JYVÄSKYLÄ STUDIES IN COMPUTING 30

Jouni Markkula

Geographic Personal Data, its Privacy Protection and Prospects in a Location-Based Service Environment

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UNIVERSITY OF JYVÄSKYLÄ

JYVÄSKYLÄ 2003

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ABSTRACT

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During the last few decades the applications and utilisation of geographic data have widened and increased steadily. This expansion has followed on from the possibilities provided by the development in information technology. The advancement in telecommunications technology in the recent years has supported and accelerated the progress. The previously professional geographic applications area is now widening to the extent of services for the public at large.

Geographic personal data forms a significant content in many geographic information applications and services. However, its collection and utilisation is restricted by the privacy protection requirement.

This study tackles the questions of geographic personal data in current and future applications and services. The topics handled cover privacy protection and statistical disclosure control, geographic information systems and data utilisation in location-based services, new mobile service environments, collection and application of dynamic geographic personal data, and its possibilities and restrictions in future mobile environments.

The contributions of the study include a specific analysis and solutions related the above mentioned research topics, involving constructive and methodological development as well as empirical testing. The statistical disclosure control problem of geographic population data is analysed and a method for solving it, called Local Restricted Imputation (LRI), is developed and tested. The new mobile Location-Based Services (LBS) environment and its geographic data handling possibilities is studied and tested in the form of a pilot system. The future prospects of dynamic geographic personal data are studied in the form of outlined Dynamic Geographic Data Service (DGDS). In handling the essential questions related to geographic personal data in various forms, the study presents a consistent view of its utilisation in present and future geographic data services and applications.

Keywords: geographic data, location-based services, mobile computing, personal data, privacy protection, statistical disclosure control

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Especially I wish to thank the persons who have made the greatest contribution to my research work as well as to the final result, my supervisors. Prof. Jari Veijalainen, who "hijacked" me into this challenging and rewarding new research area, mobile computing and location-based services. He provided me with excellent possibilities to carry out research in an interesting context. Prof. Antti Penttinen, who, before that, directed me to the research field of geographic data and supported me, in his well-known manner, in the initial phase of this study. Research director Dr. Jarmo Ahonen, who gave the needed "final kick" to get this study out of the folders of the researcher and into covers. In addition, I wish to give special thanks to Prof. Jukka Heikkilä (Jups), who has supported the finalisation of the study in many ways.

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Research work is never unrelated to the "real life" outside the "walls of the university". And the most significant component of life is the people around you. These people affect your work and in return your work affects your relationship with them. Therefore, I now wish to remember here the people who have been close to me during these years; people who have affected or been affected by, the much involving work that was required to produce the final result presented here. "Remembering" means expressing my gratitude to you, for your presence and affect. However, in some cases it also means apologising to you, for the affects caused by the work.

Finally, I wish to give my greatest gratitude and thanks to my parents, Anneli and Erkki, who have supported my academic studies and work in all the possible ways from the very beginning, and before that. Most importantly, I wish to remember here my dear son Kerkko, who has always been wonderful, understanding and patient. Even if he has all too many times heard the phrase "Sorry, I have to work this weekend".

Jouni Markkula
In Jyväskylä on May Day 2003

LIST OF INCLUDED ARTICLES

I Markkula, J. (1999). Statistical Disclosure Control of Small Area Statistics Using Local Restricted Imputation. In *The 52nd Session of the International Statistical Institute (ISI 99), August 10–18, 1999, Helsinki, Finland*, Bulletin of the International Statistical Institute, Volume LVIII, Contributed Papers, Book 2. Helsinki. 267-268.

II Markkula, J. (2003). Disclosure Control of Geographic Population Data and Local Restricted Imputation Method. Submitted to *the Journal of Official Statistics* (JOS).

III Virrantaus, K., Veijalainen J., Markkula, J., Katasonov, A., Garmash, A., Tirri, H. & Terziyan, V. (2002). Developing GIS-Supported Location-Based Services. In C. Claramunt, W. Winiwarter, Y. Kambayashi & Y. Zhang (eds.) *Proceedings of the 2nd International Conference on Web Information Systems Engineering (WISE 2001), December 3-6, 2001, Kyoto, Japan*, Volume 2. IEEE Computer Society, Los Alamos, California. 66–75.

IV Markkula, J., Katasonov, A. & Garmash, A. (2002). 6.4 Developing MLS Location-Based Service Pilot System. In O. Martikainen, K. Raatikainen, J. Hyvärinen (eds.) *Smart Networks*, IFIP TC6/WG6.7 Seventh international Conference on Intelligence in Networks (SmartNet 2002), April 8–10, 2002, Saariselkä, Lapland, Finland. Kluwer, Boston. 229-244.

V Markkula, J. (2001). Dynamic Geographic Personal Data – New Opportunity and Challenge Introduced by the Location-Aware Networks. *Cluster Computing*, Vol. 4, No. 4. 369-377.

CONTENTS

CHAPTER 1

INTRODUCTION AND OVERVIEW

1 INTRODUCTION

The rapid development of information technology during the last decades has been a strong driving force behind the expansion of geographic applications and geographic data markets. Recently, the advancements in telecommunications technology have contributed significantly to the expanding development. The previously professional geographic applications area is now widening to the extent of services for the public at large. This boost, a result of implementing the location ability to the mobile telecommunications infrastructure, is expected to explode geographic data and applications markets. However, this “explosion” in public mobile services is still in the early stages.

One type of geographic data is personal data with georeference. Many actors in the public and commercial sector have collected and are collecting personal data in different forms. A majority of the data sets are, or potentially can be, georeferenced. In the public sector, maybe the best examples are national statistical institutes, such as Statistics Finland, who are responsible for the collection and dissemination of national official data. In the commercial sector, clear examples are customer databases.

There exist large databases of geographic personal data in the possession of public institutions and private companies. They have a wide variety of potential applications. However, utilisation of personal data always requires considerations of privacy of the individual persons. Privacy protection is a major limiting factor in the efficient utilisation of any personal data. Privacy is expressed in the personal data protection legislation of many countries, as in EU member states guided by EU directives. The privacy problem does not completely prevent the utilisation of the data in all of its forms, especially if appropriate methods are used for protecting the data from the risk of disclosing information about individuals.

The development in mobile terminals, networks and data services has revealed new possibilities also for geographic personal data. An important new feature of the mobile networks is the ability to position the mobile terminals.

Some mobile terminals have also complemented with satellite positioning features. The positioning capability has made a new type of services possible, known as Location-Based Services (LBS). A wide dispersion of location-based services to the mobile user population will evidently take some time. Development of more advanced services will depend on the adoption of the services and related economical aspects. However, development in this direction seems quite evident. Facilitating technology will become a standard feature, available to the population at large, at a reasonable cost.

Location-based services have a two-way significance considering geographic personal data. On one side, they open new applications and markets to geographic data. From the other side, they make it possible to collect a new type of geographic personal data, to a potentially large extent.

This study consists of five papers. Four of the papers are published and one submitted for publication. These papers tackle specific, and currently highly relevant, aspects of geographic data and its utilisation, as well as its prospects in the future. The first two papers present the problem of privacy protection and disclosure control of geographic personal data and propose a methodological solution. The next two papers study the location-based services environment and the geographic data and applications in it. The last paper studies the possibilities and problems of geographic personal data in location-based services, combining and concluding the topics of research presented in the earlier papers.

2 GEOGRAPHIC PERSONAL DATA

Geographic data can be defined as data on a located entity. A located entity is a feature or object whose permanent or temporary location is determined. Geographic data consists of spatial data component and associated attribute data component. Spatial data consists of geometry, co-ordinates and possibly topological information. Attribute data consists of any identifying, locating, timing or descriptive information about the entity. Attributes are observable, measurable or otherwise known properties of the entity. (National Land Survey of Finland 2002; see also other definitions: Association of Geographic Information 2002, Tekniikan sanastokeskus 2002.)

Based on the definition above, two types of geographic data can be separated: static and dynamic. In static geographic data, the entities' locations are (relatively) permanent. Typically, data on geographic features, such as cities and roads, are static. In dynamic geographic data, the locations of the entities are expected or assumed to change over time. Naturally, the data on moving objects, such as vehicles, are dynamic. However, the mobility of the object does not imply dynamic data. The static or dynamic nature of the data depends on the collection methods and intended purpose of the data. Dynamic object data

can also be allocated to static geographic features forming, for example, the traffic density profile of a city.

When the data collection entities are people, and it is a question of an individual person, we are in the domain of personal data. In order to speak about personal data in its exact meaning, some further considerations are needed. In the Finnish Personal Data Act (Henkilötietolaki 1999, 3§) personal data is defined as: Any data that describes a natural person or her/his properties or living conditions, which can be identified as concerning her/him or her/his family or persons living in a common household with her/him. In the EC Data Protection Directive (Directive 95/46/EC, Article 2): "'Personal data' shall mean any information relating to an identified or identifiable natural person ('data subject'); an identifiable person is one who can be identified, directly or indirectly, in particular by reference to an identification number or to one or more factors specific to his physical, physiological, mental, economic, cultural or social identity". Those definitions reveal the essential feature of personal data. Personal data is always identifiable, it can be associated with a real existing natural person. In the simplest, and commonly understood, form this means some direct identifier in the data set. However, identification can also be indirect, as pointed out in the EC Directive definition.

Another type of data about people can be differentiated from identified or identifiable personal data. Data about people, which cannot be associated with any identifiable person, can be called population data. Population data can be further divided into individual level data, called microdata, and aggregated group level data, called macrodata.

Personal data is potentially dynamic, based on the mobility of people. However, at least up to now, most of the geographic personal databases have contained static data. Typically, persons are associated with their home addresses, which can be further associated into geographic locations. This is the case, for example, in Finland's official statistical data, where the georeference of persons is the centroid point of the building where they are living. Static personal data in this form does not describe the actual spatio-temporal behaviour of the people, in a narrow time scale. The collection of the real spatio-temporal dynamic personal data has been mostly restricted to limited cases, because of the difficult and expensive collection methods.

Geographic personal data and population data derived from it, are valuable information resources. There already exist large databases of, mostly static, geographic personal data. Good examples of this are public sector official population statistics and customer databases of companies. Geographic population data are used, for example, for administration and planning in the public sector and for marketing analysis in the commercial sector. Research also has a long tradition in utilising this type of data, concerning, for example, epidemiological studies. Not many possibilities have yet been offered for private persons to utilise this kind of information. However, applications can be easily found when thinking, for example, of selecting a preferable residential area based on the population profile of the areas.

The major restriction in the efficient utilisation of high quality, spatially precise, geographic population databases is the problem of privacy.

3 PRIVACY PROTECTION AND DISCLOSURE CONTROL

Privacy protection is a fundamental requirement set to management of any personal data. Protection of privacy is to be taken care of in collection, storing, processing, using and disseminating of personal data. In many countries privacy protection is regulated carefully and stated in the legislation; as in the EU in the Data Protection Directive (Directive 95/46/EC), and the corresponding national legislation.

A related question, to which often little attention is paid, is a person's trust in data collection and collectors. In many cases of data collection, people themselves can control if, and to what extent, they make information about themselves available. If people do not trust that their privacy is respected, even if the regulation formally exists, they do not make data about themselves available. People can give consent to collect and use their personal information in forms that are otherwise excluded by regulation.

The above-mentioned EC Data Protection Directive (Directive 95/46/EC) and Finnish Personal Data Act (Henkilötietolaki 1999) present the primary legislation concerning personal data protection in EU and Finland. In addition to those, there is also other relevant legislation. Considering mobile services, the Directive on Privacy and Electronic Communications (Directive 2002/58/EC) is of especial importance. It replaces and renews the old Tele Privacy Directive (Directive 97/66/EC). This new directive should be brought into force by the member states by the end of October 2003. Notable in the new directive (Directive 2002/58/EC) is that it explicitly takes into account location data as the geographic position of the terminal. The privacy questions of this location data and associated services, which have become available through the technological development during the last years, were not handled in the previous directive. Information about the relevant legislation and its analysis can be found, for example, from Simojoki (2002), Tervo-Pellikka (2002) and Liikenne- ja viestintäministeriö (2003).

For the present purpose, a few central definitions are collected here from the EC Data Protection Directive (Directive 95/46/EC, Articles 2 and 6):

- 'Personal data' shall mean any information relating to an identified or identifiable natural person ('data subject'); an identifiable person is one who can be identified, directly or indirectly, in particular by reference to an identification number or to one or more factors specific to his physical, physiological, mental, economic, cultural or social identity.
- 'Processing of personal data' ('processing') shall mean any operation or set of operations which is performed upon personal data, whether or not by automatic means, such as collection, recording, organization, storage, adaptation or alteration,

retrieval, consultation, use, disclosure by transmission, dissemination or otherwise making available, alignment or combination, blocking, erasure or destruction.

- 'Controller' shall mean the natural or legal person, public authority, agency or any other body which alone or jointly with others determines the purposes and means of the processing of personal data; where the purposes and means of processing are determined by national or Community laws or regulations, the controller or the specific criteria for his nomination may be designated by national or Community law.
- 'Processor' shall mean a natural or legal person, public authority, agency or any other body which processes personal data on behalf of the controller.
- 'Third party' shall mean any natural or legal person, public authority, agency or any other body other than the data subject, the controller, the processor and the persons who, under the direct authority of the controller or the processor, are authorized to process the data.
- 'The data subject's consent' shall mean any freely given specific and informed indication of his wishes by which the data subject signifies his agreement to personal data relating to him being processed.
- Personal data must be collected for specified, explicit and legitimate purposes and not further processed in a way incompatible with those purposes. Further processing of data for historical, statistical or scientific purposes shall not be considered as incompatible provided that Member States provide appropriate safeguards.

The key points in the definitions and regulations above can be summarised in the following way. Personal data collection and processing is bound by the purpose. The data subject can give her/his consent to personal data collection and processing. Personal data means any data that can be associated with an identifiable person, either directly or indirectly. The controller, which is often the same party as the processor, is responsible for the data and may not disclose it to third parties, excluding some defined juridical cases. The controller is not allowed to give any third parties access to the data, to disseminate or to transmit it to others.

Considering the dissemination and transmission of the personal data, the essential point is identification. If the data is not identified or identifiable to any person, it is not anymore personal data de jure. The personal data protection legislation does not apply to it anymore. Then it is a question of population data, as defined earlier, remembering of course that the original purpose restriction of the personal data collection is still valid. Unidentifiable population data does not cause any threat to the privacy of the persons either.

The identification question is not as simple as it might appear to be at first sight. Identifiable personal data is generally seen as formed of direct identifiers, such as a personal identification number or mobile phone number (MSISDN), and other attribute variables. One could easily think that anonymisation, the removing of the direct identifiers, would make the data unidentifiable. However, this is not true in general. Any of the other attribute variables, or combinations of them, can be potentially used for identifying a person.

The problem of protecting personal data from the risk of identification is well known in the official statistics field, where it is called statistical disclosure control. There exist several methods that are used for ordinary statistical data. A

comprehensive review of the principles and methods can be found from Willenborg and de Waal (1996), Willenborg et al. (2000) and Hänninen (1997), and some specific information, for example, from Dalenius (1977) and Skinner et al. (1994).

Considering the present context, the problem of the existing disclosure control methods is that they are developed for ordinary non-spatial data. Because of this, they are not directly applicable, or efficient, for geographic data. For that reason the Local Restricted Imputation (LRI) method, presented here in Chapter 2 and 3, was developed. Geographic data has certain specific features that are not taken into account by the traditional disclosure control methods; such as strongly identifying georeference and unit structure defined by the spatial configuration of the data. The LRI method takes into account special properties and applications of geographic data. It utilises modifiability of the units, natural hierarchy and spatial relations of the data. In that way, it tends to preserve maximal amount of information content of geographic data. The LRI method is being tested in Statistics Finland (Tammilehto-Luode 2001). The LRI appears to be a practically applicable and empirically efficient method for its intended purpose, as shown in Chapter 3.

4 LOCATION-BASED SERVICES

Location-Based Services (LBS) are a new type of services that have become available to mobile users during the last few years. Location-based services can be defined as value-added services that use the position information provided by the user or a positioning device or device that can be positioned (Tekniikan sanastokeskus 2002). However, value-added services for mobile users, even if they are the main concern here, are not the only type of services that use mobile terminals' location. Other service types are emergency services, lawful interception and network operator services, such as charging (ETSI 2000).

The starting point for intensive development of LBS can be seen to be the US Federal Communications Commission (FCC) Wireless E911 Rules (FCC 1999, FCC 2000). The requirements set now, after several modifications of the requirements and timetables, are that by the end of the year 2005, all of the emergency calls from mobile phones should be able to be located with a certain precision. The precision depends on the selected solution. The precision requirement for a handset-based solution is 50m for 67% of calls and 150m for 95% of calls. The precision requirement for network-based solution is 100m for 67% of calls and 300m for 95% of calls. The commercial value of the possibility of locating the mobile phones was also soon noted, and the development of value-added LBS started. The information about location of the terminals has always been an implicit part of the mobile network infrastructure. The design of base station structure, call routing, handover and roaming are based on spatial configurations and information. However, earlier location was used only for

network operators' internal operations. Now the development has lead to explicit utilisation of location. Mobile telecommunication terminals are augmented with positioning devices (GPS) and components supporting positioning, i.e. Location Service (LCS), are added to network infrastructure.

Explicit utilisation of location in mobile network and terminal infrastructure can be called location-aware mobile network. Its defining feature is that it is possible to identify and report the current location of the user's terminal in standard format (e.g. geographic co-ordinates), and make the information available to the user, mobile equipment, network operator, service provider, value-added service providers and mobile network operators' internal operations (ETSI 2000). Standardised support of location service features allows new and innovative location-based services to be developed.

Location-based services have generated a new technological environment, which extends information services and applications to new fields. They are expected to generate widening markets when they have reached and been adopted by professional and especially customer masses of mobile people. The positioning, at least at the basic level, has become a standard feature of existing mobile networks. Following this, location will be utilised in an increasing number of mobile data services.

Location-based services always involve some level of personal data. At the minimum, it includes identification of the terminal and its present location. For more advanced and usable services, typically more personal information is required. The development in that direction can be seen for example from W3C (2002) Platform for Privacy Preferences -specification.

5 LOCATION-BASED SERVICES AS A NEW MEANS OF COLLECTING AND UTILISING GEOGRAPHIC PERSONAL DATA

As a new technological environment, location-based services have strong potential. The possibilities can easily be seen, but fully discovered and explored only in time. Considering the possibilities, the adoption of the services and spread of the user base to mass market level is one of the key questions.

When the user base widens, it will generate significant new markets in geographic data and applications. This can be seen as a continuation of an increasing demand of geographic data in public and private sector GIS applications. In this development, especially commercial applications have played an increasing role. Due to mobile services for personal use, private individuals will most likely have an even more significant effect on the markets.

In these private customers lie also new markets of geographic personal data. One part of the markets is generated by private customers' need for population data, and related applications, in association with their present

environment (cf. Saarinen 2001). The other part is formed by “friend find” type of applications, where individual level geographic personal data is needed.

The other promise of location-based service environment, which might be even more revolutionary, is the ability to collect dynamic geographic personal data. The popularisation of location-enabled mobile terminals makes that type of data available to an extent that has never before been possible. Dynamic personal data in different forms would have extensive application possibilities, in public as well as in private sectors; thinking for example of mobility statistics (cf. Rainio 2001).

A lot of open questions still exist, as well as restrictive problems in the efficient collection and utilisation of geographic personal data in a location-based service environment. One of the key problems is privacy protection and personal data disclosure control.

6 SUMMARY OF THE PAPERS

This study consists of five papers, of which four are previously published. Three of them are written by the author and based on his own research work. The other two are jointly done with other researchers.

In this section, a summary of each paper is presented. They condense the contents and results of the paper. In the case of the joint papers, there is also a description of the authors’ contribution to it.

At the end, the relevant content of the separate papers is summarised from the viewpoint of the dissertation and their relationships to the comprehensive whole are presented.

6.1 Statistical Disclosure Control of Small Area Statistics Using Local Restricted Imputation (Chapter 2)

The paper was published in *The 52nd Session of the International Statistical Institute (ISI 99), August 10–18, 1999, Helsinki, Finland*, Bulletin of the International Statistical Institute, Volume LVIII, Contributed Papers, Book 2. Helsinki, 1999. 267-268.

The paper presents a statistical disclosure control method, Local Restricted Imputation (LRI), for geographic population data. The LRI method was developed by the author and it is being tested by Statistics Finland.

The LRI is a privacy protection method designed for protecting geographic personal data from the risk of disclosing any individual level information. The method can be applied to any (static) geographic personal data, subject to personal data protection legislation. The outcome of applying

the method is a “safe” data set, where individual level information is protected from disclosure. The resulting safe data set can be used more effectively and for a wider variety of purposes. It can be also disseminated to third parties, if other conditions, such as the specified purposes of collection, are satisfied.

The contribution of the LRI method is that it is the first statistical disclosure control method designed especially for geographic data. A number of statistical disclosure control methods exist, but they are developed, and mostly applicable, to non-geographic data. The LRI takes into account the special properties and applications of geographic data. It utilises modifiability of the areal units, as well as natural hierarchy and spatial relations of the data, while aspiring to preserve maximal amount of information content.

The LRI method is based on spatial aggregation of the data. The procedure of applying the method involves definition of the setting, identification of the disclosure risk areas and imputation of new values for the risk areas. The properties of the method are: the changes to the data are minimal, the influence to the statistical distribution of the variables is small or even non-existent, the precision of the data is preserved, the resulting data are locally consistent, and the spatial relations are mostly retained.

6.2 Disclosure Control of Geographic Population Data and Local Restricted Imputation Method (Chapter 3)

The paper has been submitted to the *Journal of Official Statistics* (JOS).

The objective of the paper is to present the statistical disclosure control problem, the problem of privacy protection of population data, in the context of geographic data, and study the solution for solving the problem with the Local Restricted Imputation (LRI) method. The LRI method was developed by the author, and already published earlier in the previous paper. However, in this paper, the method and its features are analysed more widely and in more detail, and studied empirically.

Utilisation and dissemination of population data is mainly restricted by the personal data privacy protection requirement, explicated and enforced in legislation. This restricts efficient, wide and beneficial utilisation of the high-quality population data sets, which are in large existence and can be collected. It is possible to use the population data in unidentifiable form, when the data is no longer subject to the personal data protection legislation. To meet this condition, there should be no possibility of disclosing any individual level information from the data. This is a problem area known as statistical disclosure control. There is a long tradition in the methodology of disclosure control in the field of official statistics. However, the widening demand and utilisation of geographic data has challenged the traditional disclosure control in new ways. The standard methods for general statistical data are not applicable, or are

inefficient, for geographic data. The LRI method was developed especially for this purpose, for disclosure control of georeferenced population data.

In the paper, first the framework of the statistical disclosure control is presented. Then the forms and features of population data and geographic data are analysed. The problem of identification and disclosure is studied in detail, leading to a model of identification risk. The tradition of statistical disclosure control is presented, and the existing disclosure control methods for non-spatial data reviewed. Later on, the LRI method is presented. The procedure of applying it is described in detail. The features of the LRI method are studied in some empirical cases. The results show that the method is applicable to the intended purpose, and it has certain clear advantages, compared to the traditional methods of handling the same cases. Also a method for supporting the LRI procedure, in specification of the spatial configuration, is introduced. Finally, the LRI method is assessed with respect to its features and parameters. At the end, further research topics are outlined and the paper concluded.

The paper shows that the LRI method is a practical, usable and efficient disclosure control method for geographic personal data. It appears to be superior to the basic techniques used earlier. However, more study and testing of the LRI method would be needed, especially considering the parameters of the method as well as application to different types of cases.

6.3 Developing GIS-Supported Location-Based Services (Chapter 4)

The paper was published in C. Claramunt, W. Winiwarter, Y. Kambayashi & Y. Zhang (eds.) *Proceedings of the 2nd International Conference on Web Information Systems Engineering (WISE 2001), December 3-6, 2001, Kyoto, Japan*, Volume 2. IEEE Computer Society, Los Alamos, California, 2002. 66–75.

The paper is a joint work with Kirsi Virrantaus, Jari Veijalainen, Artem Katasonov, Artem Garmash, Henry Tirri, and Vagan Terziyan. A major part of the location-based services section is written by the author. The author is responsible also for a large part of the structure and central content, together with the first two authors. The contribution to the pilot system section corresponds to the role expressed in the next paper. The technical contribution was co-ordination of the writing of the paper. This paper and the next paper are results of the same research work, conducted in the MultiMeetMobile project. The papers were produced simultaneously, even if the publication years are different. They have some overlapping content, as well as a different group of writers. However, as can easily be seen, the actual topic, approach, and major part of the content, are different in these papers.

The objective of the paper was to study the relationship of LBS and GIS, as well as the possibilities of GIS in supporting development of more advanced LBS systems.

The starting point of the paper was the present state of location-based services. The first generation of LBS has been implemented and they are slowly being adopted by mobile users. The LBS have been born on the mobile telecommunications area, and are developed based on the network's ability to locate the mobile user through her/his mobile terminal. The existing LBS are relatively simple and do not use very precise positioning methods. However, when more users adopt the LBS and get accustomed to them, the development will steadily lead to more elaborate services. The advanced services will be more complex, integrating different information systems and data. They are going to be more useful for the everyday usage of mobile users.

GIS field has a long history on professional geographic data management and utilisation. The existing GIS field and systems have extensive knowledge and elaborated methods and tools, as well large databases, which can be effectively utilised in the development of future advanced LBSs.

The telecommunications-based LBS field and geoinformatics-based GIS field have certain common ground. The development of both areas will gain from each other's advancements and they are expected to support each other more in the future. The driving force will be an increasing demand of geographic applications and services, generated by popularisation of the LBS, leading to widening markets for geographic data in different forms.

6.4 Developing MLS Location-Based Service Pilot System (Chapter 5)

The paper was published in O. Martikainen, K. Raatikainen, J. Hyvärinen (eds.) *Smart Networks*, IFIP TC6/WG6.7 Seventh international Conference on Intelligence in Networks (SmartNet 2002), April 8–10, 2002, Saariselkä, Lapland, Finland. Kluwer, Boston, 2002. 229-244.

The paper is a joint work with Artem Katasonov and Artem Garmash. The author has made the major contribution to this paper, which has been in the design and assessment of the principles and solutions of the MLS system, as well as supervising the solving and implementation of specific solutions conducted by the co-authors. As noted earlier, this paper was a result of the same MultiMeetMobile research project as the previous paper.

The objective of the paper was to study the properties and features of LBS systems. The research was carried out by designing and implementing a LBS pilot system, called MLS, based on the background research done in the MultiMeetMobile research project. The purpose of the pilot was to demonstrate and test specific design principles, mobile computing environments and

architectural solutions. The pilot system was also intended to be an empirical platform for further research. The design was planned to be a general solution allowing empirical testing of advanced and more complex LBS.

The essential feature of the design was to use geographic vector data, and XML-based format, for transmitting location-based information to the client. This gives some efficiency advantages in the data transmission and storing. Furthermore, it allows the potentially delegation of some computing to the client, even in "stand-alone" conditions. Other features under study were intelligent data selection and transaction management support. The architectural solutions take into account different types of LBS data contents: mobile users' location data, geographic base data, and georeferenced value-added data. Based on those features, the MLS pilot system operating in the client-server environment can be used for further study of geographic data utilisation and collection.

6.5 Dynamic Geographic Personal Data – New Opportunity and Challenge Introduced by the Location-Aware Networks (Chapter 6)

The paper was published in *Cluster Computing*, Vol. 4, No. 4, 2001. 369-377.

The objective of the paper was to study the new possibilities of collecting dynamic geographic personal data. The new possibilities follow on from the development of mobile networks and terminals, which allow the locating of mobile users. These possibilities were tackled by outlining a service, called Dynamic Geographic Data Service (DGDS), to an existing mobile computing environment.

The starting point of the paper was the already existing and steadily widening utilisation of locating enabled mobile terminals and supporting mobile networks, making location-based services available. These services involve inherently some dynamic geographic personal data, and they can be used also for collecting other additional data. This type of data would be very valuable for both the commercial and public sector. The major problem limiting the data collection is the privacy protection problem. However, the paper proposes that it can be handled, and even solved more easily, with the appropriate methodology built into the data collection system.

This paper brings together the topics handled in the earlier research papers presented here. In the paper, the personal data content in LBS is studied and DGDS is outlined as a service collecting and disseminating the data. The DGDS functionality involves: anonymising, personal data collecting, data management and analysis, and population data server.

6.6 Concluding Summary of the Papers

The five papers, summarised above, handle topics related to the application of geographic data, and especially geographic personal data. They study privacy protection and disclosure control, geographic information systems and geographic data utilisation, and location-based services. The first paper (Chapter 2) presents a solution for the privacy problem of static geographic personal data. It introduces for the first time a disclosure control method developed especially for geographic data. The second paper (Chapter 3) presents and analyses the problem of statistical disclosure control more deeply and widely. It presents the developed LRI method in more detail. It is also analysed theoretically and tested empirically. The paper shows evidence of the usefulness and effectiveness of the method. The third paper (Chapter 4) handles the issue of development of advanced LBSs and the contribution of GIS field to this. In this paper, the economic aspects and different types of geographic data content are also presented. The fourth paper (Chapter 5) studies the LBS system in the mobile computing environment. The paper presents a study of the technological environment, upon which the potential of new geographic data utilisation and collection possibilities will lie. The fifth paper (Chapter 6) presents the idea and outlines a system for utilising the LBS system environment for collecting dynamic geographic personal data and making it available for efficient utilisation, taking into account the privacy protection problem.

The underlying and uniting idea of the research presented in the papers is the collection and utilisation of geographic personal data. That is not explicitly presented in every paper, but it has been a motivating force in the background. Appropriate disclosure control methods, handled in the first two papers, play a key role in a widening and more efficient utilisation of geographic personal data. The third paper brings the question of collection, management and utilisation of geographic data in geographic information systems to the field of new mobile geographic information collection and dissemination technology, location-based service systems. Population data is one important type of data, which can be used as a source for information content in the LBS context. The fourth paper presents a research and development study of a LBS system. For the present context, it contributes as a study of computing environment and data management in developing LBS systems. The knowledge of technological enablers and their possibilities, as well as restrictions, have a significant role in defining the present situation and further developments of the field. The last paper collects and combines the questions handled in the earlier papers. It studies the possibilities and problems of geographic personal data in LBS environment, in the near future.

7 CONCLUSIONS

The research presented here, as a combination of five papers, has been an ongoing undertaking starting from the privacy protection problem and continuing to the new mobile application environment. The final point reached is directed at a view of the future, the prospects and problems of dynamic geographic personal data.

The underlying view in this research has been the noted tendency of the increasing demand of geographic personal data as well as the enormous potential of new applications. Geographic personal data has high practical and economical value when it can be efficiently collected and used for supporting the needs of private and public sectors, and also the people themselves.

Considering the future, the mobile location-based service environment opens new and interesting possibilities for data and applications. On one side, the prospects lie in the new and wide data markets. From the other, the new data collection possibilities are significant. In the centre of both of these possibilities lies the privacy protection problem.

Privacy is a restricting factor associated with any personal data. However, it does not limit the utilisation of personal data when it is handled in an appropriate way. It was shown that with proper methods, such as LRI, privacy can be granted while maintaining the usability of data for applications.

At the present time, the potential of geographic personal data is not yet fully realised, even if there is great interest in using it. In addition, there are still many open questions, both theoretical and practical, that require further research before the more useful applications can be realised.

Based on the experience collected during the research, some essential research problems for the further study were identified. The major emphasis in identification of the problems was in the future advanced location-based services.

At first, considering privacy protection, the most important problem would probably be the extension of systematic analysis and methodological development of the mobile environment. In disclosure control, the key point is the identification of an individual. The identification problem is more complex and demanding in the case of dynamic data. For example, the movement of a person actually describes her/his behaviour in such a way that she/he can be identified. Dynamic data sets new challenges to the disclosure control methodology, implying a new dimension.

Secondly, in commercial applications, an essential question is the significance and utilisation of the geographic persona data in electronic commerce. Mobile electronic commerce necessarily involves geographic personal data in business transactions. It can have also a significant role in marketing directed at mobile people.

The third identified problem was connected to the technological and business environment of the location-based services. In here, the most urgent

problem is how privacy is related to the location-based service architectures and business models. The service architectures involve several different actors in various roles. Usable services require transmission of geographical personal data between the different actors, which easily challenges the privacy of the individuals. In this context, the question also arises of combining personal data sets from different sources for efficient utilisation.

The research presented here contributes to a dynamic and rapidly developing information and communications technology field. The problems mentioned above are the directions in which the presented study can be continued in the near future. However, the relevance of the research topics is strongly dependent on technological and commercial development of the field as well.

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YHTEENVETO (FINNISH SUMMARY)

Tämän tutkimuksen aiheena ovat henkilöpaikkatietoaineistot, niiden tietosuoja ja hyödyntämismahdollisuudet paikkaperusteisissa palveluissa. Tutkimus koostuu viidestä artikkelista sekä artikkeleiden sisällön kokoavasta yhteenvedosta. Siinä käsitellään henkilöpaikkatietoaineistoihin liittyviä keskeisiä ja ajankohtaisia kysymyksiä. Tarkastelun kohteena ovat niiden tietosuojaongelma, uudet mobiilit palvelu- ja sovellusympäristöt sekä tulevaisuudennäkymät mahdollisuuksineen.

Lähtökohtana tutkimukselle on ollut informaatioteknologian kehityksen myötä tapahtunut paikkatietoaineistojen kysynnän kasvu ja sovellusalueiden laajeneminen. Henkilöpaikkatietoaineistot muodostavat tärkeän osan paikkatietoaineistoja, joilla on laajat hyödyntämismahdollisuudet sekä julkisella että yksityisellä sektorilla. Henkilöpaikkatietoaineistot ovat henkilötietoja sisältäviä paikkatietoaineistoja, joissa henkilötietoihin liittyy sijaintitieto. Hyvä esimerkki henkilöpaikkatietoaineistoista ovat Suomen Tilastokeskuksen keräämät tilastoaineistot kansalaisista, joissa henkilöt liitetään kotiosoitteeseen ja edelleen asuinrakennusten sijainnin kautta maantieteellisiin koordinaatteihin.

Mobiilin viestintäteknologian leviäminen ja viimevuosien aikana tapahtunut kehitys on antanut merkittävän sysäyksen myös paikkatiedon hyödyntämiseen. Matkaviestinverkon ominaisuuksiin on lisätty mahdollisuus paikantaa matkaviestimet ja joihinkin matkaviestimiin on jopa integroitu itsenäinen satelliittipaikannusominaisuus. Tämä on tehnyt mahdolliseksi uudentyyppiset paikkaperusteiset palvelut (Location-Based Services, LBS) joissa käytetään hyväksi mahdollisuutta paikantaa mobiililaite ja välittää sen sijaintitieto. Esimerkkejä tällaisista palveluista ovat lähimmän ravintolan sijainnin haku tai lähialueen kartan tilaus matkaviestimeen. Paikkaperusteiset palvelut hyödyntävät paikkatietoaineistoja sen eri muodoissa. Uudet mobiilit paikkaperusteiset palvelut tarjoavat myös uusia mahdollisuuksia hyödyntää olemassa olevia laajoja paikkatietoaineistoja. Paikkatietoaineistojen hyödyntämisen lisäksi mobiililaitteita voidaan käyttää myös aineistojen keräämiseen. Laajasti käytössä olevien matkaviestimien hyödyntäminen avaa mielenkiintoisia mahdollisuuksia erityisesti dynaamisten henkilöpaikkatietoaineistojen keräämiselle. Se ei ole aiemmin ollut käytännössä mahdollista laajemmassa mittakaavassa.

Henkilötietojen keräämistä ja hyödyntämistä rajoittaa aina yksityisyyden suoja, henkilötietojen tietosuojavaatimus. Henkilötietojen tietosuoja on useissa maissa turvattu lainsäädännöllä, kuten esimerkiksi EU:ssa direktiiveillä ja niiden pohjalta johdetuilla kansallisilla laeilla. Yksilöön liitettävissä olevia tietoja ei saa kerätä ja käyttää vapaasti mihin tahansa tarkoituksiin, eikä niitä saa luovuttaa muille osapuolille.

Tutkimuksen ensimmäisessä osassa (kaksi ensimmäistä artikkelia) tarkastellaan henkilöpaikkatietoaineistojen tietosuojaa. Tietosuojaongelma ja sen erityispiirteet paikkatietoaineistojen tapauksessa analysoidaan ja ongelman ratkaisemiseksi esitetään uusi tilastollinen tietosuojamenetelmä. Tätä menetelmää

kutsutaan paikalliseksi rajoitetuksi imputoinniksi (Local Restricted Imputation, LRI). Menetelmän ominaisuuksia tarkastellaan ja sitä testataan todellisella empiirisellä aineistolla. Menetelmä on käytännössä toimiva. Sitä käyttäen voidaan henkilöpaikkatietoaineisto suojata yksilötason henkilötiedon paljastumiselta ja se säilyttää aineiston informaatiosisällön merkittävästi paremmin kuin tämäntyyppisessä tilanteessa normaalisti käytetyt menetelmät.

Toisessa osassa tutkimusta (kaksi seuraavaa artikkelia) tarkastellaan uuden mobiiliympäristön ominaisuuksia ja mahdollisuuksia paikkaperusteisten palvelujen kehittämisessä ja paikkatiedon hyödyntämisessä. Paikkaperusteisia palveluita analysoidaan ja mobiiliympäristön paikkatietoaineistojen käytön mahdollisuuksia ja rajoitteita tutkitaan suunnitellun ja toteutetun pilottijärjestelmän avulla.

Tutkimuksen loppuosa (viimeinen artikkeli) kokoaa yhteen edellisissä osissa käsitellyt aiheet suuntautuen myös tulevaisuuteen. Siinä tarkastellaan mobiiliteknologian kehityksen mukanaan tuomia mahdollisuuksia kerätä ja hyödyntää dynaamisia henkilöpaikkatietoaineistoja. Dynaamisten henkilöpaikkatietoaineistojen mahdollisuuksia tutkitaan luonnostelemalla mobiiliverkkoon liittyvä dynaamisen paikkatiedon palvelu (Dynamic Geographic Data Service, DGDS). Palvelun toiminnallisuuteen sisältyvät: anonymointi, henkilöpaikkatiedon keräys, aineistojen hallinta ja analyysi sekä aineistojen välittäminen.

Tutkimus käsittelee henkilöpaikkatietoaineistojen keskeisiä kysymyksiä niiden eri käyttömuodoissaan. Näin se muodostaa yhtenäisen kuvan henkilöpaikkatietoaineistojen hyödyntämisestä nykyisissä ja tulevissa paikkatietosovelluksissa ja palveluissa.

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