
MOBILE ENVIRONMENTAL INFORMATION SYSTEMS

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This paper presents the foundations for building mobile environmental information systems (MEISs) requiring an interdisciplinary approach. MEISs require expertise from the disciplines of environmental biology, geography, and mobile technology. MEISs show great promise for the acquisition of

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environmental information using different mobile devices. Automatic mobile acquisition enables the forwarding of the information to central databases for storage, further processing, and transmission to the mobile devices in a form that is useful to the users. Furthermore, these systems have the potential to be used both in the protection of nature, as well as in recreational use in a way that takes the constraints of nature into account. In this paper we describe the preliminary results of the MINNE project and the prototypes currently under research in the project.

INTRODUCTION

Information technology, mobile applications, and environmental science are all important growth areas. According to the Seventh Technology Foresight, NISTEP report 71¹ (Figure 1), they have been forecasted to be among the fastest growing fields of science and technology in the coming years. In addition, location-based services (LBSs) are predicted to become the most-used type of mobile service by the middle of this decade (Beinat 2001).

Combining these disciplines into mobile environmental information systems (MEISs) has the potential for great benefits for the environment. The aim of this research is to explore the possibilities for ambient-aware mobile applications in the domain of environmental information systems. The basic research question is this: How can smart and location-aware mobile applications be utilized in the ecological and environmental domains? This can include applications in biological, environmental, and geographical research, environmental protection, tourism, and education with the common goal of applying both existing and new environmental information more widely to promote eco-efficiency and environmental awareness.

RELATED RESEARCH IN ENVIRONMENTAL APPLICATIONS

In the discipline of environmental sciences, some related research projects are, or have been, in progress. For example, the Hypergeo and the WebPark projects (Mountain and Raper 2000, 2001), funded by the European Union 5th Framework Programme Information Society Technologies, study the potential of location-based services in tourism and in professional use.

¹Published in July 2001 and available at <http://www.nistep.go.jp>.

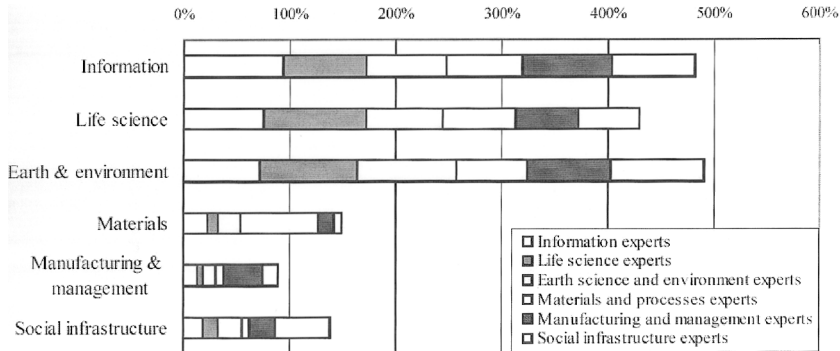


Figure 1. Science and technology forecast until 2010.

The Hypergeo project, which has already completed its final testing stage, gathered expertise in tourism-related use and that expertise is now being utilized in the current WebPark project. The WebPark project (Krug et al. 2003) is developing personalized, location-aware, and timely access to National Parks Information Systems for mobile devices. The test areas are the Swiss National Park (Switzerland), Waddenzee National Park (The Netherlands), and Dartmoor National Park (England).

This has many similarities with the ReGeo project, started in 2002, which aims at developing a decentralized tourist information system based on multimedia and geodata. Test areas include national parks in Austria and the Czech Republic, a landscape park in central Poland, and a nature park in Germany (Almer et al. 2002).

The GIPSY project, in turn, launched by three Dutch universities, is developing a wireless supported learning environment, where location-based services will be utilized in fieldwork (e.g., in studies of soil and vegetation) (van Lammeren et al. 2002).

In addition to some of the aforementioned projects, several tourism-related research projects have been launched, particularly in the member countries of the European Union, with special emphasis on using the potential of mobile location-based services in the development of the tourist industry. In most cases, the services are designed for urban settings (Blechschild et al. 2003; Schmidt-Belz et al. 2003; Zariakas et al. 2001), but there are some projects that seek to use LBS in promoting tourism, especially in rural and mountainous areas (Löhnert et al. 2001; Werner 2001).

There are numerous ongoing research efforts in the Oulu area (Finland) that combine habitat data, geographic data, and individual observations including, for example, managing northern boreal forests for biodiversity, the spatial effects of predation on species interactions, demography and the dynamics of small plant populations, and the extinction risk and management of rare plants (Colpaert et al. 2003; Reunanen et al. 2000; Tornberg and Colpaert 2001). Automatic data acquisition using mobile devices with GPS and real-time communication channels can enhance the efficiency of these studies.

Successful studies involving radio tagging of birds and mammals or even fish and other “unconventional” animals have been performed worldwide. This technique has also been used by the Department of Biology of the University of Oulu in researching the landscape ecology of the flying squirrel (Reunanen 2001), goshawk (Tornberg 2000), and partridge (Putala and Hissa 1998), and by the Finnish Game and Fisheries Research Institute in monitoring the movement and behavior of wolves (Kojola et al. 2003). However, typically these studies have used older technology, where the location of the transmitter and animal is determined using a plain radio tracking receiver, without any resource to today’s wireless or mobile networks and Internet.

The LUIAS project,² funded by the Academy of Finland, is a joint venture of the Finnish Game and Fisheries Research Institute and the Department of Geography at the University of Oulu. It uses GPS to track reindeer in northern Finland (Kumpula et al. 2001). A novel application consists of real-time monitoring of reindeer using GPS receivers combined with GSM (Global System for Mobile Communication) transceivers, which sends the coordinates to a server by SMS (Short Message Service) messages.³

In spite of the many characteristics that these ongoing research projects have in common with the MINNE project, none of the related projects address both the mobile environmental information gathering and user guidance in nature in an integrated way similar to the MINNE project.

ENVIRONMENTAL APPLICATIONS AND MOBILITY

Wireless information systems are defined by Katz (1994) as “computing systems that provide the ability to compute, communicate and

²The project started in April 2001; see http://terra.oulu.fi/aka/www_luias.htm.

³First results from experiments with reindeer using the GPS collar were published in 1997; see http://www.environmental-studies.de/projects/13/gps-gsm_collars_on_reindeer.html.

collaborate anywhere at any time.” The use of computers in environment-related research and monitoring is well established. Tools like geographical information systems (GISs), databases, and digital collections are essential for any large-scale study about the natural environment. However, the usage of mobile computing devices in this domain has not yet been documented. In this context, we define MEISs as *wireless information systems* used to study, monitor, and exploit the natural environment and its interaction with human activities. From our point of view, location and ambient awareness are essential characteristics for the success of any environment information transmitted via mobile applications.

MEISs increase the dimensions of spatial and temporal mobility when compared to the more traditional research methods. To develop such applications, an interdisciplinary approach is required, combining expertise from such diverse disciplines as biology, geography, and mobile technology. With the use of GIS and positioning technologies, MEISs show great promise in enhancing the acquisition of environmental information via a multitude of mobile devices carried by biologists, amateur specialists, and hikers. Automatic mobile acquisition makes it easy to forward the information to central databases for storage, further processing, and transmission to the mobile devices in a form useful to the users of the mobile devices (Figure 2). These systems can be used to protect nature, as well as in recreational use, in a way that will take the constraints of nature into account.

Mobile applications are a generic class of software running on mobile terminals with restricting capabilities like miniaturized keypads and small screens (Rainio 2001), and they must be designed to take these restrictions into account. The ultimate goal of any application is to satisfy its customers’ needs, so a careful balance has to be achieved between the features and the usage of the resource. The dissemination and collection of environmental and geographic information may lead to dealing with very large sets of data, which poses additional challenges to the development of MEIS.

To date, categories of typical location-based applications (e.g., Beaulieu and Cooper 2001; McGeough 2001; Niedzwiadek 2001) have seldom taken account of biological or environmental information and conditions. Following the conventions of distinguishing different types of LBSs, the main function of MEISs is to serve as an information service, which forms a basis for more advanced functionality for the collection, processing, and sharing of environmental data.

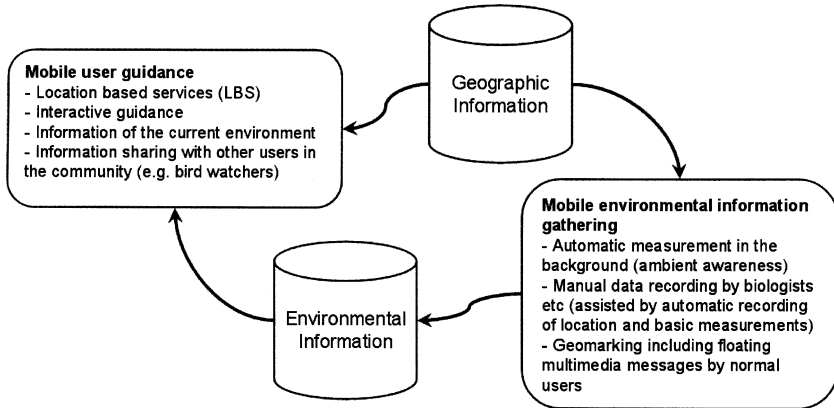


Figure 2. Intelligent environmental services based on the utilization of geographic information as a means of improving the use of environmental information.

The location tracking of mobile devices is usually based either on a wireless network cell-based location, or some technology supported by the mobile devices, for example, a phone with a GPS module. Table 1 shows the different classes of location management, which are based on the required location precision. The requirement for the precision of the location depends a lot on the type of the application—not all applications need to know the exact location with the accuracy of a few meters. One example of a major cellular network's location management scheme is time difference of arrival. Location tracking can also be performed in other wireless networks besides cellular networks and satellites, such as wireless local area networks or a personal area network using Bluetooth.

Mobile location information is quite precise when GPS technology is used for the creation of location and time-based content, which often explains why this positioning method is preferred to other methods.

Table 1. Classes of location precision (Varshney 2001)

| Class | Location precision | Possible schemes |
|---------|--------------------|---|
| Network | 10s kilometers | Existing location management schemes |
| Cluster | 1000s meters | Existing location management schemes |
| Cell | 100s meters | Modified IS-41/GSM (busy business area, city) |
| Subcell | 10s meters | E911 schemes (GPS, A-GPS, triangulation) |

Aside from its accuracy, the additional advantages of GPS over other positioning techniques are its worldwide coverage, accessibility, three-dimensionality, and cost efficiency. However, the major disadvantage of GPS is the fact that it always requires a direct sky view of at least three satellites. This means that a GPS-based service does not work indoors or in situations where the user is surrounded by tall buildings or dense vegetation (e.g., Davies et al. 2001; Hjelm 2002).

MINNE PROJECT PROTOTYPES

The MINNE project was started in 2002 at the University of Oulu in collaboration between the Departments of Biology, Geography, and Information Processing Science. It aims to investigate the area of MEIS by applying an innovative, experimental approach. One major goal of the research in MINNE is to make a prestudy, using wireless and GPS technologies, in the context of developing mobile LBSs that exploit environmental information. The resulting prototypes are used to demonstrate the possibilities of mobile commerce (m-commerce) applications in the collection, use, and transmission of ecological data for both private and organizational users.

Research Methodology

A classical research plan would have started with an extensive survey of the state of play, followed by the development of a theoretical foundation, based on speculative methods. To validate the conclusions, in a later stage, one or more prototype applications would have been designed and documented as proof of the concept. Only in the final phase would some aspects of the designed applications have been implemented as prototypes, mainly for demonstration purposes.

This traditional approach was unsuitable for the MINNE project for two main reasons:

1. MEIS is a new field, so the number of existing studies is very small. An empirical basis of observations and knowledge is required to reach theoretical conclusions.
2. The spectrum of required knowledge is very wide, which calls for a heterogeneous, multidisciplinary research team. In order to cooperate,

a common language, understanding, and set of representations need to be shared between the members. These are difficult to achieve by individual researchers, in a relatively short period of time, without work experience in the related fields.

The strategy applied in MINNE started with a small study of the current state of the domain. Application ideas were collected next in an attempt to loosely determine the main classes of problems and situations on which mobile devices can produce a positive impact. The ideas were transformed into general application descriptions, with a much lower level of detail than full software requirement documents. Those descriptions were then implemented as prototypes, in an attempt to follow an agile software development methodology derived from Extreme Programming (Beck 2000).

The process was planned to be intensely iterative, characterized by short release cycles and high “customer” involvement. The customers (a role played in MINNE by biologists and geographers that are directly involved in field testing) write their requirements for the applications in the form of “short stories.” Based on a decision process, the development team—composed of software and mobile technology specialists—selects stories for implementation, and with every iteration (usually 2–3 weeks) the application grows in functionality. The development team also receives input in the form of “expertise” whenever issues regarding geography or biology (such as algorithms or data formats) need to be considered in the software. This process is detailed in Figure 3.

Following this procedure, a series of objectives can be reached:

- Mobile environmental applications are created and used, not only in special testing sessions, but in the daily activities of the field scientists.
- The usefulness of those applications increases with every step and grows from crude, experimental versions to full featured tools. Also their usability is continually refined, so throughout their development the applications become more suitable for their intended usage.
- Researchers from different fields come into contact with concepts from related disciplines that are relevant for their main activity. In that way, their multidisciplinary expertise increases naturally and does not disrupt the focus of their main work.
- Practical focused teamwork enables the team to build a common understanding and a shared set of work concepts.

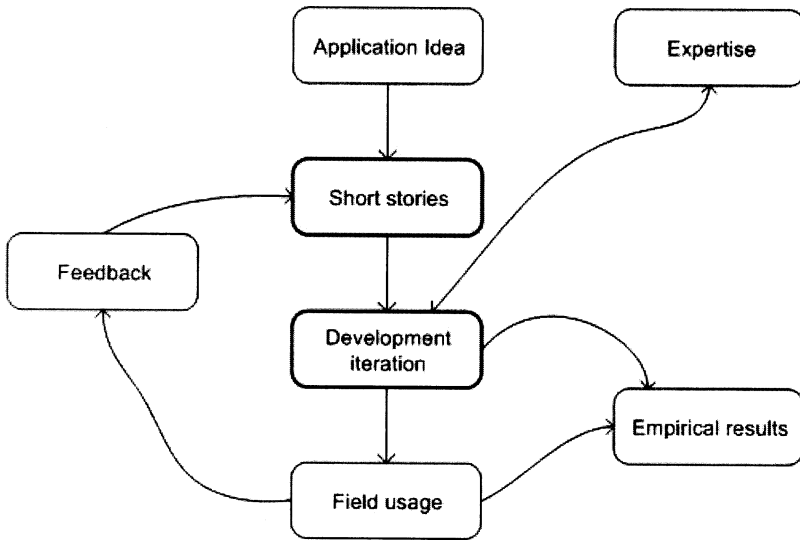


Figure 3. Interdisciplinary cooperation process in the MINNE project.

- Individual research topics can also be pursued within this larger framework. For example, an experimental software engineering approach (Wohlin et al. 2000) is planned in order to study methodological issues, especially with regard to the suitability of agile methodologies for mobile applications.

Botanical Garden

The first prototype to be developed was a simple location-based application for visiting the University's botanical garden, which is situated within the campus area. Using the garden as a primary demonstration environment has several benefits, which include its close location to the university and its compact size and versatile nature. The role of the first implementation was to familiarize the development team with the programming environment, its specific tools and techniques, as well as to develop a set of basic components to be used as a basis for further applications.

The "Botanical Garden Prototype" was set up using Java 2 Micro Edition and Symbian OS running on a smart mobile telephone. The device's local memory stores information about the area, such as digital maps of walking paths or the position and description of plant species. A GPS receiver provides positioning information, which is used to guide, and

inform, a potential visitor on a tour of the garden. Experiments with a related prototype application, running solely on a PDA device, are also being carried out. This prototype will take advantage of the GIS tools provided by the development environment based on a GIS software package consisting of GeoMedia Professional and IntelliWhere OnDemand.⁴

In a later stage, larger experimental areas are planned to include national parks, recreational areas, and tourist attractions, where the current MEIS services can be implemented. This is based on the assumption that the most important application potential for MEIS is the combination of mobile environmental measurement and information systems and ecological tourism. This application may provide new attractive business opportunities, especially at the local level, and may also help in the tradeoff between business and the environment. The following sections describe the more advanced concepts of potential mobile environmental applications envisaged in the MINNE project.

Biology Survey Tools

This is a service designed for use by professional biologists or amateur nature observers. A field biological survey consists of repeatedly recording the quantitative or qualitative features of natural phenomena, with regard to time and location, and compiling large sets of data using statistical methods. Traditional data-gathering tools in the field are notebooks and maps, while computers and GIS are employed for processing the results. Location-aware devices can be used to streamline the process, allowing automatic association of position and time information with observation data sets (Figure 4). Results can be updated in real time in a central system via wireless network connectivity, thus facilitating the work of multiple teams in remote geographical areas. The user interface of the field device can be configured to fit a particular application's requirements. Possible applications include researching the migration of birds and monitoring endangered species or industrial pollution.

Nature Sight Service

Nature Sight Service (NSS) helps a user find a location where it is possible to have a guided nature tour. The system presents a map of the area

⁴The Department of Geography at the University of Oulu is a member of the Team GeoMedia Registered Research Laboratory program.

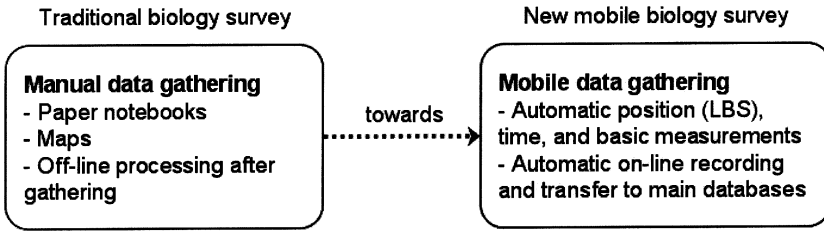


Figure 4. Data collection process enhanced by automated or semi-automated features of LBS.

on the mobile device. Several locations are offered to the user. The current climatic conditions are taken into account, so the user will not be shown, for example, swimming beaches during winter. Locations could include, for example, hiking paths, cross-country skiing opportunities, and places for picking berries or National Park services. The mobile device tracks the user's movement on the map until the person leaves the area. Pictures of the different locations can also be relayed to the user before the selection is made. This helps avoid unwelcome surprises—for example, too-challenging hiking paths. Other relevant information is transmitted to the user during the user period. This helps the user have a more pleasant experience and gives information about guide services during the tour. The service can also be used to minimize the negative local effects of tourism, for example by directing the visitors of a national park to avoid sensitive areas of high erosion of soil or the breeding areas of rare animals.

As part of the NSS service, users can record their own observations on the mobile service, which makes the information available to other users. This geomarking service can serve a lot of different user groups (e.g., birdwatchers), and it can also be used for versatile environmental monitoring purposes. A user can mark a location on the mobile device's map and convey information to the server. Users can also establish interest groups and set criteria for the information that they want to have. With the help of this service, large databases can be created.

Edutainment Applications for Elementary School

While wireless information devices (e.g., i-mode mobile telephones, PDAs) are sometimes used in the education process in schools and further education, very few studies have been carried out into the feasibility

of using such technology for younger learners. This research direction aims to identify the strengths and weaknesses of involving location-based applications to teach natural sciences (geography and biology) to elementary school students. Pedagogical games are incorporated in iteratively, using the expertise of education specialists. The applications are tested in real environments, such as in visits to the botanical garden, and feedback is used to develop subsequent versions.

FUTURE RESEARCH

The integration of environmental data collection with recreational services poses many interesting research questions. Tourists can become automatic environmental data collectors when equipped with intelligent mobile navigation and guiding devices that can collect environmental

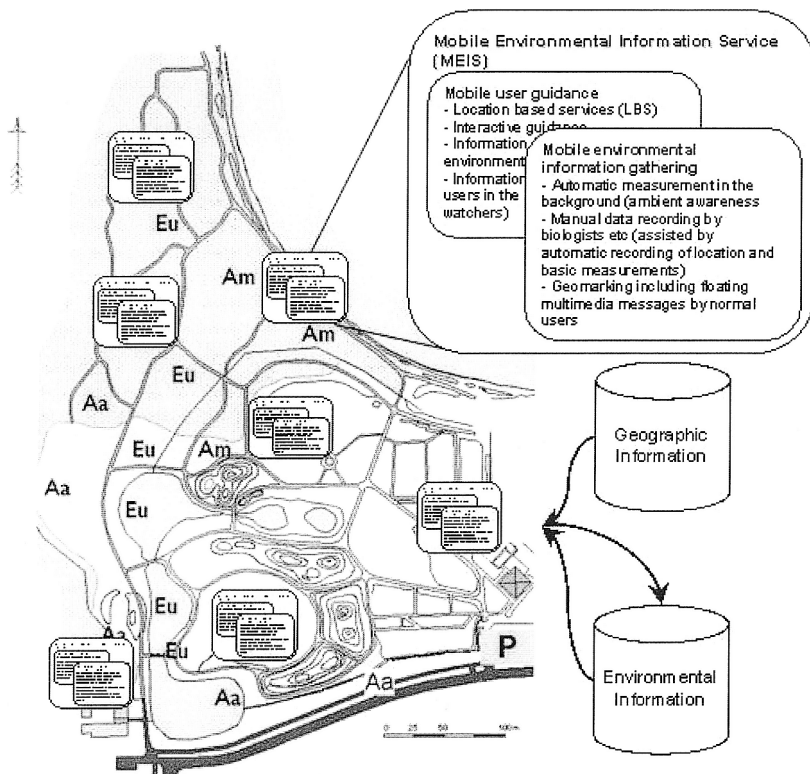


Figure 5. Regional environmental networks.

information while the user is wandering around outdoors. An example of how a large number of MEIS devices may form a dynamic real-time wide area environmental information collection and measurement network is illustrated in Figure 5. Connecting mobile data collection to central environmental databases is also an interesting direction for further research.

CONCLUSIONS

MEISs offer great promise for the acquisition of environmental information. MEISs offer infinite acquisition potential by and for various groups wandering in nature areas, either doing their jobs (like biologists) or at leisure. They can form a network of “automatic intelligent mobile sensors” and they can also benefit from the information gathered by the various mobile communities MEISs can automatically collect and forward environmental information to centralized databases, where they can be available for further use and research locally or via the Internet to a wider research community.

The main result expected from the MINNE project is to establish a consumer role for mobile devices which can contribute to implementing and maintaining a sustainable and eco-efficient society by developing theories, models, techniques, and processes that with help develop high-quality m-commerce environmental applications in a reliable and efficient way. However, given the exploratory character of the research to date, the range of possible results is still open at the beginning of the study.

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