【原著論文】

Availability of a mobile GIS loading GPS for census operations

— A case study of the development and application in Korea —

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Abstract: As a Personal Digital Assistant (PDA) emerges as one of major vehicles to realize GIS, the concept of mobile GIS has recently come into existence. Developed as a navigation system, the mobile GIS could be more applicable to census operations. With the advantages of the mobile GIS, if the system would be adopted, it is highly expected for the creation of the optimal census-taking environment and management infrastructure. Moreover, the study on modifiable areal unit problem (MAUP) would be given an impetus since it is easy to produce statistics on different combinations of small areas with this system. This paper aims to introduce a case study of a mobile GIS loading GPS that is developed and applied to an area in *Gangnam-gu, Seoul, Korea*.

Keywords: Mobile GIS, GPS, Personal Digital Assistant (PDA), Census, Modifiable Areal Unit Problem (MAUP), Enumeration Districts (EDs), Seoul

1. Introduction

A mobile GIS, which is composed of PDA and GIS, has come into existence recently. A navigation system is a major vehicle of the mobile GIS. However, it has some constraints for further utilization in various fields (Shinoaki, 1997; Okunuki, et al., 2000). It requires a series of techniques to operate the mobile GIS, i.e., portable terminals, mobile communication service, and techniques in content utilization including mapping information. One of advantages of the mobile GIS is to acquire individual information instantly on the spot. Wherein, individual information is digitalized spatially through the Global Positioning System (GPS) (Kohsaka and Murayama, 2001).

As is the case of facility management and Point of Sales (POS), the mobile GIS is believed to be possibly used also in census operations. A census is covering

all the objects within whole country at a given period of time. Generally, it is vulnerable to large non-sampling errors since it mobilizes huge manpower and takes several years; it ranges from planning to delineating EDs, enumerating, data capturing and to tabulating (Clark, 1982; Johnston, 1983; Walter and Fritsch, 1999). In this regard, if a mobile GIS loading GPS could be introduced to census-taking, some census operations would be more effective and efficient.

On the other hand, census data are usually provided either at an individual level on a sample basis or at an aggregated level. However, the aggregated data are essentially arbitrary geographical areas. The areal units used to report census data (basic unit districts, enumeration districts, various administrative levels) have no natural or meaningful geographical identity. Unfortunately, this means that analyses of these area aggregations may be conditional upon the set of zones, which are presented. This effect is known as the modifiable areal unit problem (MAUP)

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and has two related aspects. First, scale effect is the variation in numerical results that occurs due to the number of zones used in the analysis. Second, results may also differ between different ways of aggregating exactly the same data to the same scale; this may be called the aggregation effect (Openshaw, 1984a). The MAUP has been discussed in the spatial analysis literature since the 1930s, but it is the recent surge in the availability of Geographical Information Systems that have caused both a resurgence of interest in the problem and greater need to learn more about it. Census planners need to notice that most census data are presented with different statistical values and implications according to the type or level of aggregation due to the existence of MAUP (Openshaw, 1984b). In order to minimize this problem, more flexible or on-demand aggregation is suggested. It has been recently a high demand that individual data should open and available to users since they are public goods. In particular, the strengthened mobile function of GIS brought by the development of information technology makes it possible to combine individual data with geographic information. Accordingly, the need of modifiable areal units is frequently raised among geographers.

This study aims to introduce the experience of a case study which developed a mobile GIS with a prototype GPS for the census-operational purpose and applied it to an area in *Gangnam-gu, Seoul, Korea*.

2. Major functions of a mobile GIS loading GPS

The functions considered for the development of a mobile GIS loading GPS in this study are as follows :

First, it is essential to detect the exact locations on the spot. An address searching function and the coordinate information should be installed on the mobile GIS. If the location information of interviewers in the field would be provided on the mobile GIS with the help of GPS function, its effective usage would be

more secured. Also, more efficient survey would be taken with the path searching function of GIS, which can trace the shortest cut in each enumeration route.

Second, the function of network should be installed to improve census-taking environment. The network among enumerators, supervisors and census officials through the mobile GIS system would make the field management more effectively.

Third, the function of buffering is to be included to provide demographic and other important information such as number of school-going children within a street or a block.

Fourth, the system should be developed in the way that the mapping information could be easily entered and updated. Generally, the mapping information, particularly boundary information of EDs or Basic Unit Districts (BUDs) loaded on the mobile GIS is frequently changed.

Fifth, the system of mobile GIS is to be devised to strengthen the ability of data collection. The information collected can be saved in the form of graphic information linked to maps. The time of enumeration would be automatically recorded while data are entered with a pen.

Sixth, when data are entered, the system should operate *Window* screen to make beginners feel easy. Past data should be available for reference. The support of a map screen for data entry on ED maps, and a functional key for data entry should be given.

Seventh, the system should support the manipulation, analysis and printing of data. When the enumerators complete their job, they could check and evaluate their work. Also, the function of matching identifiable nature of information such as name, sex, age and address should be serviceable to facilitate making each summary sheet by EDs.

Last, as one of the most important function of the system, data should be tabulated for areas in which researchers and users are interested. This would provide a practical tool for the study of MAUP. Also,

Mesh and other small area statistics are to be available in this system.

3. Development of the system and its application to the 2000 census in Korea

The delineation of EDs is usually accomplished ahead of the field operation in a census. Each ED in the 2000 Census in Korea was delineated to comprise approximately 60 households. This task is executed in order not only to allocate a proportionate workload to enumerators but also to prevent the omission and duplication in census counts. The success of ED delineation largely depends on how accurately to freeze the boundary of EDs. Therefore, the accuracy of base maps is one of major concerns for census planners. In order to improve the quality of base maps, the 2000 Population and Housing Census in Korea adopted first the digital maps produced by the National Geographic Information System (NGIS) pro-

gram instead of the raster maps used in the previous censuses.

The scale of base map is 1/1,000 in urban areas (refer to Figure 1), 1/5,000 for rural areas and 1/25,000 for mountainous areas.

This study chose an area of *Nonhyun-dong, Gangnam-gu* for the test and application of mobile GIS. This area was selected because it had experienced little changes recently and showed a proportionate distribution between detached houses and apartments.

For the application of the system to the field operation in a census, a mobile GIS was developed by using the PDA. It was designed on *Windows CE3.0*, and thus can be operated with *Window95* and higher version. It is so light, merely 170g, that enumerators can easily carry during the field operation. The data in PDA can be sent to and received from the server through a wireless communication system (refer to Figure 2).

Figure 1 A base map of the 2000 Census in Korea

On the other hand, in the 2000 Census in Korea conducted as of November 1 for 10 days, enumerators had different workloads according to their enumeration areas. One ED in sample enumeration areas (long-form areas) or two EDs in complete enumeration areas (short-form areas) or three EDs in complete enumeration areas among households residing in apartments are the workloads given to an enumerator respectively. The absolute coordinates, as UTM location (see UtmX and UtmY columns in Figure 6), are created on *Microsoft Access*: after location information of living quarters and households at each ED is entered (refer to Figure 3). Figure 3 shows an example of how to enter living quarter and household numbers and their addresses when a pen points 020-1 ED from the base map (Figure 1). The number of items for short-form was 20 whereas that for long-form was 50; the items of short-form are name, relationship to household head, sex, age, education, marital status, place of birth, type of living quarters, type of household, number of rooms, total area of housing site, etc.; and those of long-form are place of residence 5

years ago, commuting status, economic activity, rent, use of PC and the Internet, type of heating, number of automobiles, parking places, etc. (National Statistical Office of Korea, 2001). The information on housings and individual household members is to be entered through a graphic user interface like census forms (refer to Figures 4 and 5). Figure 4 shows a screen for data entry on housing items such as type of household, number of rooms in use, housing facilities, and type of occupancy while Figure 5 on individual items such as education attainment, place of birth, and marital status.

The entered information is to be queried by *Microsoft Access*. This system has the coordinate information on streets and houses, and most features of map consist of layers (refer to Figure 6).

4. The expected effects and implications of the system development

The mobile GIS system could be a very useful tool for the delineation of EDs. Generally, either duplication or omission of areas happens in the delineation

Figure 2 Network system configuration
Note: KNSO (Korea National Statistical Office)

of EDs due mainly to the inaccuracy of base maps. As stated earlier, the 2000 Census in Korea used digital maps for this reason. With this digital information of geography, if combined with census data, the system would enhance the accuracy of ED delineation.

To put it more specified, the system would help census-takers to delineate each ED more analogous in terms of its geographical size and the number of households. The ED delineation is usually accomplished by the rule of thumb using relatively inaccurate registration data.

On the other hand, the enumeration procedure in the field will be more convenient and more accurate with the GPS function of the system. It would help enumerators locate buildings and living quarters and find out routes more effectively. They could be assisted largely with the mobile GIS system when they have to revisit households in particular.

Also, it would enhance the data quality by enabling enumerators to check instantly the answers collected. Not only range checking but also logical checking would be available as soon as the answers are

entered into the PDA.

This system is expected to facilitate more effective field management in census-taking by establishing networks among enumerators, supervisors and census officials.

Census officials could monitor easily the activities of enumerators on a real time, and solve consistently the problems met by enumerators in the field. With these advantages of the mobile GIS, if the system would be adopted, it is highly expected for the creation of the optimal census-taking environment and management infrastructure.

One of the important benefits of the system to be addressed is the expedition of the study on modifiable areal unit problem (MAUP) since it is easy to produce statistics on different combinations of small areas with this system. The use of individual data would be more emphasized with this system. For the public use of full set of individual data, of course, the protection of privacy should be highly considered. In this regard, the contradictions between the positive attitude on users' side and the negative attitude on

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Figure 3 Location information

producers' side toward the use of individual information should be arbitrated. In a sense, it can be exclaimed that it's thoroughly a job of census authorities since they are the only group not only holding the complete their individual data but also being free in using them without the breach of regulations on privacy information.

Now it is about time that the census takers should start to recognize that their usual practice in data aggregation might lead policy-makers in wrong direction and therefore they should start to review the feasibility of their areal units on which census data are cross-tabulated, and of user-defined areal units.

Another important benefit to be pointed out is more active use of individual data. The panel survey would be easier than before by in-depth analyses of individual data. The areal combination of household

survey and establishment survey would produce more meaningful and valuable results. It is also expected more efficient accomplishment in spatial analysis with the absolute coordinates created in this system.

5. Concluding remarks

Considered the close relationships between census and computer technology, the census in the 21st century would see a big improvement in census-taking method due to fast developing information technologies. For example, the census in the future would be the e-census that does not require questionnaires in paper, and might need one-stop processing in field operation. In this context, as revealed in this study, a mobile GIS loading GPS could be a useful tool to meet such needs.

주택 정보 입력

가구구분
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별도로 사용 방수
방이란 사면이 벽 또는 문으로 막혀 있고, 높이는 1.8m, 넓이는 3평 이상이 것을 말합니다. (별도로 차단된 식당수는 식당이 벽 또는 문등으로 거실과 차단된 경우만 해당합니다.)

사용 방 수

거실(대청마루) 수

별도로 차단된 식당수

주거시설형태
이 주택의 부엌, 화장실, 목욕 시설은 어떤 형태이며, 어떻게 사용하고 있습니까?

부엌은 이며 사용

화장실은 이며 사용

목욕 시설은 이며 사용

점유 형태 구분
이 집은 주거전용입니까, 영업전용입니까? 또 자기집입니까, 아니면 셋집입니까?

주거 구분

소유 구분

Figure 4 Data entry screen for housing items

가구원 정보 입력2

교육정도
교육부장관이 인정하는 학력을 정규 교육으로 봅니다. 검정고시 합격은 정규 교육을 받은 것으로 인정합니다.

정규 교육은 어디까지 받았습니까?

졸업여부

출생지
태어날 당시 어머니가 살고 계셨던 곳을 말합니다.

태어난 곳

다른 시/군/구일 때는 해당되는 시/도, 시/군/구의 현재 행정구역명을 기입하여 주십시오. 북한의 경우에는 당시의 시/도, 시/군/구를, 외국일 경우에는 국가명만 기입합니다.

광역시/도

시/군/구

혼인상태
나이가 16세 이상만 기입할 수 있습니다. 호적과 관계없이 실제 혼인 상태를 체크하여 주십시오.

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Figure 5 Data entry screen for population items

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Figure 6 Date file in Microsoft Access

First of all, using a graphic-user interface, it does not require paper questionnaires. Answers can be directly entered into and retrieved from the PDA by enumerators.

Furthermore, the efficiency of field operation in census would be promoted to a larger extent with its function of network and GPS. The accuracy of census also would be enhanced highly with the function of checking and querying answers in this system. In addition, since this system can help researchers and users to compile statistics just within the area they are interested in, it is expected that some studies on the MAUP would benefit from it by manipulating areal aggregation more freely.

However, the cost-effective maintenance of the system, particularly for the continuous up-to-date of mapping information is Achilles' tendon in this system. Therefore, it is suggested for the success of the system that the future study should be focused on both the development of technical side and the institutional side to support and maintain its infrastructure.

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