Software Architecture for Map-based Services in Ubiquitous Computing Environment

Masaki Ito, Jin Nakazawa, Hideyuki Tokuda
{niya, jin, hxt}@ht.sfc.keio.ac.jp
Graduate School of Media and Governance, Keio University
http://www.ht.sfc.keio.ac.jp/~niya/mpath/

1. INTRODUCTION

A mobile device has been simply regarded as a viewer for a long time. We have only been using mobile devices to see ready-made information, such as a schedule, an address book or a map. Although most mobile devices are equipped with input devices such as a numeric keypad and a touch screen, these input devices are not useful to input complex commands and data. We can say the same thing about map-based services for mobile users. Simply watching maps on a small screen was the main feature of the services. We could only scroll or zoom in or out the map, or at most, make the map automatically change its image following our movement.

However, emerging two technologies for mobile devices are changing our interaction with map-based services in mobile environment. The first technology is installation of sensors on mobile devices, and the second one is a communication among devices by short range wireless technologies like Bluetooth. By using these technologies, map-based mobile services will become more interactive and context-awareness.

Sensors on mobile devices will make it possible to recognize user's activity and context digitally. Several sensors are already going to be installed to mobile devices especially mobile phone: a GPS for acquisition of current location and movement history, an accelerometer for acquiring an angle of a mobile device, a digital camera for visual information of certain location, an electronic money for getting shopping information. These sensors help recognition of user's location, situation, activity, and other properties, and make services personal and context-aware.

A short range wireless technology enables coordination of several mobile devices and public devices [6]. A mobile phone, a portable music player, a digital camera and other mobile devices will be parts of platform for providing mobile services. For example, a mobile shopping guide will give guidance as voice by a music player, and give instruction of goods through a LCD on a digital camera. Public information terminal will also be equipped with a communication function. It will help the actuation of services. For example, public display will give a large and fine-grained map instead of a LCD on a mobile phone.

In this paper, we argue the feature of map-based services for the advanced mobile devices, and propose software architecture named mPATH Framework for providing advanced mapping. We also demonstrate an application example to show the detailed function of the framework.

2. SOFTWARE ARCHITECTURE FOR ADVANCED MOBILE DEVICES

In this section we introduce a detail of mobile devices of next generation, and argue problems when we develop map based services for the mobile devices.

2.1 Advanced Mobile Devices

There are several projects which propose advanced mobile devices [1][7]. One example is Ubiquitous Core (uCore), which we are developing as our on going project. Figure 1 shows its early prototype. The uCore is a small mobile device, which is designed to be carried inside a bag of a user. The uCore itself has a computing, storage and communication mechanism, and it interacts with sensors and I/O devices within a certain distance. The uCore captures and stores personal activity in its storage. We utilize the data to personalize services.

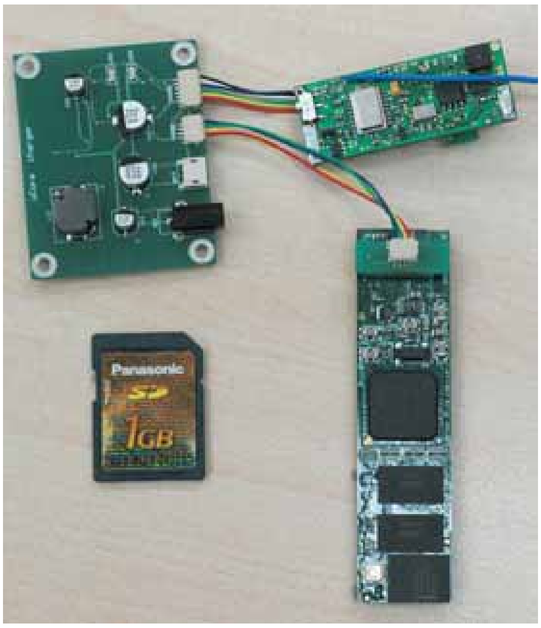


Figure 1 uCore

Another example in our research group is u-Texture [5]. The u-Texture is configurable material for furniture. The u-Texture itself is a thin display device with a computer, sensors and network devices, and we can flexibly construct various furniture by the devices. Figure 2 shows its image and furniture constructed by uTextures.

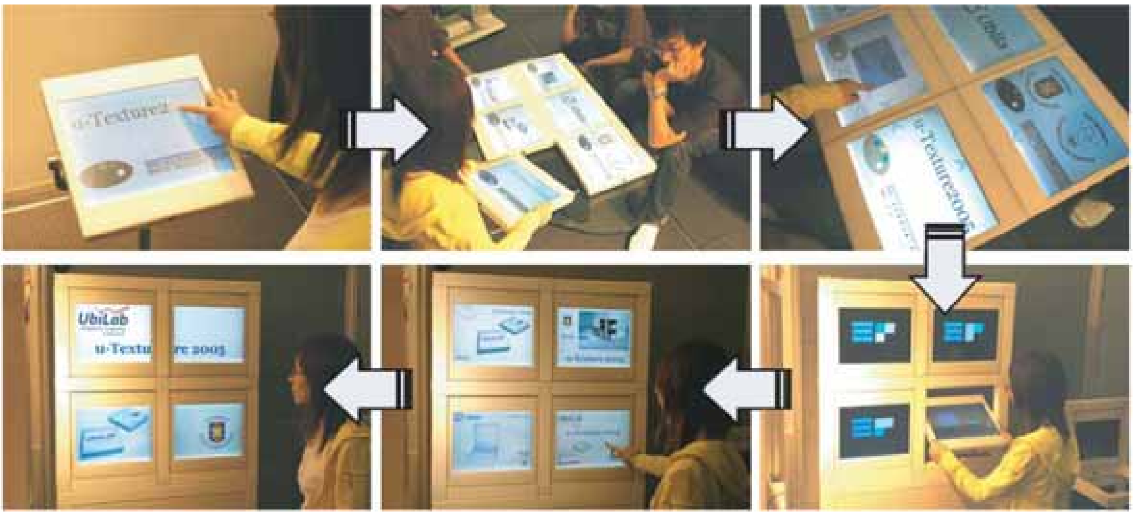


Figure 2. uTexture and their Composition

2.2 Map-Based Services on Distributed Mobile Devices

Though it is tough to express a whole structure of map-based services on the advanced mobile devices, we can give some keywords of mapping in advanced services. Following keywords will help to consider features of advanced map-based services.

Context-Awareness

Context awareness is a key feature of services in ubiquitous computing environment. Map given by advanced mobile devices also should be contest-aware. For example information on the map should be selected and emphasized based on user's requirement and situation.

Activity-based Mapping

A map, it was historically considered to be a public media should be a personal media. It should reflect user's geographical activity such as movement, interest, or intention. The advancement of sensor technology will help to acquire data of personal activity. The technology of visualizing such information intuitively is also needed. [2] shows a possibility for creating activity-based services.

Dynamic Generation

Information on the map should be updated dynamically. Since the information on a map is actually changing, map also should keep changing and show up-to-date information. If past data is also accessible, it may be helpful to give a map at a certain time for a certain services.

Information Sharing

When a map becomes a personal media, we can utilize it to share personal activity intuitively in a group. JIKUKAN-POEMER [8] is one example of such utilization. It helps us to share photograph on a map.

2.3 Software Architecture for Distributed Mobile Devices

For the map-based services on advanced mobile devices, maps are context-aware and generated dynamically. Providing such maps requires advance in software architecture of map-based services. Following features are required for the software.

Aggregation of Distributed Data

Since each mobile device works to capture and store data for mapping, we need to gather various data on demand for the maps on advanced mobile devices. For example, photographs with location information may be stored in a digital camera, and shopping history data with shop location may be in a mobile phone. A generic map for a background and a recommendation message from his or her company may be acquired from the Internet. Therefore, a software system must have a feature to exchange these geographical data among mobile devices and other nodes through the Internet.

In addition, the software system has to deal with a rendering process flexibly. To create maps, we need to convert diverse data into raster format, and superimpose them. In the existing client/server (C/S) architecture, only a server executes this process. However, since the data for mapping are distributed, we need to execute rendering and superimposing process distributedly.

Access control for data

For the map-based services on advanced mobile devices, many people, companies and even sensor-modules produce data for mapping. Some data may be private, and some other may be public. Some data require payment and password, some may be free. We mast deal with these data under the appropriate access control when we integrate these diverse data into a map.

The function for access control should not be limited in a simple one. Since the data for mapping are classified into vector and raster data, we also need to consider both of their characteristics. Vector data consist of geographic topology and other properties. Although we need to wait while rendering every time we see the data as a map, the vector format is applicable to other purpose such as geographic data processing, utilizing as textual database, since they contain shape and properties in original format. Some content provider, however, does not like such unrestricted utilization of their data, and hope their data to be provided only as raster image. Therefore, the access control has to deal with both characteristics of data format.

3. mPATH FRAMEWORK

We propose mPATH framework as a middleware for map based services on the advanced mobile environment. The mPATH framework is a component based software framework to analyze and visualize temporal and regional data. On the framework, data for mapping, function of visualization, filtering of data, and any other functions to deal with data for mapping are divided into composable software modules, named mPAH module. We can easily create an original map by composing these software modules. We provide a visual programming interface to ease the composition. Figure 3 shows its overview and example of filters. On the screen shown on the center of the figure 3, every module is shown as an icon, and we can flexibly select and connect icons by mouse operation.

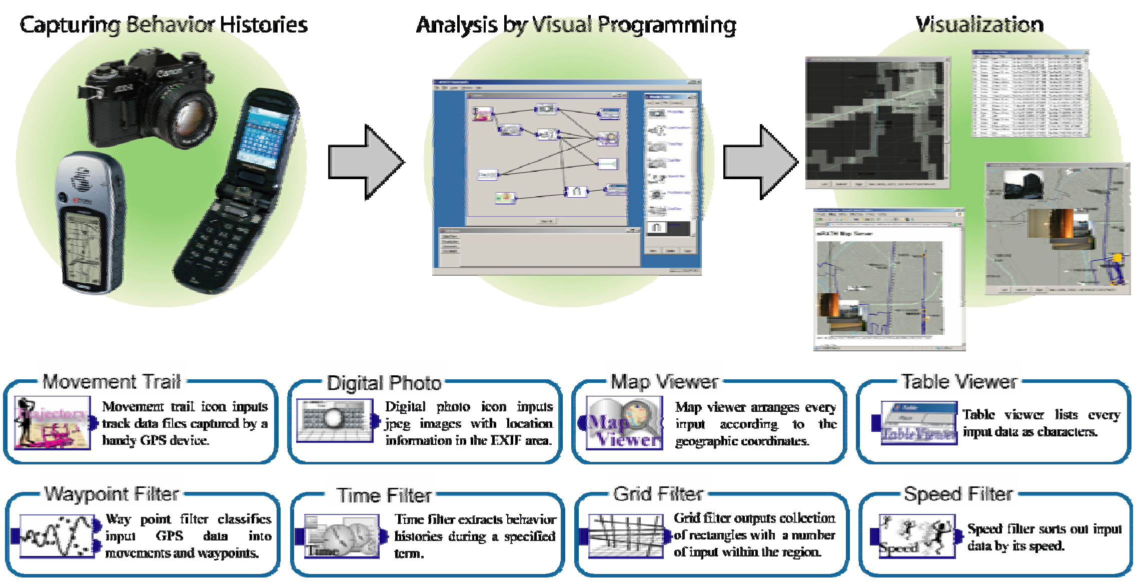


Figure 3: An Overview of the mPATH Framework

The mPATH framework is our research product, which was initially designed to analyze regional and temporal aspects of human activity [3]. We utilized the software to find and visualize certain human activity. The information is useful to develop context-aware applications which dynamically reflect user’s activity and pattern. However, now we extended the applicability of the software to be utilized as a middleware for map-based services.

3.1 Features of the mPATH Framework

Following features are the fruits of our extension of the mPATH framework, and they solve problems on developing map-based services.

Dynamic Composition of Modules

Since the information for mapping changes according to its context, the framework supports dynamic composition of modules. The data stream between mPATH modules can be connected and disconnected even while the service is running. By using this feature, a service can provide suitable map-based service to user’s situation and requirement.

Double Layered Data Stream (Distribution of Rendering Module)

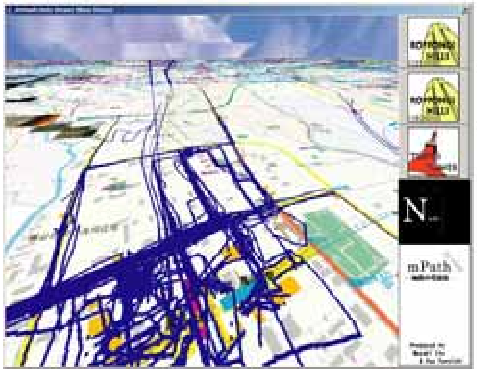
We divided inside data stream between mPATH modules into vector data stream and raster data stream. Since there is a requirement for access control, there are some data which only provided in raster format. And, for the performance reason, some data such as a complex map should be rendered in a high-performance computer rather than a mobile device. In the mPATH framework, we defined two types of data-stream, and select automatically or manually.

3.2 Application Example

We will show an application named mPATH View [4], which is developed on the mPATH framework.

mPATH View

The mPATH View is an application which provides user’s past geographical activity on a 3D map. Figure 4 shows its screenshot and usage. We designed this system to enhance our communication by sharing our past activity in a group when users go up to an observatory. The handy viewer shown in Figure 4 is one prototype of the uTexture. The map keeps changing its image to synchronize it with viewer's orientation and angle. Since the map shown on the viewer is generated on demand, we can select users' activity according to what we want to see at that time by operating visual programming interface.



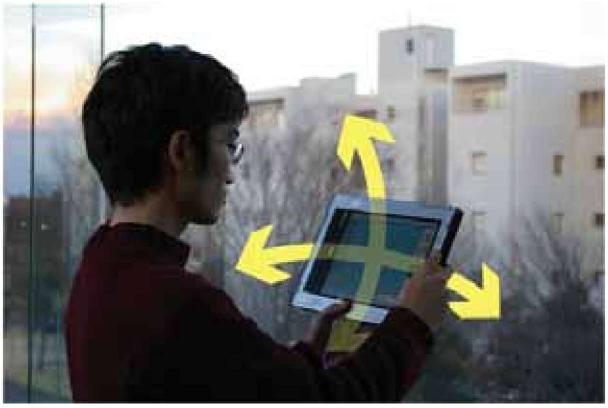


Figure 4　mPATH View

Figure 5 shows its software architecture constructed upon the mPATH framework. In this figure, controller assumes a public service terminal, and viewer is a personal mobile device. We at first upload personal activity history to the public terminal, which are shown as icons of movement trail and digital photo, and execute filtering on the terminal. We also acquire map data from the Internet as a background map. Then the composed map is transmitted to the viewer, which is equipped with accelerometer. For the performance reason, the map is transmitted as a raster image between the controller and the viewer. Controller aggregates and renders all the data, and viewer concentrate to provide 3D interaction.

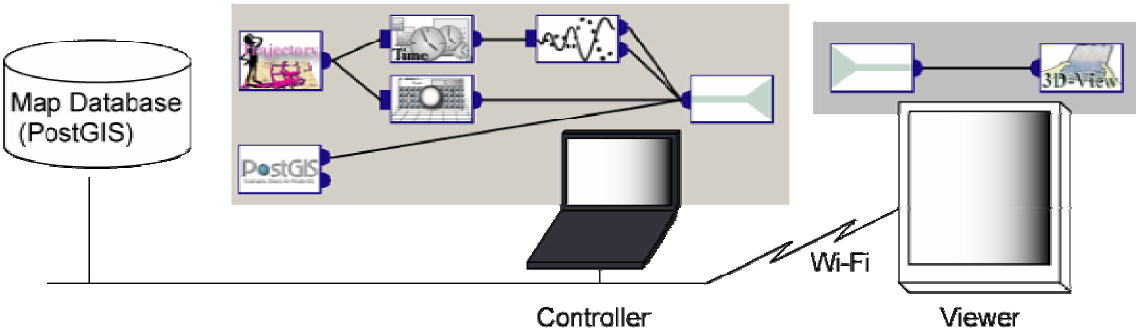


Figure 5. A System Architecture of the mPATH View

4. Summary

In this paper, we introduced two emerging technologies which are changing mobile devices. We gave the uCore and the uTexture as examples of advanced mobile devices which are equipped with sensor technology and short-range wireless technology. Then we argued features of map-based services in the advanced mobile devices. “Context-awaness”, “Activity-based mapping”, “Dynamic generation”, and “Information sharing” are the keywords of advanced map-based services which we introduce. We claimed that existing C/S software architecture is not enough to provide mobile map-based services with these characteristics, and proposed mPATH framework as a middleware to develop advanced map-based services. We demonstrated mPATH view as an application on the mPATH framework.

We are now developing the mPATH Framework, and planning to evaluate its function and performance as a middleware. We are also going to develop other applications on the framework.

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