*Recommended Paper*

# Mobile Info Search: Information Integration for Location-Aware Computing

Katsumi Takahashi,† Nobuyuki Miura,†† Seiji Yokoji† and Ken-ichi Shima††

As a result of the progress in mobile computing, people can access various kinds of local information on the Internet for use in daily life. However, such contents and services are heterogeneous and distributed. There is thus a need for a mobile-computing methodology and services for utilizing local information from the Internet. In this paper we introduce a research project entitled Mobile Info Search (MIS), and describe its goal, architecture, implementation, and experimental results. The goal of MIS is to collect, structure, and integrate distributed and diverse local information from the Internet in a practicable form and make it available through a simple interface to mobile users in various situations or contexts. We do this in a location-oriented way. The experimental MIS application features a "location-oriented meta search" for Web database servers, a "location-oriented robot-based search" called kokono Search for distributed Web documents, and a simple interface based on the latitude and longitude of the user's location, which are obtained from the user's PHS or GPS. Analysis of a trial service shows that multiple services, such as maps and textual information, are often requested together for one location within a short period of time. This shows our method works well enough to provide simple information integration, and that the MIS concept was welcomed.

## 1. Introduction

Is information obtained from the Internet helpful in daily life? Can mobile computing facilitate shopping or sightseeing? The growth of the Internet has made available much attractive local information, including information about good restaurants, public transportation, and the local weather. However, it takes a lot of time to complete a task such as preparing for a business trip by accessing online data. Insufficient use is made of local information on the Internet. The reasons for this are as follows:

- The content is not designed for mobile computing, or mobile terminals are not powerful enough to handle it.
- Because the contents are designed independently, a user may have to search several sites to gather the desired information.
- Search interfaces are complicated and vary greatly.

In this paper we discuss information that is related to a certain location or area, which we call "local information." A mobile computing technique that enables a person to use this local information in daily life would be very helpful.

Mobile Info Search (MIS) is the name of our research project and Internet-based application. The long-term goal of MIS is to integrate local information from a network and real-world information into a form suitable for mobile-computing users. The local information to be integrated includes information on the Web, in databases, and obtained from people and communities related to the location (**Fig. 1**). The core technique required for this integration is overlapping of the computer-synthesized world with the real world. Such integration has been studied in the field of augmented realty [1),2)]. MIS is characterized by the use of location information. It supposes that every object has location information representing the object's geographical position or area. Thus the location of the mobile user and extraction of the location from the information source play important roles. We call this integration "location-oriented information integration."

Mobile Info Search was implemented experimentally on the Internet in 1997 and has been open to the public since then. Our prototype MIS service is at *http://www.kokono.net/*.

† NTT Information Sharing Platform Laboratories, Nippon Telegraph and Telephone Corporation
†† NTT DoCoMo Multimedia Laboratories, NTT DoCoMo, Inc.

The content of this paper was presented at the meeting of SIG-Mobile Computing on Sep. 1998, and this paper is recommended to be appeared in the Journal of IPSJ by a chairman of SIG-Mobile computing.

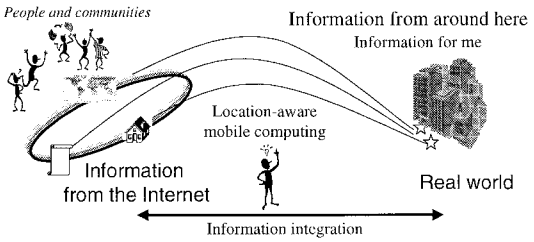


**Fig. 1** Concept of Mobile Info Search.

It provides local information ("*kokono*" is a Japanese word meaning "here") about shops, maps, the weather, transportation, and so on.

The MIS prototype has three features. Local information on the Internet today can be divided into two categories. One is information in Web database servers such as telephone directories and map servers; the other is information in static files such as HTML files describing good restaurants and sightseeing spots. The prototype's first two features are for these two information categories and the third feature is for a user interface:

- It has a "location-oriented meta search" that provides a simple interface for various Web database servers. This enables the user to search for information on shops and services, maps, public transportation information, and so on around his or her current or selected location.
- It has a "location-oriented robot-based search" for distributed Web documents that searches robot-collected information for local information in a location-oriented way. This search is called kokono Search.
- The third feature is a simple interface for accessing information, based on the latitude and longitude of the user's location. If the user carries a device such as a PHS handset or a GPS unit, the user's location can be obtained from it and used for MIS.

In this paper we first describe services suitable for MIS. In Section 3, we describe the architecture of MIS. In Sections 4 and 5 we introduce the MIS prototype. In Section 6 we discuss the results of an experiment. After a look at related work, we conclude with a summary.

## 2. Services Suitable for Mobile Info Search

### 2.1 Characteristics of Mobile Info Search Services

MIS is a location-aware, location-based information service. In this section, we discuss service suitable for MIS.

Location-aware computing can be divided into two main types according the usage of location information. One type uses the locations of mobile objects such as vehicles, birds, and human beings; the other uses the locations of fixed objects such as buildings, exhibits, and geographical areas. An example of the former is a monitoring service. MIS falls into the latter category. It provides information relevant to the place that a user is interested in, the area that a mobile user is in, or the object that a user is looking at. The range of locations for which information services are available varies from an entire nation through regions, towns, or streets, to buildings, rooms or things on the desk. For each range of locations, many information services are available in the forms of newspapers, public information from the government, advertisements on signboards or trains, guidebooks, magazines, and so on. We think that a service that provides information relevant to a certain location is suitable for MIS. For information users, this service may support their daily activities or business by providing information on eating places, public transportation, weather, accommodations, or interesting sights in the location. For information providers, it can give them a chance to advertise or disseminate public information about the location. The characteristics of MIS service are as follows:

- Provision of information relevant to the requested location
- Support for users' daily activities and business through provision of local information
- Creation of a marketplace for provision of local information or advertisements

### 2.2 Location-Related Information on the Internet

We are going to design such services using information on the Internet. In this section, we briefly examine the availability of local information on the Internet.

**Table 1** shows the availability of Japanese Web pages that contain some address string. We analyzed 10,000 documents randomly collected from the Web (by an automatic information collection method using a breadth-first information collection robot). 14.8% contained Japanese address strings and they could be related to some location indicated by the address. Thus at least about 14.8% of Web documents can be regarded as containing local information,

**Table 1** Percentages of Japanese Web documents that contain address strings.

| TOTAL | No address | Pref. | City | Town | Block No. |
|---|---|---|---|---|---|
| 10,000 | 8,520 | 445 | 549 | 433 | 53 |
| 100% | 85.2% | 4.5% | 5.5% | 4.3% | 0.5% |

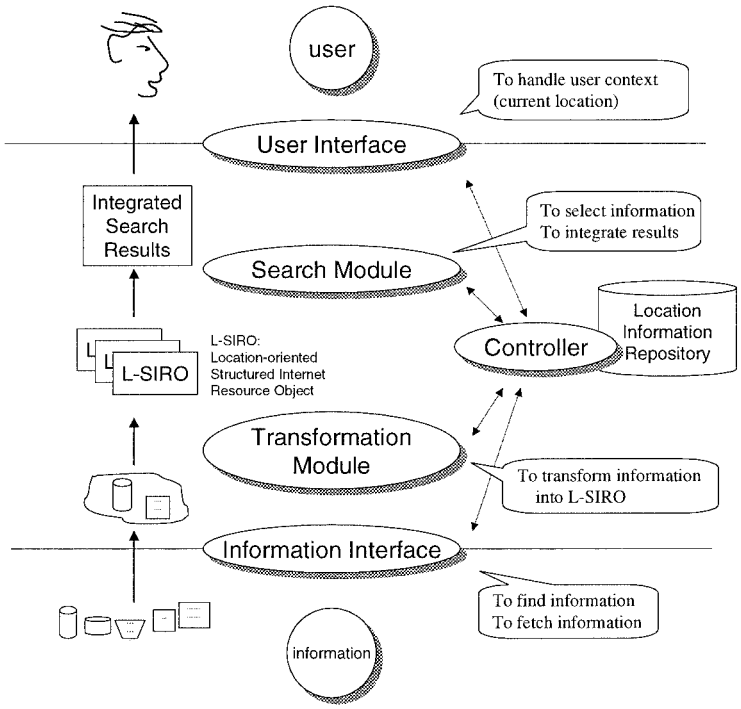


**Fig. 2** Architecture for Mobile Info Search.

and thus as potential contents for our location-based information service.

Note that the sequence Japanese addressing method is prefecture, city, town, *chome* (block number of the town), *banchi* (smaller block No.), *go* (house No.).

In the following sections, we describe the basic architecture of MIS and the system we have developed for collecting and organizing information.

## 3. Architecture of Mobile Info Search

The architecture for MIS is illustrated in **Fig. 2**. The goal of MIS is to integrate information on the user's location by collecting and compiling information on the Internet. To integrate the information, we use the location information, such as an address string in a document, which indicates the geographical position of it. This is the basic idea of location-oriented information integration.

MIS is located between the users and the information sources on the network. This kind of software system is referred to as a mediator [3].

We defined several mediation services on four MIS modules:

- User Interface
  - Handles feature of the user context such as the location and the user's preferences
- Search Module
  - Selects information from a set of structured objects
  - Integrates selected information into a handy form
- Transformation Module
  - Transforms raw information into structured objects
- Information Interface
  - Finds relevant resources
  - Fetches information from the resources

### 3.1 User Interface

The User Interface is the interface module between the user and MIS. It's role is to handle

the user context and transform it into a format. The user context contains the user's location, action, and preferences. These attributes are normalized in some form in the object. The normalization level depends on the application requirements. In primary MIS, at least the location is normalized into geographical polygons (or coordinates of longitude and latitude). As the location information can be represented by address strings, nearby landmarks, or some coordinates depending on the user's devices, these variations are unified by using the Location Information Repository. This repository defines the relations among the different kinds of location information and enables them to be converted from one into another. The transformed user context is used by the Search Module and other modules.

### 3.2 Information Interface

The bottom module of Fig. 2 is the Information Interface. It's function is to find relevant resources and fetch information from them. The task of finding information sources is one of the main difficulties and a general method of doing so for Internet resources is not known. In software-agent research, a broker system that assists in matchmaking between services has been proposed. The broker system generally uses exchanges of service specifications by agents. However, since information sources do not have an agent interface, this task is still an open problem in MIS.

For the fetching role, variations in the services' access methods need to be uniformed. If semantic conversion, such as the location-information conversion, is required for fetching the local information from the target resources, the Location Information Repository is consulted.

### 3.3 Transformation Module

This module executes the central concept of MIS, transforming fetched information into a structured object format called L-SIRO (Location-oriented Structured Internet Resource Object), shown in **Fig. 3**. A document that has tags for semantic attributes is called a structured document. L-SIRO is a structured object that has location information or a geographical polygon that represents the area in which the information is relevant. Every object in MIS is regarded as an L-SIRO. Location information included in the fetched information can be found as address strings, the names of nearby train stations, or postal codes. This module utilizes the Location Information Repository to introduce the location information into the original information.

```
<L-SIRO>
  <Polygon>
   (123, 456), (765, 432), (890, 321), . . .
  </ Polygon>
  <Address>
    Tokyo, Minato-ku
  </Address>
  <Name>
    Tokyo Tower
  </Name>
   ----------
</L-SIRO>
```

**Fig. 3** Example of L-SIRO format.

### 3.4 Search Module

The role of the Search Module is selecting and integrating information. As this system is for location-oriented structured documents, it must have a geographical search method that can retrieve documents within a certain distance from a requested point. In addition, it must be able to select or even recommend information.

In its integrating capacity, it deletes duplicated information, unifies the results, and combines them with other kinds of information. For example, it might add a map to restaurant information.

### 3.5 Overall Architecture

An abstract architecture has been described and the roles of the four modules have been defined. These modules work together to complete a task. A Controller module is required to mediate between these modules or agents. In the following two sections, a practical architecture based on this abstract architecture is described.

## 4. Mobile Info Search 1: The First Trial Service

### 4.1 Experiments and Service Outline

Our first trial service, MIS1, performed a "location-oriented meta search" and provided a simple interface to various kinds of resources [4]. Two examples of searches are shown in **Figs. 4** and **5**. Users only had to select a remote service name from the MIS1 menu. A query for the target server was created by MIS1 and the results were displayed automatically on the user's terminal.

This experimental service was provided by

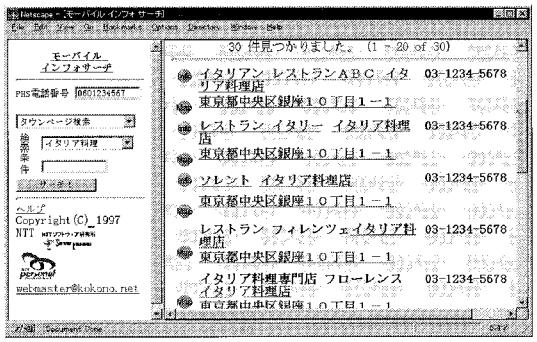


**Fig. 4** Nearest Italian restaurants from *Internet TOWNPAGE*, *http://itp.ne.jp/*. The left window is the MIS index. The right window is for external servers.

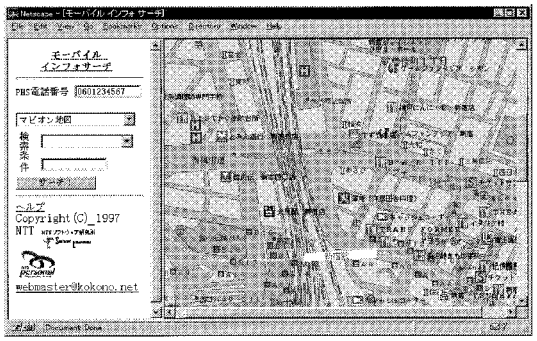


**Fig. 5** Map of current location from *Mapion*, *http://www.mapion.co.jp/*.

NTT Laboratories and NTT Central Personal Communications Network Inc. (currently NTT DoCoMo, Inc.) as a free WWW service. It lasted from September 1997 to May 1998. User access was realized through an LI-PHS (location-information PHS handset that transmitted the user's location in longitude-latitude form. NTT Personal Inc. provided a limited number of handsets for trial use during this period). MIS1 provided local information based on the user's current location.

About 400 users accessed 11 WWW services, provided by courtesy of eight companies. These services included textual information in the form of Yellow Pages, city information such as hotels and restaurants, and pictorial information such as maps. Maps requests accounted for 65% of the total number of accesses. One of the reasons of the frequency of map requests was that the LI-PHS was a novelty that was used to test new functions of PHSs.

### 4.2 Architecture

The basic architecture of MIS1 is shown in

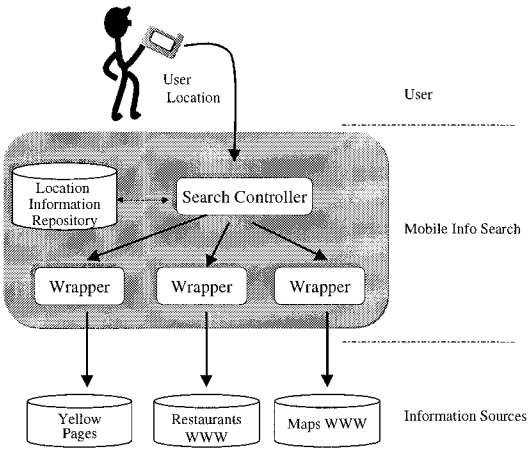


**Fig. 6** Basic architecture of MIS1: "location-oriented meta search."

**Fig. 6**. The role of this service was to create a query for the target information-server on behalf of the user. The service converted the location information into a form suitable for the target. Hand-coded wrapper software for each Web server was implemented as an Information Interface module. The role of finding information resources was played by the MIS1 operator manually. The Information Interface created a query for the target site, using the user's location as follows. It had site-specific information, such as the query format and location-representation information. One server might accept only a longitude-latitude representation, while another might accept an address or station name. This local information was converted by using the Location Information Repository. As this service had no compilation method for search results, results obtained from the remote host were returned directly to the user [5].

Location-oriented meta search is performed as follows:

(1) Receive the user location (longitude and latitude) and the target service name
E.g., `(x=139.36.27, y=35.25.24, target = AYellowPages)`

(2) Convert the user's location into a suitable form for the target, using the Location Information Repository
E.g., `(x=139.36.27, y=35.25.24)` → `address = ''Tokyo, Chuo-ku, Ginza 4''`

(3) Determine the search scope of the location for the target
E.g., `''Tokyo''`, or `''Tokyo, Chuo-ku''`, or

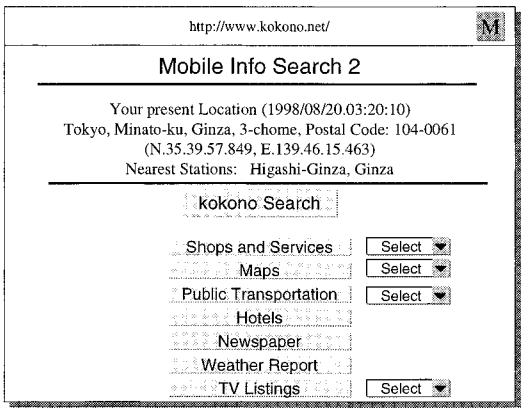


**Fig. 7** Index page of MIS2.

`''Tokyo, Chuo-ku, Ginza''`, ...

(4) Create a query
E.g., `http://www.AYellowPages...co.jp/search.cgi?address=''Tokyo, Chuo-ku, Ginza 4''`

(5) Search

## 5. Mobile Info Search 2: Introducing kokono Search

### 5.1 Experiments and Service Outline

Our newest service is MIS2, which has been available since June 1998. It differs from the first version in two ways: (1) it supports additional location notification methods: LI-PHS (a commercial service had been started), GPS, maps, and the selection of textual information, such as addresses, station names, and postal codes that specify a location; and (2) a "location-oriented robot-based search" called kokono Search has been added.

kokono Search is a kind of a search engine that lists Web pages not on the basis of keywords but on the basis of their locations. It searches for documents within a certain distance from a user's location and displays an outline of each such as its title, URL, location, and distance from the user's location.

The initial screen of MIS2 is shown in **Fig. 7**. This page is automatically displayed when MIS2 is accessed. The user's current location is displayed at the top of the page as the address, the longitude and latitude, the postal code, and the nearest station. kokono Search and other seven categories follow. About 20 available services are assigned to these eight categories. Web pages within a certain distance are listed in the right frame.

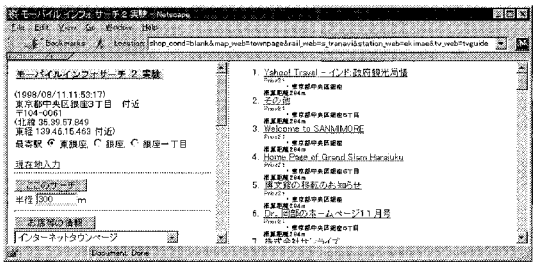

**Fig. 8** Example of *kokono Search*.

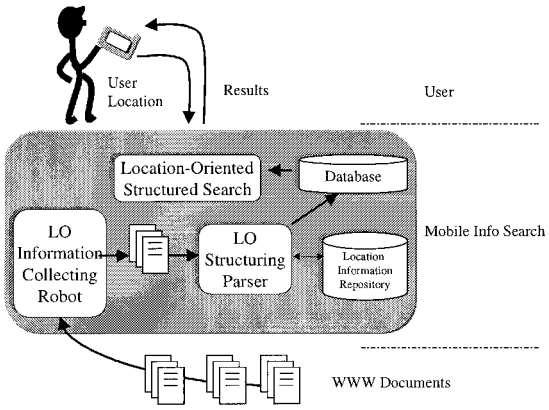


**Fig. 9** Basic architecture of kokono Search in MIS2: "location-oriented robot-based search."

An example of kokono Search is shown in **Fig. 8**.

### 5.2 Architecture

The basic architecture of kokono Search is shown in **Fig. 9**. It has three modules. The Location-Oriented Information Collecting Robot as the Information Interface and the Location-Oriented Structuring Parser as the Transformation Module work together to create the local information database beforehand. The Parser generates L-SIROs from the collected documents. The Search Module's Location-Oriented Structured Search calculates the distance between the L-SIRO and the object representing the user information, and outputs outlines of the documents within a certain distance [6]. The flow of kokono Search is briefly described below.

(1) Create a location-oriented database

- The Location-Oriented Information Collecting Robot collects documents from the Internet.
- The Location-Oriented Structuring Parser parses the obtained documents to look up the location information (address strings) and store the documents with spatial information (longitude and latitude) by consulting the Location Information Repository.

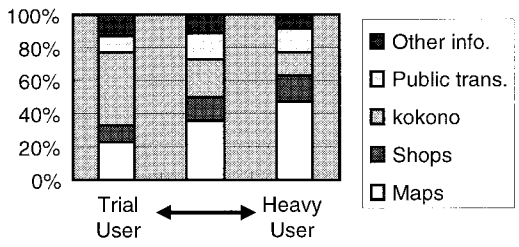


**Fig. 10** Search trend of Mobile Info Search.

(2) Perform a search
- Search for documents within a certain distance of the requested location
- Display the documents in order of distance

## 6. Experimental Results

In this section, we analyze the experimental results of the trial service. As MIS is open to the public, anyone connected to the Internet can enjoy all the services described in this article. We did not call for participants in this experiment; almost all our users have visited the site voluntarily.

Mobile Info Search provides about 20 services in eight categories (Fig. 7), including kokono Search, Shops and Services, and Maps. Each search for a service is initiated by clicking the button. Between October 1998 and February 1999, a total of 51,799 searches (421.1 per day) for some service were recorded as Web log files. We used 24,287 complete searches from the log files for analysis.

### 6.1 Search Trends

An analysis of accesses is shown in **Fig. 10**. We classified users into three groups according to the duration of their searches during the evaluation period. One group consisted of "trial users" those who accessed our server only once (shown by the left bar in the graph, with a total of 4,923 searches). Another group, labeled "heavy users," consisted of those who accessed our server more than 10 times (shown by the right bar, with a total of 9,647 searches). The last group is the inbetween (shown by the middle bar, with a total of 9,717 searches). kokono Search was the most frequently requested service for "trial users." This seems to reflect the user interface, since the kokono Search button is located at the top of the index page (Fig. 7). On the other hand, maps were requested more often as the users becomes the repeaters. While maps were the most frequently requested contents, other services were used with almost equal frequencies, even by heavy users.

Another set of analysis results is shown in **Fig. 11**. This analyzes consecutive requests from a user. An MIS user can receive local information by specifying the target location and the service. The upper graph shows the interval of time between the first request of the day from a user and the second request to the MIS services (maps, shops, kokono Search, etc.). According to the analysis, 26.8% of users re-requested within 1 minute (A) and 53.5% re-requested within 3 minutes (A+B). On the other hand, 38.2% did not request any service and left the server (D). Since this experiment was conducted as an open Web service and some users may not have known the concept or purpose of the service, this value may include requests from trial users. Users can modify the target location to which they want to refer. Around 80% of re-requests within a short interval were for the same location as the first one (E+G). Users select the target service for each request. Over 60% of requests within a short interval were for a different service from the first one; for example, after requesting a map, the user requested a kokono Search. In total, 53.5% of users requested the MIS service more than once within three minutes (A+B in A+B+C+D) and 28.9% of users requested different services for the same location (J+L in A+B+C+D) within three minutes.

On the basis of this analysis, we make following observation:
- The map service was the most frequently requested, but other types of information were also requested constantly.
- Multiple categories of services were often requested together for the same location.

We believe that our simple interface, which provides multiple types of local information for each location, was welcomed and that some information integration technique for organizing the maps and other local information in a handy form is required.

### 6.2 Comparison of Mobile Users and Common Users

We compared the MIS usage of mobile users and common users. Since MIS is designed for mobile users, both mobile and static users can use it. Since it is not possible to detect whether a user is "mobile" or "static" from the server side, some MIS users are regarded as "mobile." MIS provides users several methods of specifying their location, by using PHS, or GPS, or by

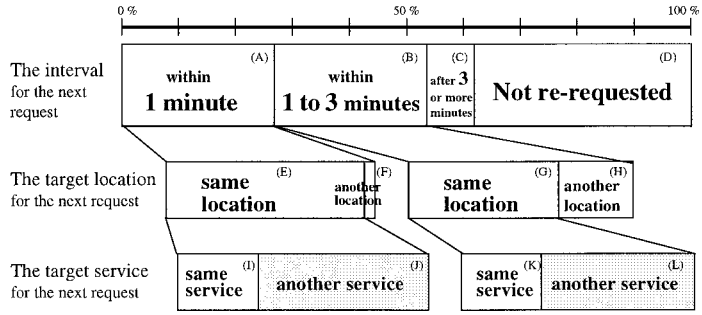


**Fig. 11** Search sessions of Mobile Info Search.

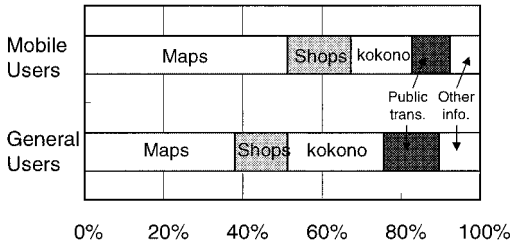


**Fig. 12** Comparison of mobile users and general users.

selecting address, railway station, and postal code. Users with LI-PHSs and GPSs can be located exactly, and can be regarded "mobile." We compared these mobile users' requests with all requests. The results are shown in **Fig. 12**. Mobile users requested maps 1.3 times as often as all users; mobile users did so in in 51.2% of instances on the average, while all users did so in 38.1% of instances. kokono Search and other textual information were requested less frequently.

On the basis of this analysis, we make following observations:

- Mobile users require maps especially frequently.
- Some types of information, such as the raw Web pages obtained by kokono Search, may not be suitable for mobile users.

We learned that mobile users require more concise, better-organized information.

## 7. Related Work

Several location-based information services have been proposed: "digitalcity—Your Local Content Source" [7] "Yahoo! Get Local," [8] and "Sidewalk" [9] are major location-based WWW information services that provide local information in the U.S. They provide indexes for specific cities. "Ekimae Tanken Club" [10] is a major Japanese local-information Web site that provides a "station-based" menu. "Monet information system" [11] is for car navigation users in Japan. These are all useful services, and show the importance of local information, but most contents are maintained manually. Application of an automatic information-collecting method to a location-based information service as in our experiment, is not yet common, we believe that the information techniques for collecting and integrating information are required for these services.

We have been studying information retrieval methods for mobile users. Our first effort was called "Intelligent Page." [12] We tried using software agents to retrieve information from diverse resources on behalf of users. Our next effort, "Action Navigator," [13] used a "recommender architecture" based on the choices made by other users.

Our work is based on the work of others. Mediator [3], for example, is a middle-ware service between end users and data resources. It integrates diverse data from multiple sources, reduces it to the appropriate level, and restructures the results. TSIMMIS [14),15)] and I3 [16)] are two major mediation research projects.

There are several Internet-based research applications similar to MIS. MetaCrawler [17)] is a parallel Web search service. It provides a single interface to the user, collects the results from various search engines, and organizes the results. Bargain Finder[18)] and Shopbot [19)] both find products by using servers and compare the prices and specifications. These research efforts are close to MIS in their motivations and goals; however, MIS differs in its location-oriented information structuring and organizing.

## 8. Conclusion

We introduced the idea and the goal of Mobile Info Search. We have designed and imple-

mented the Mobile Info Search application with the goal of collecting, structuring, and integrating distributed and heterogeneous local information gathered from the Internet in a practicable form. Another goal is to provide a simple interface to mobile users in various situations.

We implemented the latest version of MIS in Sept. 1998 (URL *http://www.kokono.net/*). It features a "location-oriented meta search" to provide a simple interface for major location-based information servers and a "location-oriented robot-based search" to provide distributed Web documents. Data provided by a user's PHS or GPS can be employed to determine the user's current location.

Analysis of our trial services yielded the following results:

- Maps are the most frequently requested contents, especially for the mobile users.
- Multiple categories of services are often requested together for the same location.
- Some information, such as raw Web pages, may not be suitable for mobile users.

We believe that our simple interface, which provides multiple types of local information for each location, is welcomed. From comments by users, we learned that Web pages have the potential to become more useful and attractive when they are organized in a location-oriented way. We will concentrate on studying techniques for producing more concise and well-organized information for mobile and static users.

Our goal of providing local information from the Internet in a practicable form cannot be achieved by simply using software technology. We also need information providers to supply useful local information and users those who love to enjoy it. We will therefore continue working with suppliers and users.

**Acknowledgments** This research is based on an Internet-based experiment. The authors would like to thank all the users and information providers who understand the purpose of MIS and support us. The original version of this article was published in IPSJ SIG-MBL. The authors also thank all those who commented on ways of improving this article.

## References

1) Wellner, P., Mackay, W.E. and Gold, R.: Computer-Augmented Environments: Back to the Real World, *CACM*, Vol.36, No.7, pp.24–26 (1993).
2) Nagao, K. and Rekimoto, J.: Agent Augmented Reality: A Software Agent Meets the Real World, *Proc. Second Intl. Conf. on Multi-Agent Systems* (*ICMAS-96*), pp.228–235 (1996).
3) Wiederhold, G.: Interoperation, Mediation, and Ontologies. *FGCS '94 Workshop on Heterogeneous Cooperative Knowledge-Bases*, pp.33–48 (1994).
4) Takahashi, K., Miura, N., Sakamoto, H. and Shima, K.: Location Oriented Information Integration, *Proc. Japan World Wide Web Conference '97* (1997). *http://www.iaj.or.jp/w3conf-japan/97/*
5) Miura, N., Takahashi, K., Yokoji, S. and Shima, K.: Location-Oriented Information Retrieval of External Resource Considering Distribution of Information, *57th IPSJ National Conf.*, Vol.3, pp.637–638 (1998).
6) Yokoji, S., Miura, N., Takahashi, K. and Shima, K.: Performance Evaluation of WWW Robot that Dynamically Changes its Retrieval Strategy Using Contents of WWW Resources, *57th IPSJ National Conf.*, Vol.3, pp.163–164 (1998).
7) digitalcity: *http://www.digitalcity.com/*
8) yahoo: *http://local.yahoo.com/*.
9) Sidewalk: Microsoft Corporation *http://www.sidewalk.com/*.
10) Ekimae Tanken Club: Toshiba Corporation. *http://ekimae.toshiba.co.jp/*.
11) Monet Information Service: *http://www.tms.ne.jp/*.
12) Takahashi, K., Nishibe, Y., Morihara, I. and Hattori, F.: Intelligent Pages: Collecting Shop and Service Information with Software Agents, *Special Issue on the Best of PAAM96, Applied Artificial Intelligence Intl. Journal*, Vol.11, No.6, pp.489–499, Taylor & Francis (1997).
13) Ohtsubo, R., Nishibe, Y., Takahashi, K. and Morihara, I.: Action Navigator: An Information Service Based on Agent-Communication for Supporting Decision-Making, *Proc. PAAM98*, pp.629–630 (1998).
14) Hammer, J., et al.: Information Translation, Mediation, and Mosaic-Based Browsing in the TSIMMIS System, *ACM SIGMOD Intl. Conf. Management of Data* (1995).
15) TSIMMIS: The Stanford-IBM Manager of Multiple Information Sources (TSIMMIS) (1998). *http://www-db.stanford.edu/tsimmis/*
16) Gunning, D.: Intelligent Integration of Information Technology (I3) (1997). *http://maco.dc.isx.com/iso/battle/i3.html*
17) Selberg, E. and Etzioni, O.: The MetaCrawler Architecture for Resource Aggregation on the

Web, *IEEE Expert*, Vol.12, No.1, pp.8–14 (1997).
18) Krulwich, B.: Bargain finder agent prototype, Technical Report, Anderson Consulting (1995). *http://bf.cstar.ac.com/bf/*
19) Doorenbos, R., Etzioni, O., and Weld, D.: A Scalable Comparison-Shopping Agent for the World-Wide Web, Autonomous Agents '97 (1997).

(Received March 9, 1999)
(Accepted January 6, 2000)

**Editer's Recommendation**

This paper proposes an automatic location-related information retrieval and Web integration system targeted for mobile users and evaluates the system on the Internet. Several location-based services have been proposed to show the importance of the local information, but they have not designed any automatic retrieval methods for the services. This paper describes the detail of the system development for the investigation of the future service-providing systems and contributes to the progress of the field. (Chairman of SIG-Mobile Computing Tadanori Mizuno)

**Katsumi Takahashi** received the BE degree in mathematics from Tokyo Institute of Technology and joined NTT in 1988. He is currently a senior research engineer at Information Sharing Platform Laboratories, NTT. His research interest includes information retrieval systems and its algorithm, intelligent agents, mobile computing, and location-based computing. He is a member of the IPSJ, ACM and JSAI.

**Nobuyuki Miura** received the BE degree and the ME degree in computer science from Tokyo Institute of Technology in 1993 and 1995, respectively. He joined NTT in 1995, and is currently a research engineer at Multimedia Laboratories, NTT DoCoMo, Inc. He works at research and development including location-based information sharing and filtering, user log analysis, and personal adapted system. He is a member of the IPSJ.

**Seiji Yokoji** studied electrical engineering and received the ME degree from Kyusyu Institute of Technology in 1995. He joined NTT in 1995. His is now a member of NTT Information Sharing Platform Laboratories. His research interest includes about intelligent integration of information and location oriented search engine. He is a member of the IPSJ.

**Ken-ichi Shima** received the BE degree in electrical engineering and the ME degree in information science from Hokkaido University, Japan, in 1976 and 1978, respectively. He joined NTT Laboratories in 1978, and is currently a director at Multimedia Laboratories, NTT DoCoMo, Inc. His research interests include knowledge extraction in software development, VLDB on Internet, and intelligent mobile information management, especially personalize technologies in mobile environment. He is a member of the IPSJ, IEICE and JSAI.