mPATH: An Interactive Visualization Framework for Behavior History

Masaki Ito [1] Jin Nakazawa [1] Hideyuki Tokuda [1 2]

[1] *Graduate School of Media and Governance, Keio University*
[2] *Faculty of Environmental Information, Keio University*
{niya, jin, hxt}@ht.sfc.keio.ac.jp

Abstract

This paper presents an interactive analysis and visualization framework for behavior histories, called mPATH framework. In ubiquitous computing environment, it is possible to infer human activities through various sensors and accumulation of their data. Visualization of such human activities is one of the key issues in terms of memory and sharing our experiences, since it acts as a memory assist when we recall, talk about, and report what we did in the past. However, current approaches for analysis and visualization are designed for a specific use, and therefore can not be applied to diverse use. Our approach provides users with programmability by a visual language interface for analyzing and visualizing the behavior histories. The framework includes icons representing data sources of behavior histories, analysis filters, and viewers. By composing them, users can create their own analysis method of behavior histories. We also demonstrate several visualizations on the framework. The visualizations show the flexibility of creating behavior history viewers on the mPATH framework.

1. Introduction

In ubiquitous computing environment where computers and sensors are embedded in our surroundings and assist our life, cognition of human behavior will be possible. Today, sensing technology is one of the hottest topics for ubiquitous computing researchers. Various technologies for generating a sensor network have developed[11][18]. By sensor networks, acquisition of information in a certain place like temperature, humidity, noise level and light level is realized. In addition, tracking an object are also enabled by the coordination of sensors.

Technologies for mobile computing[5][1][6] are also useful to sense our activities and environmental information. Sensors equipped with a mobile device acquire various information of the user such as a location, movement orientation and a physiological status by alone or coordination with infrastructures in surroundings[21][16].

Inferring highly abstracted behavior of a user and creating predictive model of user's behavior from the sensed data are also hot challenges in ubiquitous computing research. There are many researches which aim to guess user's context and provide adaptive services. Several context processing technologies are proposed for the purpose[23][22].

In addition to processing sensor data in a certain time, storing and utilizing an accumulation of behavior data brings us a possibility to develop new applications[2]. A well presented behavior history helps human activities in terms of memory and sharing our experiences since it acts as a memory assist when we recall, talk about, and report what we did in the past[17][13]. For example, displaying user's shopping log reminds him or her of goods which he or she intended to buy, and helps explanation of his or her intention of shopping to his or her company. Analysis techniques of behavior history are important to find useful information from it.

There are already various proposed methods for analyzing accumulated behavior history. However these methods are designed for a specific use, and hence users may not acquire applicable information. The analysis method of behavior history, therefore, should be flexible enough to find various information from behavior history.

In this paper, we presents a programmable analysis and visualization framework for behavior histories, called mPATH framework. In the mPATH framework, analysis methods are modularized and we can create various analysis methods using visual programming language. The framework allow every developers and users to mine behavior history intuitively and flexibly.

This paper is organized as follows. In the next section, we argue problems of visualization of behavior history. In section 3, we introduce mPATH framework which realizes flexible analysis of behavior history using visual language. We also introduce several visualizations on the mPATH framework in section 4. We evaluate the framework in section 5 and introduce related works in section 6. In the final session, we conclude this paper.

2. Visualization of Behavior History

In this paper, behavior history is an aggregated form of information which contains location, date and description of behavior about a certain person. Location track data obtained by a GPS receiver is an example of the behavior history. A digital photo image is also behavior history if it contains a time stamp and a location information as its meta-data.

Well presented behavior histories help our memory and communication. We often remember our past behavior in daily life. For example, we often plan what we will do for the weekend remembering stores and places which attracted us in the past. Also, we often talk with people remembering our past experiences. There are several researches to assist memory and communication by visualizing past behaviors[19][17][13].

When we remember our past behaviors, we do not merely remember them chronologically, but remember them selecting and organizing the informations that we need then. For instance, when you tell about the travel that you had, you will tell the places and foods that you were interested in. Also, you might focus on the places where you visited with the listener. Thus, which information you need in your past behavior varies depending on the situation.

Behavior history also useful in modeling user's activity and predicting next action. In many context-aware application, researchers uses behavior history for adaptive behavior of the systems. Such applications infer user's interest and purpose by analyzing behavior histories. While developing a context-aware application, developer need to select and organize for a certain application.

2.1. Behavior History Analysis for Visualization

We focus on the analysis process of behavior histories to find interesting data and organize them when we develop memory assist applications and context-aware applications. Following functions are required for analysis system of behavior history.

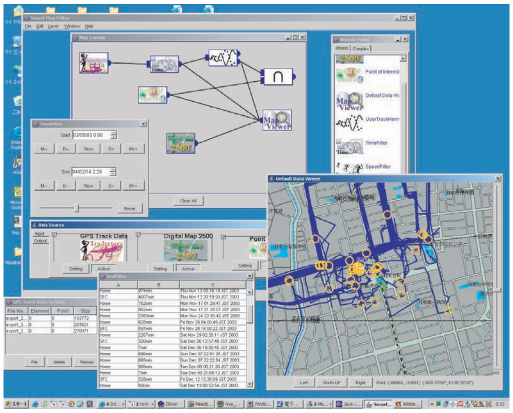
Support of Temporal and Spatial Analysis. Since behavior histories are characterized as their location and time parameter, supporting temporal and spatial analysis is required in addition to generic numeric analysis. Selection of data within a certain location or period is one example. Joining multiple data using a certain time or location as a key is another example. These analysis assist in finding characteristics in behavior histories.

Support of Trial and Error Analysis. The diversity and irregularity of captured data from sensors require heuristic development of analysis method. Users who analyze behavior history need to adjust algorism and parameters for a certain history data. Thus, the system should be programmable to support such trial and error development of analysis method.

Reusability of Analysis Method. Since there are various behavior histories, developed analysis method specialized to a certain behavior history should be reused to other histories. For example, analysis method for finding interesting points from a shopping history should be applied to photography history. Analysis methods, therefore, are independent of a certain history format.

3. An Interactive Behavior History Mining Framework

In this paper, we propose an interactive behavior history analysis framework called mPATH framework. We can input various behavior histories to the framework and analyze in various ways on it. The mPATH framework provides a visual programming interface, so that users can develop various analysis method intuitively through GUI. Figure 1 shows the screen shot of the system.



File Na...	Element	Point	Size
export_2...	0	0	193772
export_2...	0	0	205621
export_2...	0	0	278071

A	B	C
Home	874min	Thu Nov 13 05:16:19 JST 2003
SFC	4607min	Thu Nov 13 20:19:58 JST 2003
Home	762min	Mon Nov 17 01:29:47 JST 2003
Home	952min	Mon Nov 17 21:28:07 JST 2003
Home	2383min	Mon Nov 24 22:30:42 JST 2003
Home	626min	Fri Nov 28 04:00:49 JST 2003
SFC	597min	Fri Nov 28 16:00:22 JST 2003
Home	2267min	Sat Nov 29 02:20:11 JST 2003
SFC	320min	Sat Dec 06 12:57:48 JST 2003
Home	7min	Sat Dec 06 19:00:45 JST 2003
Home	686min	Sun Dec 07 02:01:26 JST 2003
Home	695min	Sun Dec 07 22:22:54 JST 2003
Home	888min	Tue Dec 09 00:21:30 JST 2003
Home	7min	Tue Dec 09 21:58:12 JST 2003
SFC	528min	Fri Dec 12 15:38:09 JST 2003
Home	60min	Sat Dec 13 00:52:54 JST 2003

Figure 1. mPATH Framework

3.1. Features of the mPATH Framework

The following are features of the mPATH framework.

Component-based Architecture. For supporting programmability and reusability, we divided the method into several components and realize development of an analysis method by combining several components like filtering data, counting data and classifying data.

Interactive Visual Programming. We provide data flow style of visual programming interface to combine multiple analysis components. Structure of analysis method is shown visually and users can modify it by simple mouse operation. User's operation is immediately reflected to the system. Therefore users can easily develop original analysis method for a certain visualization.

Unified Behavior History Format. We defined unified internal data format of behavior history and geographic information. Since all internal data can be accessed by the unified way, we can easily reuse analysis method to various behavior history.

3.2. Input of Behavior History

By utilizing icons of behavior history and geographic information, we can input data to mPATH framework. Various ways to acquire data are shown equally as icons such as acquisition of data from files, through a network, or from a equipped device. Following data can be input in current implementation.

GPS Location Track Data. We implemented an input function of location track data acquired by GPS. With this function, we can input track data files of handy GPS, Garmin eTrex[12]. We can also input real time location data from the handy GPS through RS-232C port with NMEA-0183 format.

Digital Photo. We implemented input function of digital photo data. The function generates behavior history of "taking pictures" by reading time stamps and location in EXIF[15] information. In addition, by matching timestamps of photos with location track data, it estimates location where the photos were taken without location information.

Vector Map. We implemented an input function of map data in a vector format. There are many map data for GIS like Shape format[10] for ArcGIS[9] and the format of the Geographical Survey Institute of Japan. These map contains points of station, lines of road and polygons of buildings. Users can infer detail of behavior in a certain position, and use the map as a background of visualization.

3.3. Analysis of Behavior History

We can analyze behavior history using icons of analysis components. All analysis components are designed as filters with input and output connector, we can combine several filters. Following filters are currently implemented.

Time Filter. Time filter extracts behavior histories during a specified term.

Speed Filter. Speed filter filters data by its speed. It is useful especially to infer transportation means from location track data.

Way point Filter. Way point filter classifies GPS point data into movements and stops. Users can change threshold of time to detect the user's stop.

Matching Filter. Matching filter joins two input data according to location. When we input one from the map data and the other from way points data, this filter adds name of places to each way point.

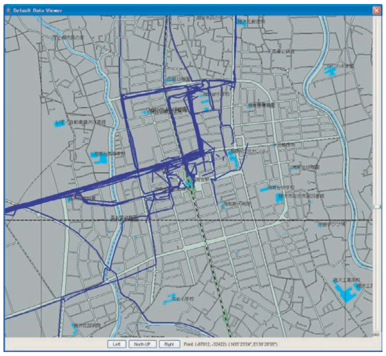
Count Filter. Inside the count filter, geographical regions are divided into a grid. The filter counts input data in every grid. Users can learn how many times he or she visited a certain point, i.e. a weight of the point, in behavior history.

3.4. Output Result of Analysis

Result of analysis is connected to an icon of output function, and utilized by various applications. Visualization application and context-aware application are examples of such applications. Applications can run not only within the framework, but also as a distributed application by transporting the result through a network.

We currently focus on developing visualization application as follows, and planning to develop distributed context-aware application using mPATH framework by developing output function through a network.

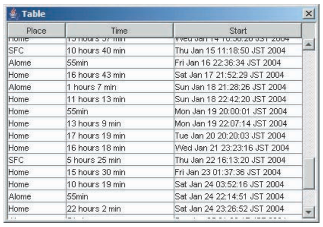
Normal Map Viewer. To visualize spatial aspect of behavior history, we developed normal map viewer. In this viewer, every input is ordered by the geographic coordinates, so that generic map-like visualization is realized. This viewer accepts multiple data and overlays them. Figure 2 shows an example of a normal map viewer.



Point: (-67612, -32422) (N35°23'24", E139°28'35")

Figure 2. Normal Map Viewer

Table Viewer. We developed table viewer to show details of data by characters and figures. This viewer lists every input data, so that it is useful especially for developing analysis method. Figure 3 shows an example of the viewer.



Place	Time	Start
Home	15 hours 37 min	Wed Jan 14 10:50:20 JST 2004
SFC	10 hours 40 min	Thu Jan 15 11:18:50 JST 2004
Alome	55min	Fri Jan 16 22:36:34 JST 2004
Home	16 hours 43 min	Sat Jan 17 21:52:29 JST 2004
Alome	1 hours 7 min	Sun Jan 18 21:28:26 JST 2004
Home	11 hours 13 min	Sun Jan 18 22:42:20 JST 2004
Home	55min	Mon Jan 19 20:00:01 JST 2004
Home	13 hours 9 min	Mon Jan 19 22:07:14 JST 2004
Home	17 hours 19 min	Tue Jan 20 20:20:03 JST 2004
Home	16 hours 18 min	Wed Jan 21 23:23:16 JST 2004
SFC	5 hours 25 min	Thu Jan 22 16:13:20 JST 2004
Home	15 hours 30 min	Fri Jan 23 01:37:36 JST 2004
Home	10 hours 19 min	Sat Jan 24 03:52:16 JST 2004
Alome	55min	Sat Jan 24 22:14:51 JST 2004
Home	22 hours 2 min	Sat Jan 24 23:26:52 JST 2004

Figure 3. Table Viewer

Weight Map Viewer. Weight Map Viewer shows weights of each geographical region visually in addition to normal map. There are several ways to visualize weights of regions such as colors of a map, scale of a map, or distortion of a map. In current implementation, we use scale of each regions to show weights. Figure 4 shows an example of a weight map viewer, which is used to emphasize the places where user passed by or took pictures.

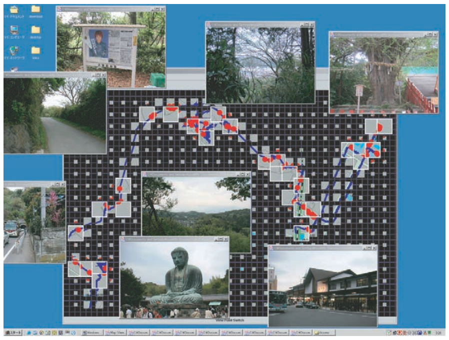


Figure 4. Weight Map Viewer

3.5. Development of mPATH Filter

In addition to combining existing filters, users can develop original filters. Following methods are prepared for developers of filters.

- **getBehaviorElement(GeoShape area):** This method was called when analysis result is required by lower filters. The filter returns all analyzed result in the given region as a unified format.
- **afterConnectFrom(BehaviorFilter fromFilter):** This method is called when other filter is connected to input. A connected filter is noticed as an argument.
- **afterDisconnectFrom(BehaviorFilter fromFilter):** This method is called when connected upper filter is disconnected.
- **preNotification(BehaviorFilter fromFilter):** This method is called when the state of upper filter is changed. The filter should analyze again the output of the upper filter.

4. Examples of Visualization

On the mPATH framework, we developed three visualization applications of behavior histories.

4.1. Visualization of Behavior History on a Map

We developed visualization application of behavior history using a map as a background. The application displays not only track data as lines, but also places where he or she stayed for more than threshold time as point. Figure 5 shows the program. We applied a time filter and a formalize filter to GPS data and displayed it with a vector map on a normal map viewer. Changing parameters of the time filter enables observation of GPS data which belong in a specific time period.

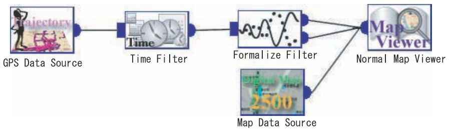


Figure 5. A Program of Visualization Behavior History on a Map

4.2. Listing Stay Point

We developed an application which lists name of points where a user stayed. We extracted the stay points by a formalize filter and matched them with a map by a matching filter. We displayed them as a list using table viewer. Figure 6 shows the program, and Figure 3 is the output of the application. We can regard places where a user stayed for a long time as places he or she made some behavior. In this example, user's home and university are extracted.

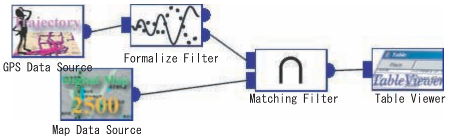


Figure 6. A Program of Listing Stay Point

4.3. Weight Visualization of Travel Log

We developed a visualization application of travel log by emphasizing regions where traveler passed through or took pictures. We developed an algorism which calculate weights of each regions by counting times the traveler passed through and took pictures.

Figure 4 shows the usage of the application to show sightseeing log, and the application weights especially places where user took pictures. The application can display photo images, so that users can use it as a photo browser.

Figure 7 shows the program of the application. Location tracking data, stay point data and photo data are counted by count filters, and used to visualize map and photo as weight.

Users can learn how many times he or she visited a certain point, i.e. a weight of the point, in behavior history.

5. Evaluation

In this section we evaluate the performance of the mPATH system. It shows if the response of the system is enough to develop analysis and visualization methods interactively. It can also be used to find functions which should be improved. For measuring the performance, we used the environment shown in table 1 and used data shown in table

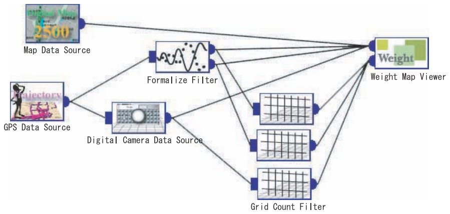


Figure 7. A Program of Weight Visualization of Travel Log

2. These data are collected from the experiment of Ito, who has been carrying handy GPS since June 2003.

Table 1. Evaluation Environment

CPU	Pentium4 2.53GHz
memory	1024MB
OS	Linux 2.4.22
JDK	J2SDK 1.4.2_03

Table 2. Data for Evaluation

Type	GPS location tracking	Map Data
description	Jun. 2003 – Nov. 2003	Fujisawa city
size	1,956,381 byte	9,261,000 byte

5.1. Overhead of Component Architecture

We measured the performance of the component architecture, therefore the architecture seemed to be an overhead compared to a hard-coding implementation. We measured simple visualization method with several time filters, in which we changed the number of the time filter.

Figure 8 shows the result of the measurement. While we increased time filter from zero to 15, the growth of the time is small. This result shows that the overhead of connecting analysis components is small.

5.2. Performance of the Visualization

We measured the performance of a visualization system constructed on the mPATH system. We used simple visualization application in which location track data and map data are rendered on a same window, and measured the time required for rendering. Figure 9 shows the result. It also shows the result of rendering single location or map.

Lowest case of rendering time is about 800ms, and in the case of small scale maps, it takes more than 1500ms. In the overlaid case, the rendering time of the map are two times the single rendering of the map, and can be reduced.

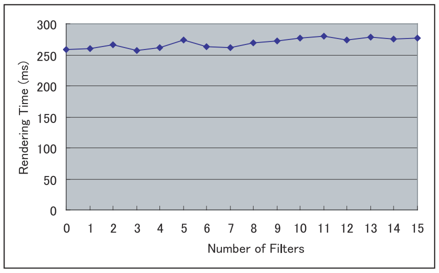


Figure 8. Measurement of the Overhead

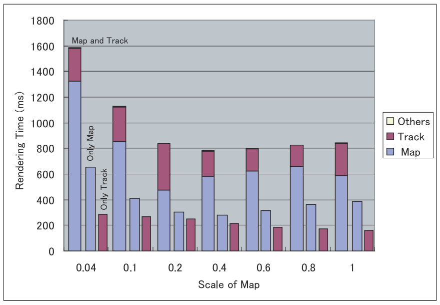


Figure 9. Application Performance

6. Related Works

We introduce several researches and products as related work of mPATH framework in points of view of an analysis of behavior history and a visual programming language.

6.1. Analyzing Behavior History

There are already many researches which aim to acquire and utilize behavior history. PEPYS[19] is one of the earliest fruits of such researches on the ubiquitous computing research area. PEPYS uses Active Badge[27] to acquire location information of each users, and generate text-based behavior logs like diaries.

Cyberguide[1] also accumulate location history to inform tourist attractions which a traveler prefers. This system uses GPS to acquire location information, however the system uses names of tourist attractions which already prepared with geographic coordination.

Analyzing location information described as geographic coordination is tough problem since the cost of calculation and creating users' activity model increases. [20] and [4] is trying to infer user's behavior and transportation means from location track data of GPS and creating user's activity model to predict future behavior.

In the research area of the transportation planning, many researchers are trying to use GPS receivers to acquire a movement of a crowd instead of counting passers in several places of a city. They argue mainly on the accuracy and correction of raw GPS data[28][26].

6.2. Visual Programming

We introduce several visual programming system which provides users with programmability for data analysis. These systems do not focus on behavior history, but provide flexibility of data analysis and representation by visual language manner.

Many data flow visual languages are proposed[14] for music[7], image processing, scientific visualization[8][3] and creating user interface. As business applications, data mining application such as Intelligent Miner of IBM, Enterprise Miner[24] of SAS and Clementine[25] of SPSS provide visual programming language to develop analysis method.

7. Conclusion

In this paper, we presented an interactive analysis and visualization framework for behavior histories, called mPATH framework. The mPATH framework provides data flow visual language, and enable flexible and interactive analysis by connecting analysis components through mouse operation. By component architecture, the framework enable providing various analysis result for various applications. We implemented mPATqH framework with Java language, and demonstrate constructing various viewer applications. We also evaluated performance of the framework, and proved its interactivity.

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