An Advanced Traveler Information System with Emerging Network Technologies

Chun-Hsin Wu[1], Da-Chun Su[1], Justin Chang[1], Chia-Chen Wei[1], Jan-Ming Ho[1], Kwei-Jay Lin[2], and D.T. Lee[1]

{wuch, starking, justin, ccwei, hoho, dtlee}@iis.sinica.edu.tw, klin@uci.edu

[1] Institute of Information Science
Academia Sinica, Nankang
Taipei, Taiwan, 115

[2] Dept. of Electrical and Computer Engineering
University of California
Irvine, CA, USA 92697

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ABSTRACT

Advanced Traveler Information Systems (ATIS) plays an important role in intelligent transportation systems; it assists travelers with pre-trip and en route travel information to improve the convenience, safety and efficiency of travel. In this paper we present a highway ATIS system which provides more decisive and valuable travel information than conventional ATIS systems by integrating it with newly emerging Web service and wireless communication technologies. Following the Web service standards, our system can aggregate multiple travel-related data from different sources and provide value-added services to application developers or users. Through multimedia messaging services or wireless LAN communication, we can support access of the system to mobile travelers with visualized real-time traffic information for pre-trip planning or en route referencing. In order to make our system more reliable and useful, the methods of lost data reconstruction and travel time prediction are also proposed and examined.

INTRODUCTION

In a highly mobile society, accurate and timely traffic information can help travelers reach their destinations quickly and safely. To serve this information need, Advanced Traveler Information Systems (ATIS) that provide real-time pre-trip and en route traveler information are introduced to help drivers avoid congestion and choose timesaving and safe route. Initially ATIS is designed to assist travelers making pre-trip travel planning. With the rapid progress in the development of computer and communication technologies, traveler information will not only be able to benefit travelers, but also can be utilized by value-added service providers. We can expect more enriched traveler information will be available, and ATIS providing en route information will also get popular soon.

Web service technology [1, 5] is one of the emerging network technologies that can enhance the reusability and interoperability of current ATIS systems. Web service standards make software components as services to be reused and integrated over the Internet. They identify the roles of service provider, requester and broker in the service supply chain, and provide basic Web services such as service publishing, searching, and binding. Standardized protocols such as UDDI, SOAP and WSDL assure flexibilities and interoperabilities among different languages and platforms. Figure 1 shows the interactions among them. XML-formatted Simple Object Access Protocol (SOAP) runs over HTTP to process remote procedure calls and allows communications between service provider and service requester. WSDL (Web Service Description Language) is a XML formatted document that describes the structure of the message transmitted and defines the address of the service source and the protocol needed for service interaction. UDDI (Universal Discovery Description Integration), a XML formatted public directory, consists of three sections: white page, yellow page and green page which describes the contents of a Web service provider. With UDDI, service requesters can search the desired services, and service providers can publish their services on the public and free Web service directory.

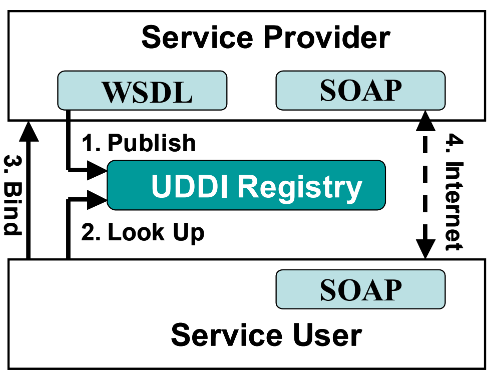

Figure 1: SOAP, WSDL and SOAP interaction

In addition to Web services, wireless communication technologies have made traveler information more available to users anytime and anywhere. With the high bandwidth brought by 2.5G cellular phone technologies, Multimedia Messaging Services (MMS) [2] can deliver messages of audio, voice, or colorful graphics. It will make the delivery of visual traveler information to mobile users easily, and promote the mobile commerce with successful business models. Besides, wireless LAN (WLAN) technologies such as 802.11b bring wireless broadband access to users. A large-scale deployment of WLAN over campus or community can serve as an inexpensive platform for providing location-based multimedia and regional navigation services to visitors [7]. This will encourage future development of rich traveler information.

This paper presents an implementation of an intelligent transportation Web services

(ITWS) [6] that integrate the emerging network technologies described above. Different from conventional ATIS applications, ITWS is designed to be a Web service infrastructure. Not only to provide traveler information to users, it also aims to be used as a modular component by other enterprises or Web service providers for application development. It can deliver real-time traffic information to MMS-enabled cellular phones, as well as mobile Internet users.

Figure 2 shows some potential applications for ITWS, including traffic information services, logistic service providers, tour and travel services, medical and emergency managements, etc. Based on the Web service technology and traffic data from ITWS, external Web service providers can customize the raw traffic data into various kinds of services with different data inspection and analysis processes. End users can also access ITWS services through different types of devices such as PDA, cellular phone, AutoPC, etc. So ITWS can be seen as "the provider of providers." For examples, with the help of ITWS services, logistic companies can improve the operational efficiency and reduce the cost by better managing the scheduling of trucking services. With the simplicity to incorporate ITWS modular applications with RPC calls, Web service developers can further enhance the reusability and distributed characteristic. Besides, the ITWS system further facilitates Intelligent Transportation Systems (ITS) researches for academic or government agencies. Therefore, a powerful yet flexible ITWS will have a very significant impact to the society and make great contributions to human life in general.

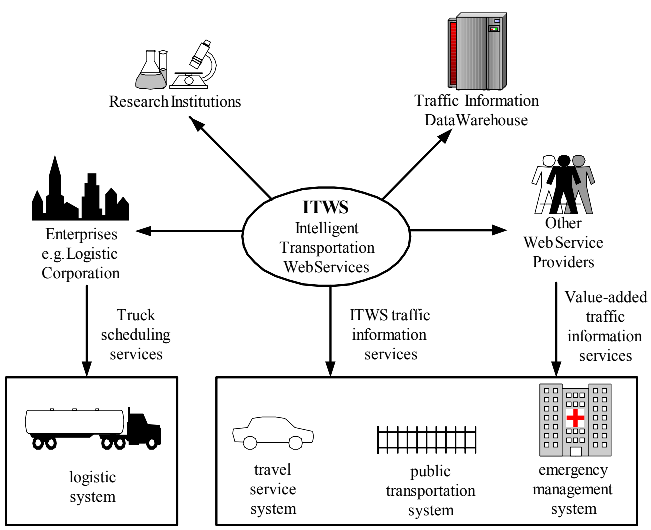

Figure 2: ITWS applications

SYSTEM ARCHITECTURE

The organization of the ITWS architecture is shown in Figure 3. The Taiwan Area National Freeway Bureau (TANFB) constantly collects vehicle speed information from loop detectors installed on the highways. The loop devices are kept 1 km apart. The speed and traffic information is then reported to their official website [4] and updated once every 3 minutes. An ITWS server provides the data storage for ITS. A crawler periodically scans real time traffic information from the TANFB website, parses through the data and stores the processed data to the local database (ITWS Database) for data analysis and verification. A log is kept to record the timestamp for each processed data and its status. Although the database has the complete information, a more user-friendly interface is needed for human users. Therefore, we create a traffic diagram server to generate graphical traffic visualizations using the traffic data from the ITWS Server via the SOAP protocol. These traffic visualizations can be generated on-line, or off-line and pre-stored on the server. An ITWS website is also created to provide the main human interface to ITWS. Users can use personal computers or portable devices such as PDA and cellular phones to access ITWS service through wireless Internet or MMS gateway [2].

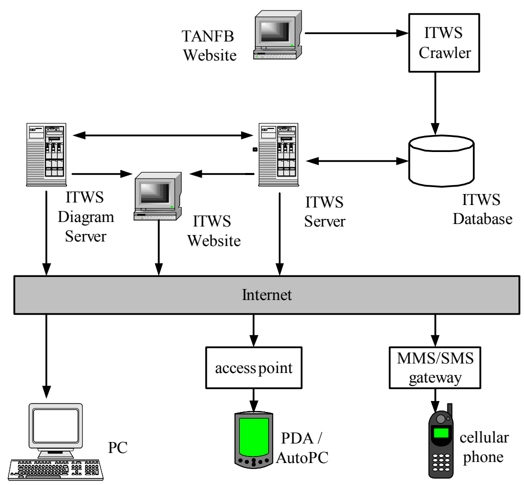

Figure 3: ITWS system architecture

DATA RECONSTRUCTION

One of the issues we discovered when building the ITWS system is the data robustness. Data corruptions are observed often at the TANFB website. For most transportation applications, missing data may induce problems and cause services to be ineffective or useless. Principal causes of the problem may be characterized into two categories: Detector malfunction, and data transmission failure between detectors and the TANFB Web server. For detector malfunction, detector data entry reads 0 in the TANFB website. If the situation persists for a long time, it may appeared in figure 4 as white vertical rectangular lost data section through out the day, or small rectangular boxes. For data transmission failure, which might caused by TANFB system crash, or negligence of refreshing old data entries, the lost data section may appear to be a horizontal rectangle across the entire detector locations.

To reinforce the reliability of ITWS information service, we conduct close examination on the validity of the detector data acquired from the TANFB website. If the detector data entry is fallacious, and might mislead service users, a cautious warning sign will appear to alert service users. Upon data processing in our system, e.g. for travel time prediction, an inspection on data validity will be conducted. Typically, daily data reconstruction ratio is around 15 %, and sensor failure contributes to the majority of the total errors. Table 1 shows the reconstruction ratios of a week during 24 – 30

October 2003. Note that data entry on Oct 30, 2002 is unacceptably large and should be processed carefully in traffic data analysis in order to reduce the chance of system degradation caused by unreliable data.

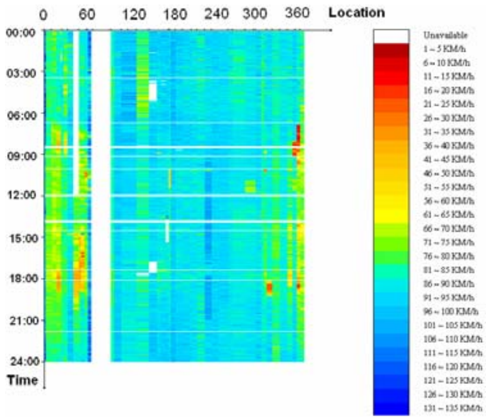

Figure 4: Traffic information with lost data sections

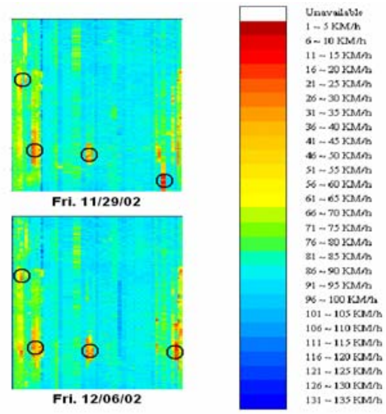

Figure 5: The highway traffic comparison between Nov 29th and Dec 6th, 2002

Table 1: Lost data reconstruction ratio

Date (2002)	Source of Error		Total Reconstruction Ratio (%)
	Sensor (%)	Other Causes (%)	
10 / 24	11.62	2.70	14.33
10 / 25	14.76	1.45	16.22
10 / 26	12.74	1.66	14.41
10 / 27	11.27	1.87	13.15
10 / 28	11.49	3.95	15.45
10 / 29	10.45	2.80	12.54
10 / 30	45.91	5.00	50.91

Lost Data Interpolation

A simple data reconstruction method using interpolation has been implemented to replace missing or invalid data. We observe that highway traffic depends very much on the time of the day, the day of the week, and the location. Certain road segments constantly have very heavy traffic during rush hours on weekdays but otherwise lightly loaded. There are also road segments that constantly have heavy traffic during weekends but almost no traffic at all during weekdays. Such intelligence should be used in reconstructing missing data.

Figure 4 shows a traffic information visualization of the SYS Highway. The x-axis identifies the location from north to south and the y-axis identifies the time of the day from early morning to midnight. Different colors are used to show the vehicle speed at each time-location. Any area with a bright red color can be easily identified as the congestion area. It is therefore quite easy to see the trouble areas during rush hours of 9am and 6pm. Note that white boxes in the figure correspond to the missing data in the database.

TRAVEL TIME PREDICTION

Figure 5 shows a typical congested traffic pattern exhibits on Friday. Two graphs, for Nov 29th, 2002 and Dec 6th, 2002, are compared, and large congestion areas are found at around the same locations during the same time of the day. Based on the fact that the traffic possesses deterministic behavior, we can predict future travel time using historical data. From empirical study of the traffic database, we can see that traffic behaviors display periodicity (Figure 6). However, since travel time is highly volatile to environmental impact, namely weather conditions and traffic incidents, obtaining impeccable predictions are highly unlikely and require substantial amount of knowledge not only on environmental factors but traveler's driving habit as well.

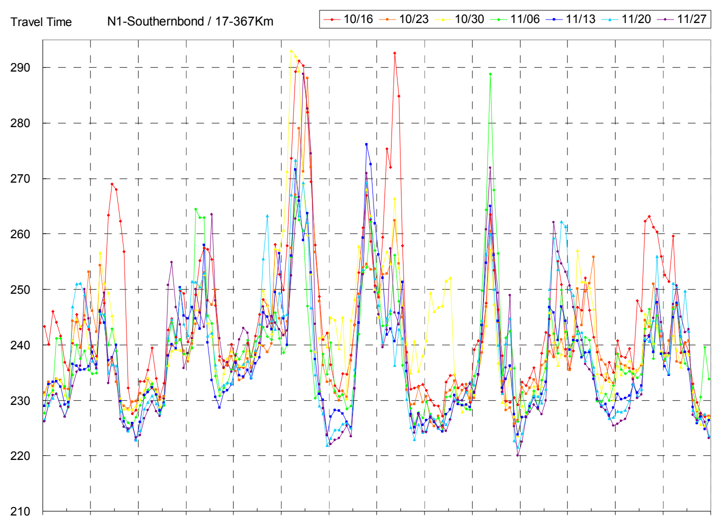

Figure 6: Weekly highway traffic pattern (Southbound, from 17-367 km)

The ITWS travel time prediction services are performed with three methods, of which two are common baseline methods, current time and historical mean predicting methods, and another is the support vector machine (SVM) predicting method. Current time predicting method computes travel time from the data available at the instant when prediction is performed. Historical mean predicting method computes travel time from the average travel time of the historical traffic data at the same time of day and day of week. SVM predicting method computes travel time using support vector regression for time series prediction. Predicting results are then re-wrapped into different representations accommodating suitable occasions.

TRAFFIC INFORMATION REPRESENTATION

Most onboard trip planners available today are designed for rendering driving directions by showing drivers the shortest path between two locations. Very few offer travel time prediction services. Even if they do, the calculation of travel time is usually based on the maximum (or average) driving speed on the roads to be traveled, not the actual traffic condition. In the ITWS system, we go one step further. We not only consider the actual traffic condition but also make use of the past traffic pattern to predict how changes in departure time and locations may affect the driving speed on the road and the travel time required. In this way, a traveler who needs to be at a certain place at a certain time can make decisions on when he/she needs to start the trip. We also provide the services that give travelers advanced warnings on when and where they may hit a congested area if they depart at a certain time.

Figure 7 shows a travel time analysis chart that helps travelers effectively manage their time and constraints. It informs users possible travel time (y-axis) based on the departure time (x-axis) from 0:00 to 23:57. Users may choose the shortest or the most convenient travel time that fits their schedules. For example, in this chart, it can be seen that any trip with a departure time between 08:00 to 14:00 will likely run into heavy congestion (the red area) close to the end of the trip. A departure time after 20:00 is probably the best since the traffic status along the trip is mostly blue and green. After a user selects an appropriate embarking time (for example, 17:00 is selected in Figure 7), the traffic condition along the road for the selected trip can be displayed in the on board traffic state forecast graph (Figure 8). Figure 8 can be used for on board navigation and can also be implemented as a visual aid in a GPS device, or hand held devices such as PDA and cellular phone [8]. The expected travel speed and location at every time instant is clearly displayed.

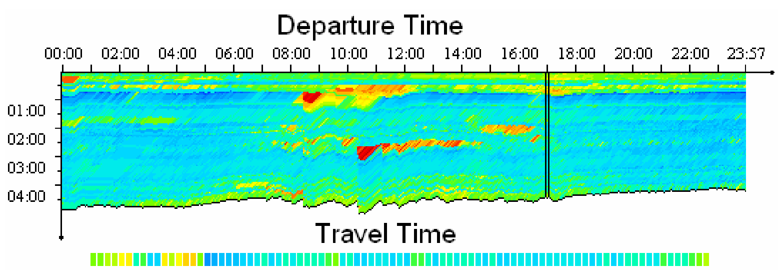

Figure 7: Pre-trip travel times from KeeLung to KaoHsiung, Nov 9, 2002

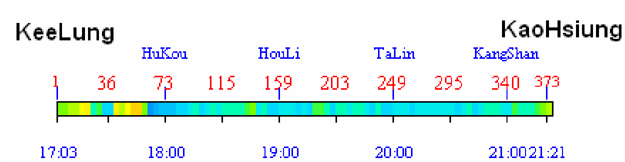

Figure 8: On-board traffic state forecast for November 9, 2002

As mentioned above, some on-board data representation methods can assist travelers to understand their travel status on the go. To better assist travelers with trip planning, we enhance the mobility of the travel information service by making the service available to handheld devices. We have built a system component that enables graphical travel information to be transmitted to mobile phone users through Multimedia Messaging Services (MMS). Figure 9 illustrates the displays of a cellular phone after ITWS transmits requested information back to the user. From left to right: arrival time at corresponding major cities on the way, a glance of overall traffic speed, and on board traffic state forecast (as in figure 8). Consequently, travelers can request an on board copy of the auxiliary travel information, the system then will deliver the above mentioned information to users and constantly update traffic conditions on the way.

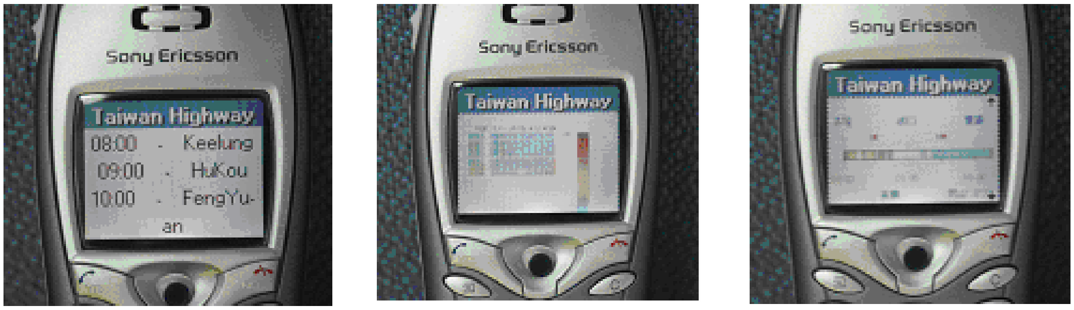

Figure 9: Delivering ITWS traveler information to cellular phone display

CONCLUSION

This paper presents our intelligent transportation Web services (ITWS) that integrates advanced traveler information systems (ATIS) with the newly emerging Web service technology and wireless communication technologies to enhance its availability and reusability. We also propose data reconstruction and travel time prediction methods to analyze and utilize the collected traffic raw data. Through Web services, ITWS can also be reused and integrated by value-added service providers. By supporting the travelers using wireless LAN communication or multimedia messaging services, we can provide more visual and valuable traveler information to mobile users. These integration approaches and studies can enhance the design of current ATIS and increase the availability and usability of traffic data to travelers.

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