A Mash-up of the Tracking System and Real-time Monitoring System Based on MAS

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Summary
In this paper, Mash-up, Multi Agent System (MAS) Architecture and GPS, GIS and Wireless Communication technologies were discussed. New application architecture of complex vehicle Location Based Service (LBS), Navigation and Intelligent Transportation system based on MAS architecture was proposed. The implementation and Web performance of mash-up methodology on the urban garbage trucks management in Shanghai Putuo district were introduced. The final system testing results were evaluated. And the future potentials of MAS based mash-up approach to solve the complex urban management and monitoring information network system were prospected.

Key words:
Input here the part of 4-5 keywords.
Mash-up, Software Agent, Multi Agent System, Web GIS, Wireless Communication

Introduction

Mash-ups are the fastest growing ecosystem on the Web and that by 2007, there will be 10 new mash-ups per day [1]. The term mash-up refers to a new breed of Web-based applications created by hackers and programmers (typically on a volunteer basis) to mix at least two different services from disparate, and even competing, Web sites. A mash-up, for example, could overlay traffic data from one source on the Internet over maps from Yahoo, Microsoft, Google or any content provider. The term mash-up comes from the hip-hop music practice of mixing two or more songs [2].

The Agent technology is becoming the most important component in constructing the socially organized system of the cyber world. Agent applications include information service, multi-dimension design, robot, e-business, computer aided cooperation, computer game, education and training, intelligent environment, society simulation, artificial life and so on. And form the definition of Agent Oriented Software Engineering, Agent and Multi Agent System become one kind of conceptual model to build different software and application scenarios. And Agent and MAS theory could be widely used to combine or integrate different web services into one followed mash-up spirit.

Location Based Service (LBS), Navigation and Intelligent Transportation are the hot research topics now. And there are many wonderful solution methods emphasis on the different research emphasis (e.g. PDA (Personal Digital Assistant)/Pocket PC and embedded software navigation research, transportation commanding center research, etc.). But our objective using Agent technology and Multi Agent System architecture is to find a mash-up solution approach to cover the main questions in this area.

Researches on Location Based Service (LBS), Navigation and Intelligent Transportation generally tackle three key basic questions (Shih-lung Shaw, 2005):

1. Where am I? (How to calculate my position)
2. What around me? (How to express the objects and environment around some place)
3. How could I go to that place? (Best way finding from A to B)

Question 1 can be solved now by the integration of GPS (Global Positioning System), sensor network positioning and embedded GIS (Geographic Information System) software. The position information can now be transferred to the users' PDA or smart mobile phone using Short Message Service (SMS) or push technologies (GPRS- General Packet Radio Service, WAP- Wireless Application Protocol, etc.).

Question 3 can be tackled by the researches on network analysis models and algorithm for way-finding. Some familiar way-finding algorithms [3][4][5]include Depth-first searching algorithm based on the network limitations, Dynamic programming algorithm in an acyclic network graph with direction identification , Dijkstra algorithm based on the adjacency matrix, to maximum dependence edge algorithm, and Dijkstra algorithm based on the greed and heuristic game etc.

But for question 2, the transportation monitoring system distributed in the different road junctions and crosses should be a better method to offering the real-time environment video frequency information around us.

Manuscript received December 5, 2006.
Manuscript revised December 25, 2006.

So the new methodology should be proposed, which integrates GPS installed on the vehicles, data transmission through wireless network service (e.g. SMS- Short Message Service, GPRS- General Packet Radio Service), direction promotions supported by the GIS based way-finding algorithms, and Web real-time video capture system. This methodology gives us the possibility to solve total Location Based Service (LBS), Navigation and Intelligent Transportation questions.
This paper proposed a MAS architecture implementation to solve these two important problems in the Web integration/ mash-up of the GPS+GIS+GPRS Tracking System and Real-time Monitoring System.

2. Mash-up

"A lot of talk about Web 2.0, web mash-ups, Ajax, etc., which in my mind are all facets of the same phenomenon: that information and presentation are being separated in ways that allow for novel forms of reuse."(Show Kuwamoto)
"The mash-up part of this equation, is the offspring of an environment where application developers see it in their own selfish interest to facilitate the creation of integrated, yet highly derivative application hybrids by third parties, something they do by providing rich public APIs to their user base." (Mark Sigal)
"We know we don't have a corner on creativity. There are creative people all around the world, hundreds of millions of them, and they are going to think of things to do with our basic platform that we didn't think of. So the mash up stuff is a wonderful way of allowing people to find new ways of applying the basic infrastructures we're propagating. This will turn out to be a major source of ideas for applying Google-based technology to a variety of applications." (Vint Cerf)[6]
A mash-up, for the unfamiliar, is a hybrid web application that uses data from an outside source to drive a web service. Mash-ups can be created using data culled from RSS feeds, public databases, or any open data source [7].
A mash-up is a website or web application that seamlessly combines content from more than one source into an integrated experience.
There's a current industry trend in which big name websites like Yahoo, Amazon and Google are offering access to their public databases and live content through the use of their publicly available programming interfaces, or APIs. Programmers can use the APIs to gather and parse data from these sites, and then incorporate that data into their own applications. The result is a new breed of website fully integrated hybrids containing both new data and repurposed data, all presented in refreshing and unexpected ways.
And that's the cool thing about mash-ups: they exhibit a new and totally creative way of using data on the web. Mash-ups can be anything from toys and simple games to tools and applications that you use every day. The best mash-ups achieve a level of visual poetry that approaches true art.
Mash-ups exemplify the height of creativity on the web right now.

3. Software Agent & Multi Agent System

Referenced to the Agent concept by M. Minsky (1994), the famous computer scientist and the one of the Artificial Intelligence founders, Software Agent should be self-governed software/integrated software package with special skills, with regard to one computer system. When you need accomplish some tasks without the knowledge about the inside process and the software, viz. it can regard the software/ integrated software package as a black box, it could be defined a Software Agent.
In other research works on the characters of Agent, the most popular and classical theory is the discussion about the Agent's "weak definition" and "strong definition" (Wooldridge 1995, 1997; Nwana 1996). After analyzing some typical research re-ports and application systems, based on the description and definition of Agent, the basic characters of Agent were found, which should include Interaction, Task/Goal Driven, Autonomous & controllable, Reactivity (Liu Da-you 2000; Sun Yu-bin 2000). These four are the basic Agent characters, then it could have other characters according to the application situation, such as Mobility, Veracity, Self-adaptability, Communication Ability, Sense, Continuance, Self-reboot, Self-benefit etc. [8] [9] [10] [11]
In the practical research and program of Software Agent, all the characters are not necessarily built in one Agent System or Multi Agent System. Usually we choose some characters of Agent to build the system according to the practical application.
But the Reactivity, Interaction, Task/Goal Driven, Autonomous & Controllable must be regarded as the basic technology and theory of Agent.
Any Software Agent is designed for the user's special task and goal, and the running mechanism of Agent is based on the Task/Goal Driven, so how to build the Task/Goal Driven is the key part of the Software Agent. The most popular one is Data Driven or Message Driven. Data Driven is usually used in Management Information Systems, all the operations and actions are activated by Data. Message Driven is often used in Windows Operating System, and the functions or actions are based on the watching and triggering. Software Agent manages the goal of the system as a whole, so it use the Task/Goal Driven

based in Data Driven, Message Driven and others (the relationship see also Fig. 1).

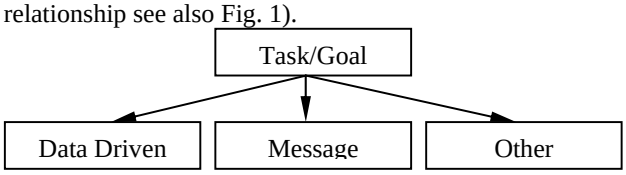

Figure 1.Task/Goal Driven buildup [12]

In other words, Software Agent is a kind of program or computing entities, which can sense the environment, self-run, realize the task/goal given by its designer or user, and give the right reaction.

3.1 The Theoretical Model of Agent

The theoretical model of Agent is the scientific abstraction of Agent as the software entity. This model analyses the target reason of Agent referenced with different Agent models and architectures, such as behavior based Agent, reactive Agent, neural Agent, emotion based Agent, Agent cognitive model, model of mind, and even BDI (Belief-Desire-Intention Theory) with the common ground, that is Agent should be a software entity. Each researcher expects Agent would own the similar active characters in the digital world like human active in the society. On the other word, Agent is built on the human activity way. [13] [14]

Generally speaking, the theoretical model ***M*** belongs to the multi dimension model, ***n*** dimensions state variables ***{m_1,m_2, ⋯,m_i, ⋯,m_n}*** decide the ***n-order*** statements of Agent. The ***n-order strategic function*** of Agent could be defined as a group of perspectives when the ***0-order strategic function {m1, m2, mi, ⋯, m_n }*** is given some constant values. And the value of each variable in this model corresponds to ***1-order Agent strategic function Si***. Some events are existed to cause the change of ***mi.*** At this time, this event is defined as ***Fi***, to cause M^* and Ag^* change, the process could be expressed as follows:

$$F_i : (M^* \times Ag^*) \rightarrow m_i$$

Fi is the state transition function.

That means in the Agent model Am_i ***mi*** decide a ***1-order Agent strategic function***, and the limited state transition function ***Fi*** describes the Agent strategic function changes caused by the event changed when the model variable ***mi*** firstly changed.

So the M-dimension theoretical model of Agent is described as figure 2 by leading in the concept of finite state machine.

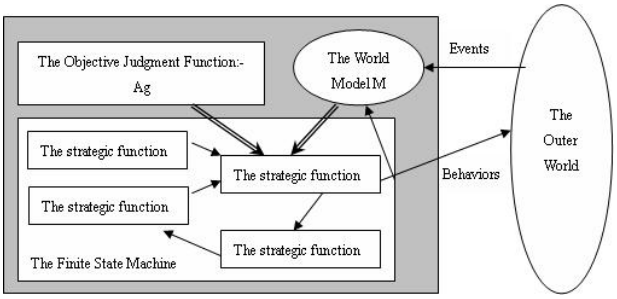

Figure 2.The Theoretical Model of Agent [15]

And inner of this Agent Model, the strategic functions relates with different concepts, functions and designs.

3.2 The Common Agent Architecture Design

As an important computation unit and application component of the digital world, Agent creation should be described as a practical engineering technology. Usually, the architecture of Agent always inter-infiltrated with software engineering main technologies, such as Object Oriented Software engineering (OOSE), and could implement the special functions according to Agent concept, such as Autonomous, Rationality, Cooperative and Mobility. There should be summarized 6 parts of Agent architecture, see figure 3.

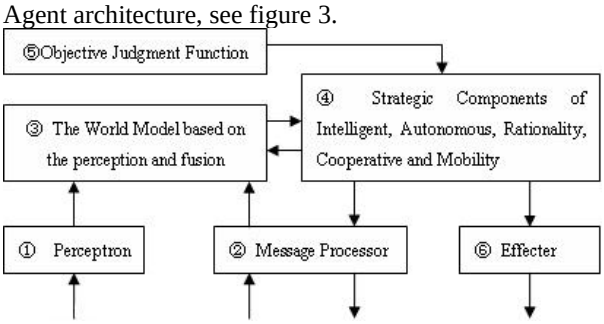

Figure 3.The Common Agent Architecture[15]

The Perceptron monitors the environment and system status, and produces the Agent input information.

The message processor was responsible for the information exchange with other Agents. This message interactive mechanism is based on the bit groupings and some self-expression texts. Usually TCP/IP (Transmission Control Protocol and Internet Protocol) always apply to describe the message processor, especially in Web service. The contents in the Socket interface include service thread, message thread, custom thread, timer, receive buffer, send buffer, send schedule and received schedule etc.

The world model based on the perception and fusion corresponds to the world model in Figure 3. In a constant period, this model acquired information from the Perceptron and Message Processor, and fuses the multi

data and information to some congruous environment status.

The Strategic Components of Agent are the function groups including the prop steps to handle the problems (or to decompose one problem to several sub-questions). Some functions are expressing the location of Agent and calculating the range of model variable values. The objective judgment function is built variously in order to solve different application problems.

Two values compared actualize a simple judgment function (e.g. comparing the GPS signal with GIS objects coordinates in order to judge the location). And there are many judgment methods including fuzzy set, range evaluation, multi attributes assessment and constraint condition judgment etc.

The Effecter is the output of system. Information produced from Agent could affect the outside object and Agent itself. One Agent system contains many executors in order to accomplish the objective. The computation results of Agent components are inner variables, and will be converted to executable programs and be arranged the execution sequences. In the software system, the Effecter might be a command word, a network packet, an alarm E-mail or some audible and visible alarm.

3.3 Multi Agent Systems

Like many developing technologies, applications and implementations keep ahead of the theoretic progresses about Software Agent. As one important computation and organization unit in the digital world, Agent system produced many creative applications from single Software Agent system to Multi Agent cooperating system, and the Mobile Agent applications. Agent technology is becoming the socially organized system and component of the digital world now, based on the intercross and integration of Artificial Intelligence (AI), Object Oriented (OO) and Distributed Computation Network (DCN). The applications of MAS cover Information Service, Multi Dimension Interface Design, Robot, E-Commerce, Computer Aided Cooperation, Computer Game, Education and Training, Simulating Society and Artificial Life etc., which not only give us an advanced computation technology, but also show a brand-new thinking method to solve the complex system problems [16] [17].Based on MAS architecture, a new complex system concept model was proposed, and many developers is doing their creative research in this field, and Belief-Desire-Intention Theory (proposed by Bratman) is considered as an important fundamental theory.

The architecture of MAS (see Figure 4) describes the basic components, the functions, the relationships and the communication mechanism between different Agents. It also shows the information interaction, the control relationship, the network surrounding, and the abilities to solve the problems.

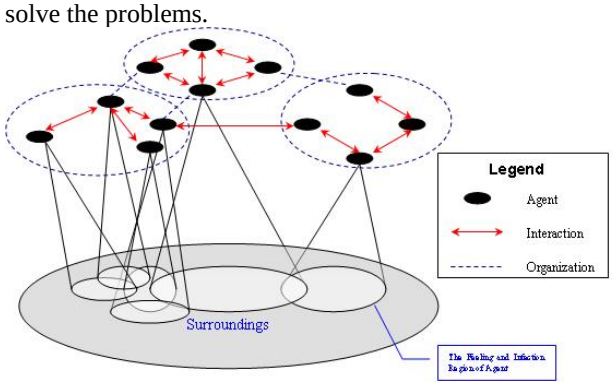

Figure 4.The Common Agent Architecture [18]

Usually the MAS architectures are grouped with 3 types, Deliberative Architecture, Reactive Architecture and Hybrid Architecture.

3.3.1 Deliberative Architecture

This architecture contains the world symbolic model for visualization. The decision of Agent is made by the template matching and logical reasoning engaged in the operations. The process of decision making likes human being making the deep consideration, so it's called Deliberative Architecture.

3.3.2 Reactive Architecture

In this Architecture contains the perceptrons to sense the changes inside and outside, one group of perceptrons make response process to some events, the other group enable some procedure execution according to the information from the sensors. The activities of Agent are enabled by some activation, so it's called Reactive Architecture.

3.3.3 Hybrid Architecture

Based on the reactive layer, this architecture is organized by both Deliberative Architecture and Reactive Architecture. In this type of MAS architecture, there is a special multi-layer architecture named Contract Net Architecture using the invitation-bidding-winning management mechanism. Agent is the administrator of the lower level Agents, and the contractor of the higher level Agents. All the control is based on the contract relationship.

3.4 MAS based Vehicle Management System Mash-up Architecture

As we discussed in the introduction, the system integration objective contained GPS systems installed in the different and mobile vehicles, GIS system offering the static environment information and location coordinates, GPRS system acting as the communication channel, the real-time video monitoring system constantly acquiring and publishing the dynamic traffic information of the settled road cross, and all the four different system must be developed and integrated in the Browse/ Server architecture in order to offer anyone, anytime, anywhere information Web service.
Because each vehicle might move anywhere with any purpose, objects mobility must be supported. And as a complex integration software system involved in different science and technologies, Agent and Multi Agent System are selected to meet the architecture design (see Figure 5).

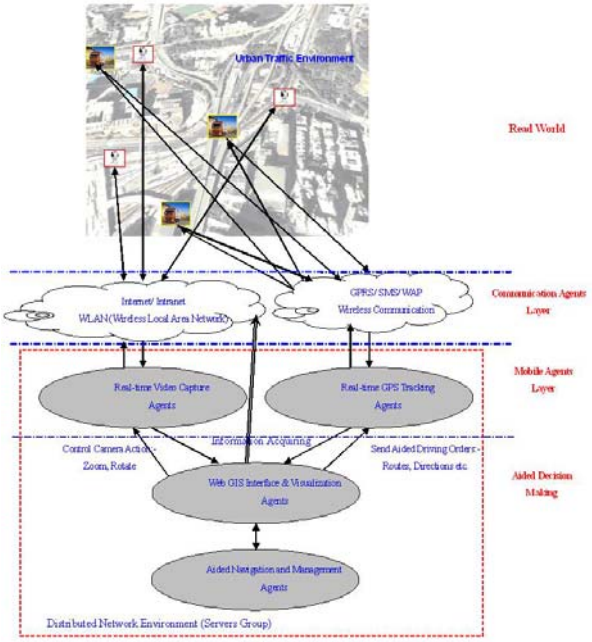

Figure 5.Vehicle Management System Based on Contract Net MAS Architecture

The communication Agents layer contains two different communication architectures. One is TCP/IP based Internet/Intranet/WLAN communication network, which should focus on the Web Service Oriented technologies based on XML, the other is the commercial wireless communication network (e.g. GSM- Global System for Mobile communications, CDMA- Code Division Multiple Access, SMS- Short Message Service, 3G- third generation etc.), and which should focus on information transmission package technologies including TCP/IP socket, WAP push, database middleware etc.
The mobile Agents layer contains real-time video capture Agents and GPS Tracking Agents. Media Flow process and publication technologies should be the key of the real-time video capture Agents. And GPS related technologies support the GPS tracking Agents. And this layer located in the distributed network, Web based information service technologies support the communication between Agents, which includes database middleware, TCP/IP socket, Web Service etc.
The aided decision making layer contains the Web GIS interface and visualization Agents and Aided Navigation and Management Agents. The Web GIS technologies support creation of the first Agents group. The way-finding algorithms and cooperation technologies with work flow system and GIS support the aided Navigation and Management Agents creation.
Except the communication between Web GIS Interface and Visualization Agents to Communication layers, the communication channels between different components and Agents are both-way. The reason of the only one-way communication channel is that the status of the communication layers which are never showed on the Web GIS interface.
And this architecture is classified into Contract Net Hybrid MAS Architecture. The Web GIS Agent is the administrator of the lower level Agents including communication Agents, Video Capture reactive Agents and GPS tracking mobile Agents. At the same time, it also takes responsibility for executing the order coming from the aided navigation and management Agents.

4. Other Components

4.1 Vehicle GPS Technologies

Vehicle GPS is an integration of software and hardware system installed on different vehicle with GPS navigation, positioning, monitoring the status of driving and controlling some vehicle electronic equipments.
One set of Vehicle GPS system contains:

4.1.1 GPS satellite signal receiver and processing all-in-one machine

This machine processes the GPS signals at real-time after receiving the information from GPS satellite, and converts data to standard format. And transmission function is supported by the standard computer interfaces (RS232, USB, CF Card, PCMCIA slots). It's also called G-MOUSE.

Figure 6.G-MOUSE

4.1.2 Laptop, PDA and Special Vehicle PC

The functions of these equipments are presenting the location, speed, height signals in the e-maps, and showing other traffic related information. Usually they also support the wireless communication protocols including Bluetooth, IEEE 802.1.x etc.

Figure 7.Laptop and PDA

4.1.3 Electronic Maps

There are two types of e-map software. One is self-navigation system, the other is positioning system. The real-time location could be shown on e-map, and some software supported route planning and voice navigation functions.

Figure 8.E-map Software Interfaces

4.1.4 Bracket

The bracket is used to fix the PDA/Laptop on the vehicles.

4.1.5 Vehicle Power Inverter or Charger as the power of the whole system

Figure 9.Vehicle Power Inverter and Charger

4.2 Communication Technologies

4.2.1 Socket in TCP/IP protocol

TCP/IP is a set of complete protocol supported by multi operating system, which is used in Windows series, UNIX, Linux etc. Different types of computer can do the reliable data exchange following TCP/IP in the network. Socket located on the transportation layer in the 4-layer model structure of TCP/IP. It supplies the uniform interface for different application software (the relationships see also Fig. 10), such as Telnet, FTP, Ping, HTTP, WWW etc.
Socket is also a software entity. It supported IPC (in-process communication by UNIX) of the distributed environment, and offered the basic component for IPC. Because we use Windows to do the test, the socket software is WinSock interface. In many advanced computer language, WinSock is capsulated in the bottom layer of API by components. Socket accomplishes the network communication according to C/S mode.

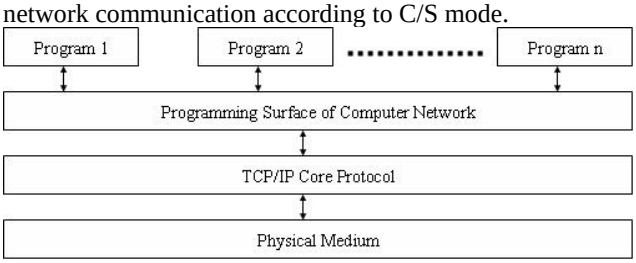

Figure 10.Relationships between TCP/IP and Programs [19]

4.2.2 XML

There have been multitudinous benchmarks for evaluating the DBMS performance in various application areas. On one hand, XML becomes a standard for data interchange [20], penetrated virtually all areas of Internet applications, and brought about massive amounts of data. XML allows you to specify the content and structure of a document in a way that lets you generate particular presentations as needed [21].

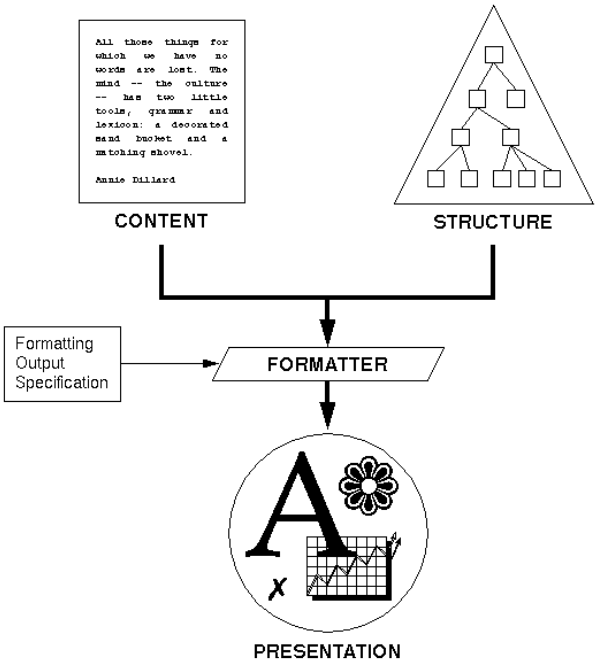

Figure 11.the XML Concept [21]

The situation is that XML-based solutions become the preferred choice for most GIS vendors and users [22] as the convergence of the increasing need for the management and exchange of spatial data in modern application with the emergence of XML as a standard for information interchange on the Web. Moreover, Geographic extensible Markup Language (GML), the XML application in the specialized domain, also becomes a standard for geospatial data sharing and transport over the web [23].

4.2.3 GPRS [24]

General packet radio service (GPRS) is a packet-based wireless data communication service designed to replace the current circuit-switched services available on the second-generation global system for mobile communications (GSM) and time division multiple access (TDMA) IS-136 networks. GSM and TDMA networks are designed for voice communication, dividing the available bandwidth into multiple channels, each of which is constantly allocated to an individual call (circuit-switched). These channels can be used for the purpose of data transmission, but they only provide a maximum transmission speed of around 9.6Kbps (kilobits per second).

As a packet-switched technology, GPRS supports the internet protocol (IP) and X.25, packet-switched standards currently used in wire line communications. As such, any service that is used on the fixed internet today will also be able to be used over GPRS. Because GPRS uses the same protocols as the internet, the networks can be seen as subsets of the internet, with the GPRS devices as hosts, potentially with their own IP addresses.

Enabling GPRS on a GSM or TDMA network requires the addition of two core modules, the Gateway GPRS Service Node (GGSN) and the Serving GPRS Service Node (SGSN). The GGSN acts as a gateway between the GPRS network and the public data networks such as IP and X.25. They also connect to other GPRS networks to enable roaming. The SGSN provides packet routing to all of the users in its service area.

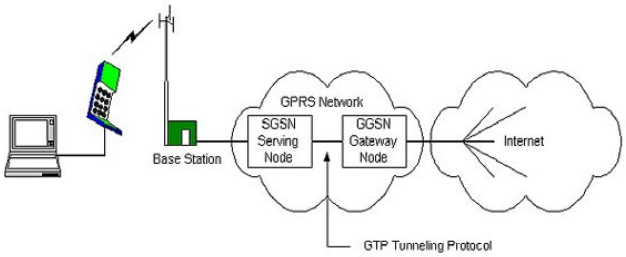

Figure 12.A GPRS configuration diagram

As well as the addition of these nodes, GSM and TDMA networks have to have several extra upgrades to cope with GPRS traffic. Packet control units have to be added and mobility management, air interface and security upgrades have to be performed.

4.2.4 Middleware and Database Middleware [25]

Middleware, software that functions as a translation layer, sits between an application residing on one server and any number of clients that want access to that application. In short, middleware allows users to interact with one another and with applications in a heterogeneous computing environment.

It's important to note that the functions middleware provides are hidden, so that applications and information can be easily - and smoothly - accessed across different architectures, protocols and networks.

The types of middleware include database middleware, application server middleware, message-oriented middleware, transaction-processing monitors and Web middleware.

While all middleware performs communication functions, the type of middleware - or the combination of products - that a company chooses will depend on exactly what information needs to be communicated.

Database middleware only enables applications to communicate with one or more local or remote databases. It doesn't transfer calls or objects. And while database-oriented middleware is easy to deploy and relatively

inexpensive, it doesn't include features found in more complex software products.
But database middleware doesn't allow for two-way communication between servers and clients. Servers can't initiate contact with clients, they can only respond when asked.
Furthermore, Application server middleware is a Web-based application server that provides interfaces to a wide variety of applications and is used as middleware between browser and legacy systems.
And Messaging-oriented middleware provides an interface between client and server applications, allowing them to send data back and forth intermittently.
Messaging middleware is similar to an e-mail system, except that it sends data between applications. If the target computer isn't available, the middleware stores the data in a message queue until the machine becomes available.

4.3 GIS and Web GIS

The geographic information system (GIS) is a technical system of geography information science, using the theories and methods of system engineering and information sciences to acquire, store, manage, analysis, distribute and utilize spatial information with the support of computer software and hardware. GIS is widely used and has become a powerful tool in many areas, such as urban planning, city infrastructure management, traffic control etc.
Web GIS is the mainstream development and application of GIS technology. Web GIS is used as the provider of spatial data browse, query and analysis. The application structures of Web GIS mainly contain C/S and B/S architectures. When using the C/S architecture, part of application software must be deployed in the client side, and the request of client is completed by the cooperation of the client and server. But for the B/S structure, the requests of user are processed in the server side, and there is no need to deploy system software in the browser side.

5. The Implementation Sample

In order to support the architecture and technologies introduced in this paper, we built a mash-up command system in Putuo district of Shanghai, P. R. China. The objective functions of this integrated system contained GPS+GIS+GPRS garbage truck real-time tracking and commanding, key refuse collection fields and main road cross real-time video monitoring and operational information automation. Through the uniformed Web interface, anyone could query the urban environmental information at anytime, anywhere. In addition, remote sensing image from Quick-Bird satellite every half year is used as the geo-referenced background (see Figure 13).

Figure 13.The Screen Copy of Real-time Monitoring of Mobile Vehicles and Video Capture of a Road Cross

The Special Functions of this integrated system besides the common Web GIS functions includes:

1) Selection cooperation with real-time video-monitoring system
2) RS image and GIS attributes integration multi-scale visualization
3) GPS tracking and monitoring in the B/S framework (see Figure 14)
4) Warning of the filled cesspools

Figure 14.Mobile Vehicle Historic GPS Track

The system Software:

1) Microsoft Windows Server 2003/ Windows XP professional
2) Microsoft SQL Server 2000 personal
3) J2SDK 1.4.2
4) IBM WebSphere/ Apache Tomcat 5.x
5) ESRI ArcIMS 9.x

And We built a Servers Group with 6 Dell 2850i, one server machine for Communication Agents, one for real-

time video capture Agents, one for GPS Agents, one for Web GIS Agents, one for non-spatial information database, one for spatial database including remote sensing images, one for system backup.

After the system testing (testing result see Table 1) and commissioning at the beginning of 2005, this system is now offering the service in Shanghai.

Table 1: Testing Result of the Implementation Mash-up System

		Merit	*Testing Value*	*Explanation*
Functionality	Compatibility	Sufficiency	0.978	1- Best
		Integrity	0.933	
		Coverage Factor	0.911	
	Exactitude	Evaluation	0.167	0- Best
Reliability	Maturity	Fault density	0.0476	
		Fault Settlement	1	1- Best
		Testing coverage factor	1	
	Recovery	Easy to Reboot	1	
Easy to use	Easy to Understand	Integrality of Description	1	
		Comprehensive Function	1	
	Easy to Operate	Intelligibility of System Messages	0	0- Best
Efficiency	Time Response	Average values	12.85s	
Transferability	Adaptability	Hardware	1	1- Best
		System Software	1	

The testing result showed enough evidence of the superiority of MAS based complex mash-up integration of web tracking and real-time monitoring services.

6. Conclusions

Usually the researchers in Location Based Service (LBS), Navigation and Intelligent Transportation area studied the different approaches around the three key questions mentioned at the beginning of this paper separately. But Agent and Multi Agent System architectures, a new methodology to solve the complex system problems, have been proved to treat with the Location Based Service (LBS), Navigation and Intelligent Transportation questions as a complete system.

The architecture based on Agent and Multi Agent System, and the successful sample system, is showing us a new methodology to solve the complex GIS related system problems, which are mash-up.

After the user requirement analysis and system requirement analysis processes, the innovative GIS application and service scenarios design are more important than separate technology discussion.

There might be no “key” technologies in web and wireless GIS application & service fields, only the suitable technologies to support more active and efficient scenarios. Different scenarios could be mash up to a total new application services group.

The potentials of those suitable technologies and the integrated architecture discussed in this paper have not been explored fully, Continuous researches is needed to further enhance the operability of the methodology proposed in this paper, such as solving the problems in transportation navigation, urban emergency reactions, and information systems integrated with real-time control sys

Acknowledgments

This research is being supported by the Shanghai Science and Technology Development Funds 2010 World Expos project (05DZ05808).

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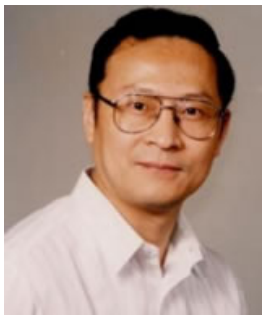

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