the current context which can be dynamic and adaptable. In other words, the MoGEO system can be seen as a locationally, temporally, and contextually driven education system. And, due to these properties, it can provide a truly individualized environment which responds to user needs or preferences, and changes in state such as performance on an exercise. For example, if a certain student has a disability that hampers their ability to conduct laboratory exercises then alternatives can be presented based on their individual needs while still maintaining the goals of the course curriculum. In addition, the MoGEO can offer individual or group activities depending on the purpose of the exercise. Individual activities may be completed by students at their own pace which helps to account for variations in learning modes and styles. As with the consideration of individual needs, the system can adapt to individual preferences based on user profiles so students will be able to further individualize the lesson. Some lessons may benefit from student cooperation so group activities are possible as well. For example, a lesson on clustering may use the locations of several students at a given time to generate the clustering index. This is another example where the overriding curriculum shapes the usage of the MoGEO system. The system is powerful and easily extensible and can be adapted to other disciplines such as forestry, archaeology, and geoscience. It can also support new teaching methods which utilize techniques such as way-finding, directed observation, experimentation, gameplay, historic exercise replay, and directed data collection. Interaction with the instructor using communication software is always an option as long as there is network connectivity and students can access online knowledge repositories as well. The ability to communicate with the instructor or other students regardless of location offers interesting modes of independent discovery and interaction while maintaining expectations from normal classroom activities. So students can go off and explore areas of their choosing and still conform to the goals of the laboratory exercise.

The MoGEO system can be seen as an educational tool which relies on knowledge from various domains including education, geography, and computer science. Figure 1 shows a conceptual view of where the MoGEO system lies in terms of particular domain knowledge. It incorporates domain specific knowledge from all of the major contributors but operates within the constraints of the stated curriculum.

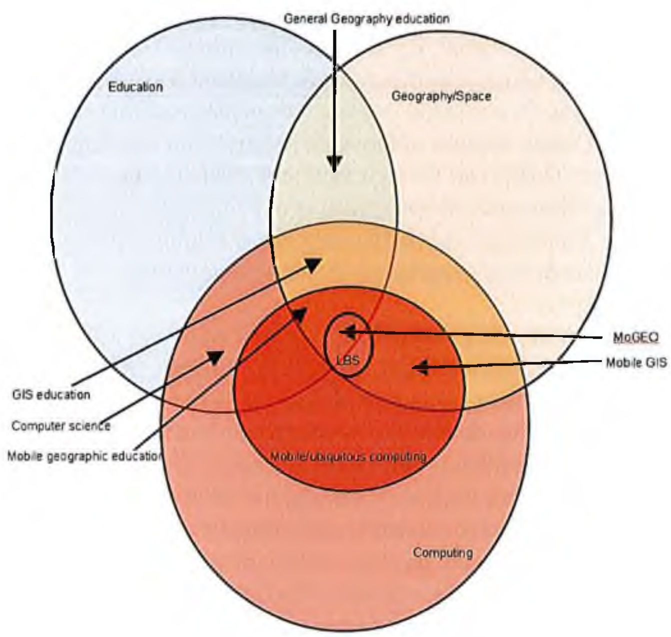

Figure 1: Conceptual overview of the MoGEO system.

TECHNOLOGY

The design of the MoGEO system was based on several fundamental features which were determined to be essential to project including the following:

a. students can participate in field-based activities while still maintaining network access using wireless protocols;

b. the system should be able to determine and monitor student locations through time;
c. applications on the server and students in the field must have access to spatial and aspatial data on the server;
d. the system must be capable of executing computationally intensive tasks and the results should be able to be returned to students in the field;
e. the students and the instructor must be able to display real-time and pre-existing datasets;
f. interactive communication between the students and the instructor must be possible;
g. the system must be able to provide adaptive and individualized learning activities; and
h. the system should utilize existing computer protocols and standards.

To provide these important features we incorporated mobile and desktop computers, wireless networks, GIS analyses, geographical information science curricula, spatial databases, and global positioning systems. We currently use Pocket PCs (see Image 1) in the field-based portion of the system with GPS and wireless network cards. Since the personal digital assistant (PDA) has limited processing power and limited battery life we tend to do most of the processing on the server side. This keeps the load on the PDA fairly low and allows older PDAs to be used in the system. This extends the usefulness of older PDAs and lowers the computing requirements for people who would like to use the system. The mobile computer has only a few duties but it proves to be critical to many aspects of the system including the field-based display environment for spatial data, the determination of the current student location using the GPS, wireless network access, interactive communication methods, and an application environment to provide dialog with the student. We use various programming and database languages to extend the functionality of the PDA such as VBScript, Javascript, XML, SQL, and Flash's Actionscript. In addition, other peripheral devices can be added to the PDAs to provide new capabilities such as digital cameras, environmental sampling devices, or headsets to improve communication.

Image 1: PDA with wireless NIC and GPS

Each of the PDAs has a wireless network interface card (NIC) that uses the IEEE 802.11b network protocol and the wired equivalent privacy (WEP) encryption protocol. Although we are currently limited to 11Mb/s bandwidth using this protocol we have determined that it is sufficient for now. We will examine some of the developing standards such as 802.11n and 802.16 for use in the MoGEO system when they are ratified and hardware is readily available. We also have the capability to set up an access point powered over Ethernet (POE) anywhere we have access to power so we do not have to remain within the campus infrastructure. This access point can be powered from a car battery therefore allowing us to set up a mobile network in remote environments. Students would not have access to the internet directly but can access data on the mobile server that is connected to the mobile access point.

The global positioning system device (GPS) on the mobile computers allows us to determine the geographical location of each student in real-time. Knowing the location of each user allows us to tailor the laboratory exercise to each student depending on the context of the situation. Each of these locations, along with approximately fifteen other fields of data based on the GPS, is stored on the server-side database at intervals set by the instructor or student. Some of the collected fields include the following: x, y, z, positional dilution of precision (PDOP), horizontal dilution of precision (HDOP), speed over ground, course over ground, time, date, and event context.

In addition to field-based exercises that require a PDA, we also use traditional computer laboratories as part of the MoGEO system. In this part of the system, the student can create maps of the work they have conducted or even replay their work showing two- or three-dimensional views of the environment they experienced in the field. Currently students can use web-based applications utilizing Flash or scalable vector graphics (SVG) to see their work from different perspectives. Eventually we intend to create 3-D models of the environments they are studying so they can replay their work using avatars in a virtual environment. We believe that the ability to view the same environment in multiple ways and to replay their experience will assist students in understanding the processes through which we study those environments and the constraints and considerations of such a process.

On the server-side we have a series of applications that add functionality to the MoGEO system. These include things like spatial databases, geoprocessing tools and functions, internet map servers, and multimedia servers. We place these applications on a networked server for several reasons which include the following: to provide increased computing power, to minimize power demands on the PDA, to provide central access to collected and existing data, to provide a powerful statistical and spatial analysis environment, and to make the system more efficient overall.

METHODS

Although the MoGEO system is somewhat complex logistically it is easy to understand the underlying concepts. Basically the three components of location, time, and context have been combined to provide educational techniques and methods for geographical information science. Through the combination of these three properties we can create a locationally, temporally, and contextually based education system which is adaptive and dynamic based on individual learning styles, personal preferences, and performance while still adhering to the departmental curriculum. In addition, allowing students to interact with the environment they are studying should provide cognitive linkages which develop between the first-hand view of the environment, different views of the same environment (e.g. aerial photography), and the abstracted or analytical view of the environment provided through GIS functions (see Figure 2). We also believe that embedding students in the environment will promote personal experimentation using parameters which they can control such as sample locations. Essentially students can use themselves or a group of students as the sampling unit for some analysis and the values can be changed as easily as moving to a new location and re-running the analysis. These analyses can be conducted by individuals or groups of students in the field or by users in the computer laboratory who can direct students to new locations through a simple interface.

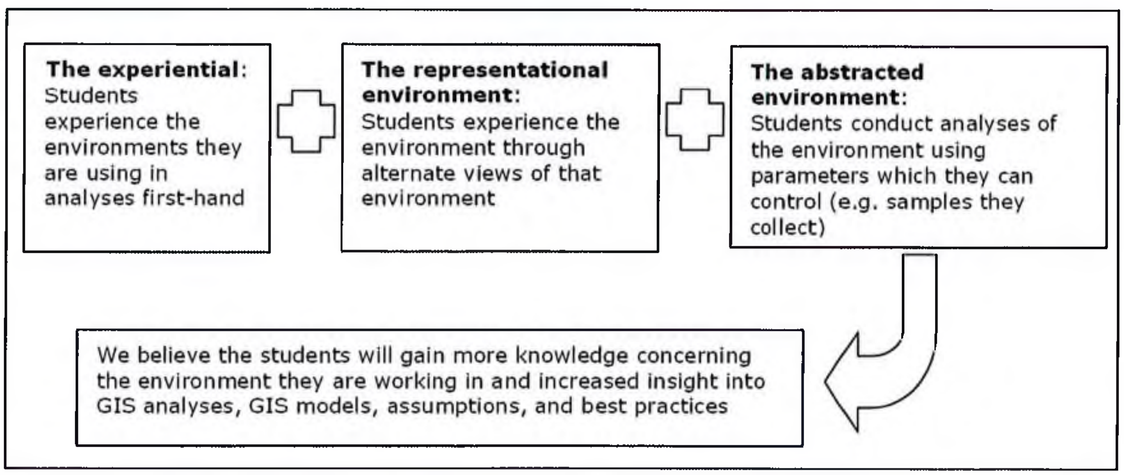

Figure 2: Conceptual model of experiential feedback in the MoGEO system.

Locational information serves as a key component of the MoGEO system. It is through the knowledge of student locations that we can introduce spatial analyses and the important concepts behind them to students. We can use individual student locations to determine things like proximity to other environmental features, environmental variables at the given location, and sampling strategies. By knowing the locations of all students we can expand the types of analyses to include things like real-time clustering analyses, interpolation and tessellation of the environment using student locations as input into the model, and gameplay.

Temporal information is a complement to the locational information because the combination of these allows us to place a student at a location at a given time. We can store this information to retain a log of student activity at a given time and place. These data can be used to provide a historic replay function which allows a student to view their activities from a different perspective. Students have full access to the historic locational information and the analyses which they ran in the field so it may provide some insight into how GIS models work.

The contextual component of the system is one of the most important features because it builds on the locational and temporal knowledge by providing a linkage with time and space. Context can be seen as an aspatial component which includes information like the class that the student is in and the laboratory exercise which they are working on. It can also be used to monitor the performance of a student and to allow adaptation of the lesson based on their performance.

The combination of these three main components allows us to develop the concept of the event trigger. The event trigger is a causal agent that makes something happen based on some criteria. By using the knowledge of space, time and context we can make sophisticated triggers that can activate a variety of events. Essentially the trigger is part of a decision-making process based on some combination of the three main components. If the trigger is primarily based on spatial conditions then the event trigger is known as a spatial trigger. For example, when students enter a certain location a popup window might indicate that they are to do something at that location. Although there is some contextual basis to this trigger it is primarily spatial in nature. Spatial triggers can use proximity or topological relationships as part of the decision-making process. The second type of trigger is the temporal trigger which is based primarily on the temporal conditions. In this case, an event can be triggered at a certain time which can be activated due to absolute (e.g. 4:00pm) or relative (e.g. 15 minutes after a student starts the exercise) temporal conditions. An example of this is the coordinate tracking data from the GPS which is sent to the database server every three seconds for each student while they are in the field. The final type of event trigger is the state or context trigger which causes an event based on some aspatial condition such as performance on a quiz. If students perform poorly then this type of trigger can cause events that are designed to assist the student in the exercise. For example, if students are struggling with answers on an assignment in the field then a website might more provided to give more information of the subject. Likewise, if students are performing extremely well then some feedback might be provided to the individual stating their excellent performance.

Event triggers can be combined to make more sophisticated triggers based on the goals defined by the instructor. For example, one trigger may have aspects of all three trigger types involved in the decision-making process. The scope and context in which the various triggers operate is explicitly defined during the design phase of the system in most cases. However, the instructor can create triggers which operate randomly if it serves the purpose of the exercise. The instructor can create complex triggers through the arrangement of the decision hierarchy, the introduction of random variables, and the use of multiple criteria from one or more types of triggers. It should be noted that events do not necessarily require activity from the student or even notification that the event has occurred. For example, the GPS tracking data is automatically forwarded to the database server without any interaction required by the student.

The event(s) caused by an event trigger can be essentially anything which is appropriate as a response. This includes things such as running a GIS analysis and returning the result, a popup dialog indicating that a student is to do something at a location, committing updates in the spatial database, or offering more information on a subject if the student is performing poorly. Events can be dynamic and adaptive but also can be shaped through various contextual dependencies such as student preferences or needs. So the final form of the event is dependent on a series of student preferences, instructor choices and design, and the operational framework of the lesson. A loosely defined typology of possible events includes forms like communication, information presentation and referral, lesson events, adaptation, geoprocessing or database events and contextual events.

EXAMPLE EXERCISES

The Department of Geography at The University of Iowa already uses the MoGEO system in its current curriculum. We have developed a series of laboratory exercises and have several more in the design phase. This section will present some of these labs.

- **GPS accuracy and precision exercise.** This lab attempts to teach students about sampling with a global positioning device. During this exercise a student is assigned certain geographic locations to visit and when they enter within a certain distance of the location a popup window is triggered. The window tells them where to go within the spatial trigger and how to record GPS observations at the feature. Students sample the location between 5 and 20 times and the coordinates are transmitted to the server where they are stored. After they visit all the locations they were assigned they return to the computer laboratory to analyze the data they collected. They are then instructed to examine the relationship between the actual location of the feature, the coordinates they collected from the GPS, and the error estimates collected with the coordinates (e.g. PDOP, HDOP).

- **Tessellation exercise.** This group activity exercise attempts to help students understand the concept of surface tessellation. In this exercise a group of students arrange themselves in the field and generate a triangulated irregular network (TIN) using their current locations as input into the model. The students can then change the arrangement and generate another TIN using the new coordinates. The coordinates and the TIN are saved to the server for later examination. This lab encourages experimentation with the arrangement of the students to see how changes affect the output.

- **Clustering exercise.** This group activity is similar to the tessellation exercise. In this exercise the students arrange themselves in the field and generate clustering indices based on their current locations. They are encouraged to change the model parameters by moving to new locations and then examining the output of the analysis. In addition, they can be provided with cluster indices and asked to replicate the cluster using trial and error.

- **Geocoding/reverse geocoding.** This exercise illustrates the process of geocoding and reverse geocoding. In this exercsise, students geocode addresses in downtown Iowa City to first show how the process works. They then proceed to the downtown and use reverse geocoding to find out tax assessor information on addresses that they visit. This lab illustrates address matching and introduces privacy issues associated with public information.

- **Wireless signal strength exercise.** This exercise is based on sampling strategies for continuous data. Students use various sampling methods (random, stratified, etc) to create a surface map of wireless signal strength on the university campus. Student compare sampling methods and interpolation methods while completing this exercise.

CONCLUSION

This paper illustrates a new educational tool for geographical information science education. We feel that the MoGEO system offers a new digitally enhanced educational experience which can help students understand complex concepts. Although it is still in development it does illustrate the use of new technology in existing curricula. Future work includes the development of new teaching modules, the addition of new functionality, testing of the effectiveness of the MoGEO system, and collaboration with other disciplines.

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