Design and Implementation of a Personal Spatial Information System with Sensor Data Mapping

Yoh Shiraishi and Masatoshi Arikawa
Center for Spatial Information Science, The University of Tokyo, Japan
E-mail: {siraisi, arikawa}@csis.u-tokyo.ac.jp

Abstract. *Various kinds of sensor data collected from distributed databases on the Internet are useful for personal spatial information systems. This paper proposes a framework of sensor data mapping for a personal spatial information system and reports the implementation of the prototype system. Our method generates a query based on user's track log for realizing direct and effective sensor data mapping. This method produces useful information from collected sensor data based on GIS methods such as spatial interpolation and overlay processing. Experimental results suggest that our framework is effective for sensor data mapping in a personal spatial information system.*

Keywords: *sensor data mapping, spatial information system, visualization, personalization, GIS*

1. Introduction

In the field of ubiquitous and pervasive computing, many location-based systems and services have been developed. These systems manage various kinds of information based on geographic location. These spatial information include map data, POI (Point of Interest) data, digital photographs, GPS (Global Positioning System) track logs and so on. Some of them are personal information related with user's movement and behavior. In this paper, we focus on a personal spatial information system that manages and browses the personal spatial information.

On the other hand, recently, sensor data such as weather and traffic information can be collected from distributed databases over the Internet [JWA, ME, MLIT a, UCSC]. Real-time sensor data explain the current situation of user's surroundings, and time-series sensor data are related with the user's past experience and memory. "Sensor data mapping" is the translation process from these collected sensor data into useful and understandable information for a user. As a result of the mapping, sensor data are related with the user's moving and living space. These sensor data can be associated with each of personal spatial information. Sensor data mapping is very useful for a personal spatial information system. However, the existing sensor data browsing system cannot provide spatial integration functions and are inadequate for sensor data mapping.

This paper proposes a framework of sensor data mapping for a personal spatial information system. Our framework sends a query to sensor data servers on a network and receives the searched results from these servers. This query is generated based on user's track log for effective sensor data mapping. Our method produces useful information from collected sensor data based on GIS methods such as spatial interpolation and overlay processing.

This paper is organized as follows. In Section 2, we mention our concept and approach for sensor data mapping. In Section 3, we describe a personal spatial information system with functions of sensor data mapping. In Section 4, we report the experimental results using the prototype system and discuss the effectiveness of our framework. Finally, we give conclusion in Section 5.

2. Our Approach for Sensor Data Mapping

Many location-based applications such as map software and navigation system can manage and show various kinds of spatial content based on location information. Some of these applications can load and manage user's track log data measured by GPS and can relate each of spatial content with the log data. A system with these functions can be used as a personal spatial information system that manages personal spatial information such as user's annotation and digital photographs. However, such a system is inadequate for sensor data mapping. Even if it can display sensor data collected from distributed databases on a network as a distribution of point data, it cannot translate these sensor data into more understandable information for a user and cannot associate the integration result with spatial content, because it does not have functions to perform more advanced spatial information processing.

On the other hand, the existing sensor data browsing services on the Web present useful information in sophisticated forms. However, such information is translated on a server-side and provided to a client, and cannot be flexibly integrated on a client-side. In this paper, we take an approach that a client (namely, a personal spatial information system) collects sensor data from distributed databases and integrates these sensor data. By taking this approach, a client can flexibly process and integrate heterogeneous sensor data from multiple databases. Also, on the existing browsing site, a user must repeat a selection of query parameters such as data type, query region and temporal interval. A direct and intuitive query interface for browsing sensor data is required.

We design a framework of sensor data mapping for a personal spatial information system as follows:
(1) Query generation and request based on user's track log
(2) Sensor data visualization and mapping using GIS methods

Our framework uses user's track log not only to manage spatial contents such as digital photographs, but also to generate a query for a request of sensor data. In many cases, the track log data will be measured by GPS. Each element of the track log is a pair of position and time. Since the track log is a sequence of positions along user's movement, it is directly related with the moving and living space of the user. By using our method based on user's track log, sensor data collected from data servers can be intuitively associated with personal spatial content such as a digital photograph, namely the past experience, observation and behavior of the user. Also, recently, a digital photograph can include position information (latitude, longitude) as metadata. The position information is the information about the point that the photograph was taken, and it is also a kind of user's track log. Our framework is a user-centric approach for browsing, mapping and personalization of sensor data distributed over the Internet.

Our framework uses GIS methods for visualization and mapping of sensor data collected from distributed databases. Many methods for spatial information processing such as spatial interpolation and overlay processing have been proposed in the field of GIS and implemented on GIS software [Longley, McCoy]. For example, spatial interpolation can translate spatial data distributed as point data into continuous coverage data. IDW (Inverse Distance Weighted) is a simple and powerful method of spatial interpolation and computes the attribute value of the specified point using the surrounding spatial data. These methods based on geographic relations are effective for sensor data visualization since sensor data is related with a point and a region in the real world.

A geographic information system generally requires much of training and experience for learning the operations. It is difficult for ordinary people to use the system as a personal spatial information system. In this paper, some of GIS methods are implemented as software components of a personal spatial information system. Our approach will provide a framework that can associate user's track log, spatial content and sensor data one another.

3. Design of a Personal Spatial Information System with Sensor Data Mapping

3.1 System Overview

Our system includes a track log manager, a map viewer, a query generator, a mapping processor, a spatial content manager and so on. A track log manager handles the log record from a portable GPS. A map viewer displays not only map data but also track log data and the results of sensor data integration. A spatial content manager manages personal spatial information such as digital photographs. A query generator generates a query based on a track log and a region specified by a user. It transmits the query to data servers that manage and provide sensor data such as temperature and precipitation data. A mapping processor collects the search results from data servers and integrates collected sensor data based on GIS methods such as spatial interpolation. The integration results are associated with personal spatial content.

3.2 Query Generation Based on User's Track Log

It is necessary to specify some parameters in a query for collecting sensor data from data servers. Query parameters such as the kind of data ("data type"), time ("temporal interval") and location ("query region") are required. Our system generates these parameters by selecting a part of a track log (shown in Figure 1). By selecting two points of the track log, the start point and the end point of the partial log are decided. The temporal interval is calculated based on the period from the time of the start point to the time of the end point. The query region (R_{query}) is decided by the region (R_{cover}) where covers the partial log. If the selected part is represented as a point of the log, query parameters are decided from the time and the position of the log element.

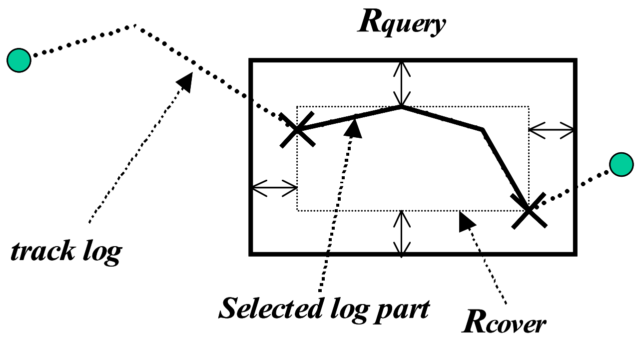

Figure 1. Query generation based on a track log

3.3 Sensor Data Mapping using Spatial Interpolation

In calculating sensor data of the specified point, it generates the rectangle centering on the point as a query region, and it performs spatial interpolation using sensor data that are contained in the region. In this paper, IDW (Inverse Distance Weighted) is used as a technique for spatial interpolation. IDW weights the neighboring data with the reciprocal of the distance from the point, and interpolates the value of the point using the weighted data.

For the rectangle query that covers the partial log, a mesh to the query region is generated. The value of the central point of each cell of the mesh is computed based on IDW. After computing for all the cells, continuous and coverage data is generated as a result of the mesh integration. This framework based on mesh integration will be effective for overlay processing of heterogeneous sensor data from multiple resources and spatial integration with various kinds of spatial data.

4. Experimental Results and Discussions

4.1 Implementation of the Prototype System

The prototype system based on our framework is implemented using Java programming language. As sample data for some experiments, we use sensor data recorded in a weather data CD-ROM "AMeDAS observation annual-report 2000" (provided by Japan Meteorological Agency). Automated Meteorological Data Acquisition System is called AMeDAS for short. This CD-ROM includes various kinds of the observation data for one year such as temperature, precipitation, wind speed and so on. These data of each sensor node of AMeDAS are recorded for every hour. We can use these observation data with the distribution of actual sensor nodes as a snapshot data or time series data.

Track log data are measured by a portable GPS. As spatial content, the prototype system manages photographs taken by a digital camera. The position information of each photograph is computed by comparing the time stamp of the photograph with each element of track log. We use the Digital National Land Information [MLIT b] of the Ministry of Land, Infrastructure and Transport. Spatial data such as administration community and coastline data, railroad data and road data are used as the background map data and for spatial integration on the implemented system.

4.2 Photo Mapping Application

As one of the applications based on our framework, we are developing a system that associates sensor data with digital photographs based on location information. Figure 2 shows the GUI (Graphical User Interface) of the photo mapping application. The mapping application can load GPS log data of a user and display each log on a map. It also manages and browses digital photographs based on GPS log data. In Figure 2, elements of a track log are displayed as a list ("log point list"). Photographs corresponding to each log element are displayed as other list ("photo list"). A photograph displayed in the "photo area" is related to the selected point of the log point list. This mapping application regards the position information of the point as the position that the photograph was taken.

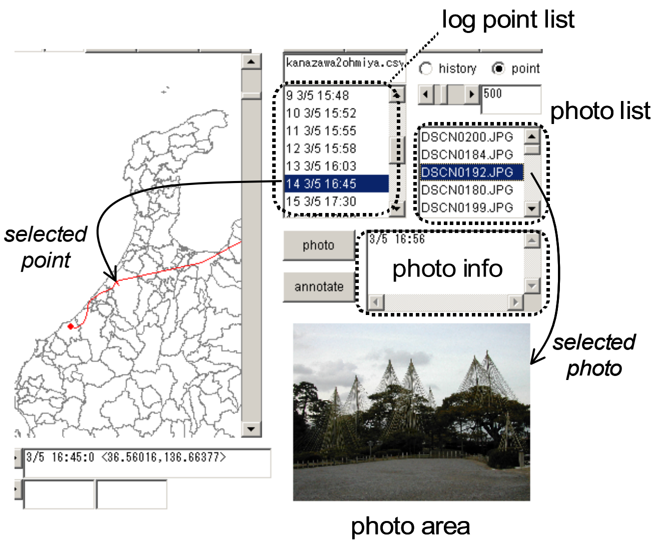

Figure 2. An example of a mapping application

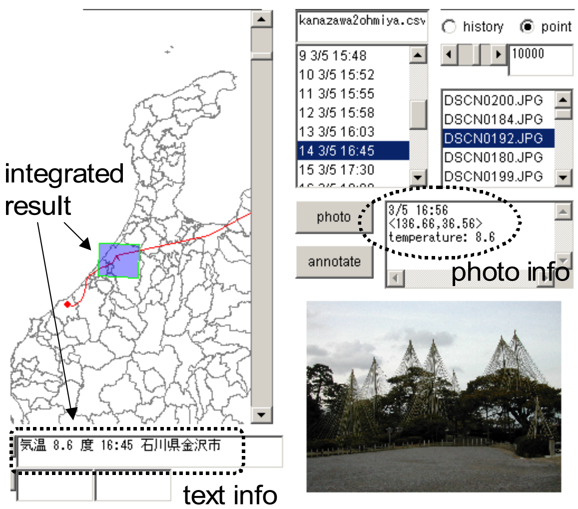

Figure 3. Mapping sensor data to a photograph

Figure 3 shows the result of mapping sensor data to a digital photograph. The value for the selected point is computed using the output data of the observation nodes that are contained in the rectangle region on the map in Figure 3. As the result of spatial integration, temperature data and the position information is displayed in the "photo info" field. These integrated results can be used as metadata for the photograph. This experimental result suggests that our framework can realize sensor data mapping for digital photographs.

4.3 Interactive Spatial Data Mapping

Figure 4 shows a result of sensor data integration for a track log. The integration result is displayed on the map area of the prototype system. The left figure shows a user's track log recorded by a portable GPS. The right figure shows the result of spatial interpolation for the average temperature data when the prototype system generates a query based on the track log and sends the query to a sensor data server. By using spatial interpolation, sensor data represented as point data can be translated into the continuous and understandable information, and it is easy for a user to grasp the overall tendency of sensor data.

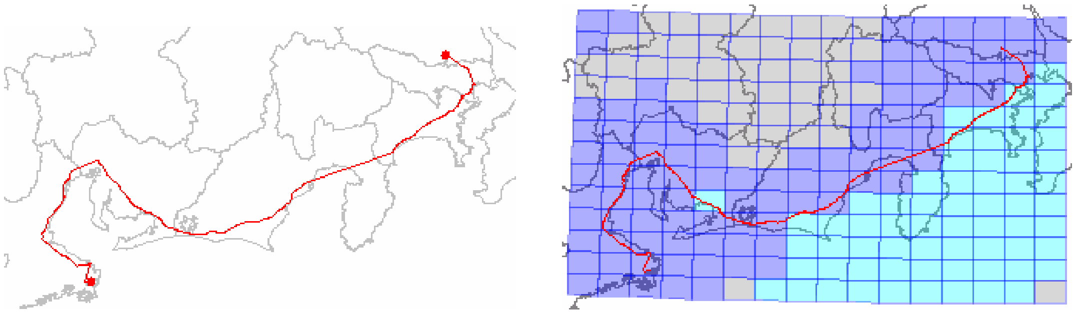

Figure 4. A result of sensor data mapping using spatial interpolation

Figure 5 shows the results of conditional filtering for the integration result in Figure 4. The left figure shows the cells with temperature lower than 10 degrees and the log parts filtered by these cells. The right figure shows the cells and the log parts filtered by the condition lower than 8 degrees. By the conditional query for the result of sensor data integration, the filtering of the user's track log can be realized.

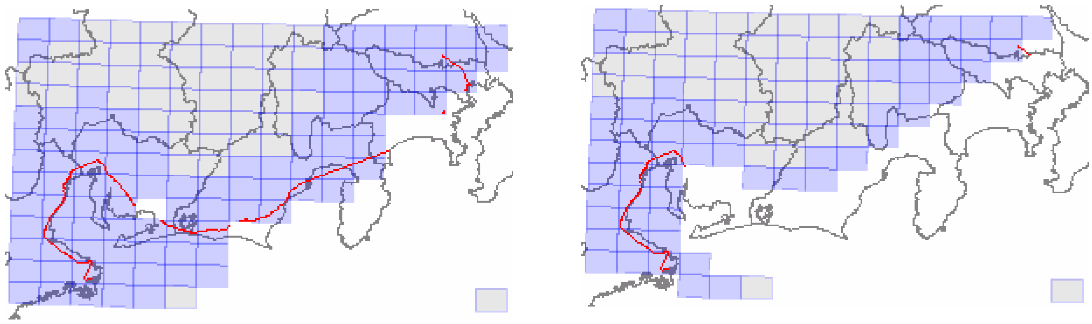

Figure 5. Filtering the track log based on results of sensor data mapping

Such filtering based on the integrated result will support interactive sensor data mapping for user's track log and spatial content that represent the user's experiences and behaviors. This function is different from a usual query for sensor data retrieval. Usually, a region and a temporal interval are specified as parameters of a query for acquiring sensor data. Our framework may support a different kind of a query that finds out location, time and spatial content from the result of sensor data integration. For example, we think the following queries: "where is the place where rain was falling when moving by train?" and "which is the photograph of the garden where snow lay? ".

By interpolating sensor data for each point of a track log, it will draw a graph from the result. The graph when a client collects and interpolates temperature data can also be regarded as the graph of the temperature that the user itself felt at that time in that place along the track log. This is an example of sensor data personalization. By using our framework for sensor data mapping, various kinds of sensor data from the surrounding sensor nodes in the public domain will be used for a personal use.

5. Conclusions

In this paper, we propose a framework of sensor data mapping for a personal spatial information system. This paper reports the implementation of the prototype system based on our framework and presents the experimental results using the system. By query generation based on user's track log and sensor data integration based on spatial interpolation, sensor data collected from distributed databases can be associated with spatial contents such as digital photographs. Our framework based on user's track log data supports direct and interactive sensor data mapping. If sensor data about an event that a user observed and experienced at the past time in a certain place are derived, augmentation of memory of the user and discovery of new information are expectable. Also, our framework will provide a function for sensor data personalization since it can manage and browse sensor data by a personal view. Future consideration includes the development of a mapping system on the mobile terminals such as a laptop computer and a portable digital assistant (PDA).

References

[Longley] Paul A. Longley, Michael F. Goodchild, David J. Maguire, and David W. Rhind, "Geographic Information Systems and Science", John Wiley & Sons, 2001.

[McCoy] Jill McCoy, and Kevin Johnston. : "Using ArcGIS Spatial Analyst", ESRI, 2001.

[JWA] Japan Weather Association, http://tenki.jp/ (*in Japanese*)

[ME] Ministry of the Environment, Atmospheric Environmental Regional Observation System: AEROS, <http://w-soramame.nies.go.jp/> (*in Japanese*).

[MLIT a] Ministry of Land, Infrastructure and Transport, River Information System, <http://www.river.go.jp/> (*in Japanese*).

[MLIT b] Ministry of Land, Infrastructure and Transport, Digital National Land Information Download Service, <http://nlftp.mlit.go.jp/ksj/> (*in Japanese*).

[UCSC] The REINAS Project, <http://www.soe.ucsc.edu/projects/reinas/>.