Urban GIS for Man-navigation system based on GPS signals via Cell phone

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Abstract:- The commercial success of a car navigation system is attributed to GPS information. However, unlike the car navigation system, which navigates broad highways without any blockages of GPS signal reception. But a man navigation system has not yet proved successful, because this system is designed for a pedestrian walking along a sidewalk, where high buildings block incoming GPS signals. Proposing solutions are 1) providing new GPS satellite with finer resolution, 2) psuedolight technology, and 3) combining GPS information with other sensors. In this paper, I elaborate on the feasibility of utilizing the man navigation system in overcrowded metropolises using only the existing GPS information.

Keywords:- cell phone based mobile location service, GPS (global positioning system), psuedolight technology, gyrocompass, an agent program

1 Introduction

The GPS has proved unsuccessful in a man navigation system in overcrowded urbanized areas. A GPS-based navigation system requires the simultaneous reception of at least four GPS signals. When with fewer than three signals,the system would not be able to accurately calculate the target location altogether[1]. Now several breakthrough approaches to rectify this condition;

- Launching a new GPS satellite with a finer resolution: This is a direct approach. In fact, both EU and Japan are planning to launch a new GPS satellite of their own, which will interact with the existing US GPS satellite network to generate signals with high resolutions targeting at the European nations and the Japanese archipelago. This approach is helpful for a car driving in the middle of highway. But it would not help a pedestrian walking along a sidewalk where tall buildings cutting off the GPS signals.
- Pseudolight technology: During the cold war, the United States government had given access to the best ground resolution solely to the U.S. army, and had allowed other users to receive a less resolved GPS signal by adding an artificial noise to it. In order to unscramble the noise-added signal, the Russians scientists came up with a small device, "a pseudolight", to be deployed underground wherever it was necessary. Before these cigar-shaped gadgets were buried underneath the ground, their precise locations were carefully recorded. Once they were underground, they started radiating signals exactly the same as the one emitted by the US GPS, indicating the locations. Thus, the Russians were able to fine-tune their locations using the more precise information obtained from the nearby pseudolight, even when the U.S. GPS was scrambled.
- Using a supplemental gear: Before the GPS, major automobile manufacturers had tried to develop a car navigation system using gyroscope and so on. However, errors accumulated as a car makes a turn at an intersection. Researchers could not find a solution for offsetting these er-

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rors. Recently, a group of Japanese researchers have been studying the feasibility of hybrid technology whereby applying a GPS and a gyrocompass concurrently.

Three cell-phone providers are offering mobile location services in Japan. However, they can only provide low resolving signals with slow processing time. It takes two to three minutes from the onset of the direction software program to search a location of a user. The cell phone transmits the GPS information to a computer server. The server extrapolates the location of the user, and creates a dot image map of the destination. Then the server sends the image as packets data back to the cell-phone. The user has to repeat these procedures as often as necessary to arrive at his/her destination

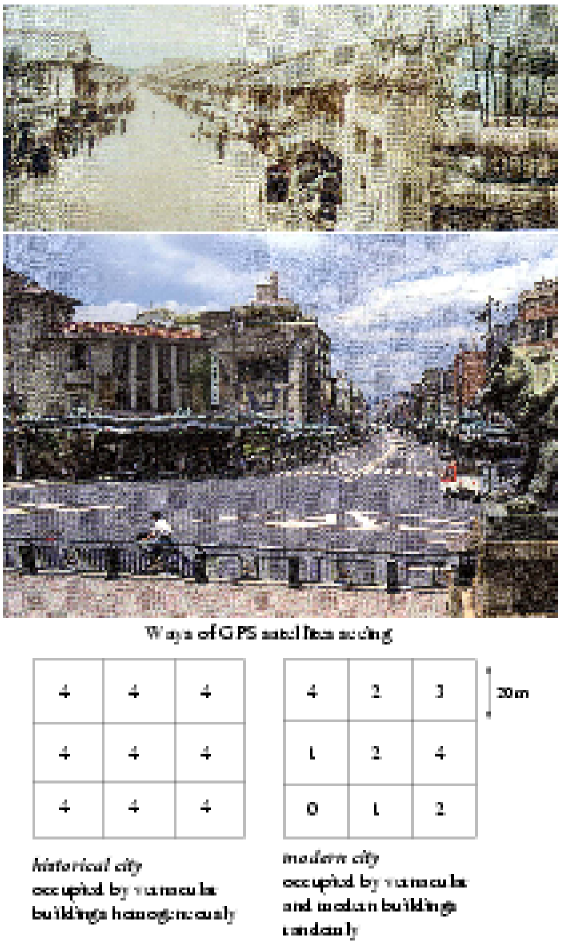

Figure 1: Kyoto, Japan in 1900 (above) and 1960 (below) photographed at the same viewpoint

2 Our Proposal

2.1 Our proposal

The proposed approaches stated above have features in common.

1. At least 4 GPS satellites must be seen on site.
2. A user of cell-phone must be connected with a server repeatedly until the user receives enough information to get to the destination. It often requires not only a prolonged time period, usually in minutes, but also has so much room for miscalculation that busy users simply cannot afford to rely on such services.

Therefore, we propose as follows:

1. Even when we cannot see any GPS satellite on site, we could still speculate our location, by using the same method the GPS uses to locate the target site, namely the use of some relevant information obtained from the surroundin
2. We need to create a smaller database so that a user is required to place just one phone call from his/her cell-phone to a server, thereby saving a lot of time as well as cost.

2.2 Background

Before motorization and reinforced concrete highrises (ca. 1900) became ways of life, the majority of large cities in the world shared a homogenous appearance, because most cities were composed of archaic housing. Figure1 shows the difference between the photographs taken in 1900 and in 1960 [2].

If we would measured GPS seeing at that time, as shown in the lower left part of Figure 1, that we would have seen GPS everywhere equally. On the other hand, large modern city is occupied by different types of buildings randomly. The lower right part of Figure 1 tells uneven GPS seeing ditribution site by site. Landscapes of modern cities are somewhot similar If I would not specify the name of cities in Figure 2, it would be difficult to distinguish modern cities each other. The population of KouriYama and Schiras are 350,000 and 1,200,000 respectively.

A busy businessman who will visit a specific building in a crowded city does not walk more than 30 minutes in general. Usually he checks the target address in advance and starts his walking from either the nearset bus stop or subway and railway station. A man walks about 1 Km per 10 minutes so that a seach area would be within a circuit with 3 to 4 Km in diameter whose center is a bus stop or a railway

Figure 2: KouriYama, Japan in 2002 (above) and Schiras, Iran in 2005 (below) photographed by the auther

exit.

Today an average memory size of cell phone is about 400 K bites. If we can create a small map database and an agent software which can be stored in the cell phone memory, we can reduce the communication with a server.

3 Measurement in the Field

To verify our hypothesis, we make a field experiment in Kouriyama city, Fukushima prefecture, Japan. It is a typical local business center and the nearest large city to Aizu city where Aizu University locates. The reason why I do not select AizuWakamatsu city is because Aizu city (less than 100,000 popupation) is a small historical town with a castle so that vernacular houses are still dominant.
Figure 2 above shows urban landscape around Kouriyama railway station which has a typical outlook of any large local cities in Japan. I have traveled and visited all the major cities in Japan. All of them are looks alike. Their characteristics are the following:

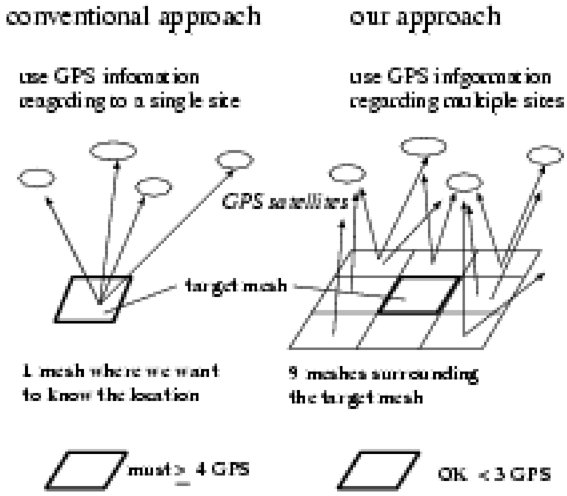

Figure 3: conventional and our approaches

1. There is a certain wide open space (bus rotary) around the bus stop or in front of a railway station where we can see more than four GPS satellites always.

2. There are multi-lane boulevards where buses can navigate. At the same time, there are a network of narrower roads and lanes where a car finds difficulty to meet another car smoothly. In the past low buildings and houses lined up along these narrow roads. If they were as it were, because of lowness of buildings, in spite of narrow roads, we could see more than four GPS satellites. However, today's urban landscape has become a mixture of low buildings and high rises without expantion of existing roads so that we can not see GPS satellites often.

First, we make 3D CG map around Kouriyama railway station by ourself. (All Japanese car navigation system vendors have their own 3D urban maps but they will not provide them freely so that I have to create a 3D map by myself.) Based on a surveyed map, we make an precise 2D CG city map where roads and buildings' lots are expressed correctly. Then, based on our field survey, we give measured hight to individual buildings. The lowest building is only one floor above the ground. The highest building has 10th floors (about 35 m in height). There are 4 lanes, 2 lanes, and 1 lane roads.

We carry GPS navigation system and measure how many GPS satellites are observable at a specific location. After many measurements, we come to a tentative hypothesis.

1. roadside trees do not shut GPS signals.

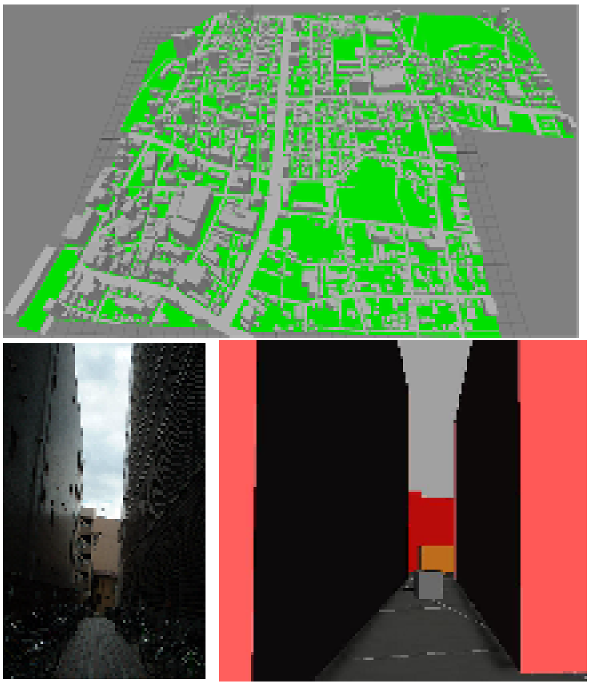

Figure 4: 3D CG map and GPS satellites seeing around KouriYama

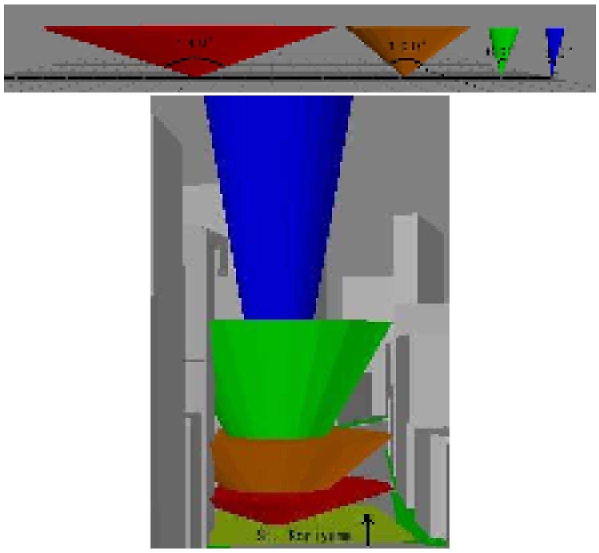

Figure 5: The interference relationship between imaginary cone and buildings

Table 1: 3D degree and number of GPS satellites

3 dimesnional degree	number of observable satellites
140	4
100	3
60	2
20	1
less than 20	0

2. multi-pass effect (a signal is reflected multiple times by building walls) is not serious. Maybe there are no super high rises here.

3. Due to satellite go around, the observed condition slightly fluctuating over time. Theoretically, a satellite circulate every 30 minutes around the Earth.

4. The critical condition which decides the observable satellites is expressed as a function of road width and surrounding building's height.

4 Calculation by Cone

The 3D CG map of ours covers about 2 x 2 Km around KouriYama railway station. We set a calculation to cover the area by mesh whose size we can decide as we wish. In this case study, we create a mesh 20 m in size. We make an imaginal cone stand in the center of a mesh (20 x 20 m). As we change the degree of cone, the cone interferences differently with surrounding buildings. The field survey tells the certain relation between the 3 dimensional digree of a imaginary cone and the number of observable GPS satellites (Figure 5).

Table 1 tells that cars drive one highways and broad bypass where car's GPS navigation system can see more than 4 GPS satellites always. Here,the 3 dimensional degree of a cone is larger than 140 degree. Figure 6 is a mesh map (20 x 20 m) whose number is the observable GPS satellites in that mesh. The lower left corner is the KouriYama railway station exit. This mesh map tells that there are some meshes where number is lower than 3, indicatig non avairability of a location service. However, when we deal with 9 meshes as one unit, the unit is unique in the mesh map. We can utilize this geographical nature.

5 Creating a Database

Today, map database format has been well discussed by international organization as for both standalone map database[3] and database supposed to be referred through internet[4]. Once a building is built,

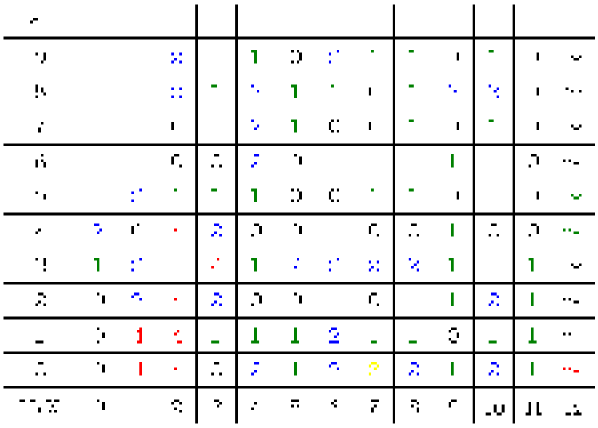

Figure 6: A mesh map showing observable GPS satellites number

it stand there for years. It indicates that a mesh map in Figure 6 is durable longer. We can calculate any mesh map as a prefrerable mesh size and a map coverarge area.
Observation of GPS satellites at a specific site provides information the following:

1. each satellite sygnals its identification number.

2. as satellites go around the Earth at half hour cycle, when we observe 4 satellites,they are not the same satellites. This indicates that we have to prepare 48 sheets of mesh map for a day. (1 map represents 30 minutes interval.)

The procedure of making mesh database is as follows.

1. Each major exit of railway and subway and bus stops are registered with its name, longititude, and latitude.

2. each mesh map has a exit or a bus stop as its origin so that each mesh is identified by two interger numbers (x,y).

3. each mesh has a observable GPS satellites number from 0 to 6.

4. identification of which satellite

5. we have to prepare 48 sheets of mesh maps in the same place.

We can express a coordinate of each mesh (x,y), and GPS number by short integer. An average size of a mesh map is about 4 Km x 4 Km (as we do not walk more than 20 minutes on search) whose origin is an exit or a bus stop. Thus, a data size of a seet of mesh map is quite small. We store these information in a server disk.

6 Simulation of Cell Phone based Directions

6.1 Agent program between Cell Phone and Server

Assume the server stores those mesh map database in advance covering the entire contry. As all car navigation system vendors own 3D urban map all over Japan, they can calculate and create the mesh database easily. A prospective user knows his destination in advance. In any spare time (while he goes on bus), he calls the server and tell his destination. An agent program stored in a cell phone is activated and tells the server the destination. Responding the inquiry, the server finds the nearest bus stop and allocates the necessary sheets of mesh map (usually several sheets). The server downloads a set of sheets of mesh data. And a necessary location service program. This is only one time communication. All information is stored in a small memory of a cell phone. We modify a agent program provided by Toshiba Ltd.[5]. Figure 8 is a shematic diagram of agent software compornents interaction.

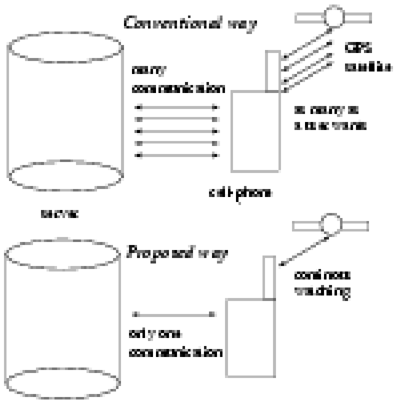

Figure 7: Conventional and proposing methods

6.2 Direction Solely by a Cell Phone

When a user arrives at the expecting exit or the bus stop, he starts the location service program. The necessarry map information is already stored in the memory so that the user does not communicate with the server anymore.

1. Keep a real time observation of GPS satellites. the observed data is being matched with the stored mesh map. As he observes, the propgram search not only single mesh but 9 meshes including the current possible mesh. We trace his

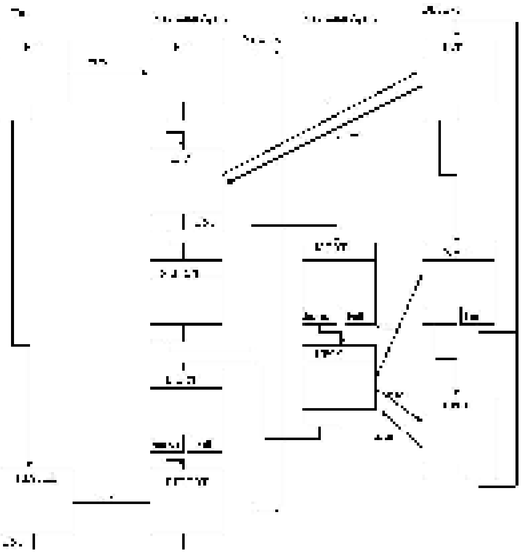

Figure 8: Schemtic diagram of agent software components

route not as single mesh but as one consisting of 9 meshes.

2. A man walks at a constant rate (e.g., 1 Km per 10 minutes) When he walks 15 minutes from the bus stop, he should be any point on a circumference with 1.5 Km radius.

This supplemental information gives larger possibility as for where he is in the neighborhood defined by 3 x 3 meshes.

We make a field test in KouriYama railway station neighbor area. Figure 9 shows that a user starts at the lower-left corner (an exit of the station) and navigates and finally arrive at the target (an department store) successfully.

7 Discussion and Conclusion

Our proposing method claims its applicability to any crowded urban area in the world, if only the area is a complex mixture of various buildings built randomly. By contraries, it is not applicable to urban area consisting of homogeneous buildings. It is a function of a combination of road width and surrounding building heights. A traditional old city in islam world such as Fes, Morocco consists of low stories buildings but it has very narrow pathes so that we can not see enough number of GPS satellites in the old islam city. Or in European city such as Paris, eventhough roads are wide enough but sometimes 5 to 6 stories high buildings might shut out of seeing GPS satellites.

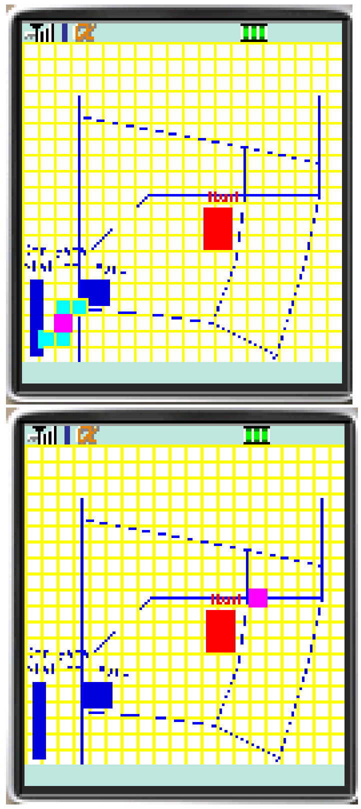

Figure 9: Start(above) and arrive(below)

References

[1] Jagoe,A.,*Mobile Location Services*,Pearson Education,Inc.,New Jersey,2002

[2] Kikuti,S.,*Kyoto Past and Present through Photographs*,Sintyou Publishing. Ltd.Tokyo, 1997

[3] ISO/TC211, *Geographical information/Geomatics*, http://www.isotc211.org/

[4] World Wide Web Consortium, *XPath Version 1.0*,http://www.doraneko.org/xml/xpath10/19991116/Overview.html

[5] TOSHIBA,*Bonding and Encapsulation Enhancement AGENT* http://www2.toshiba.co.jp/beegent/