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An Upgraded Intelligent Mobile Information Multi-Agent System with Universal Application Interfaces based on Open Data of Taiwan Government

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ABSTRACT. *This paper presents Dr. What-Info II as an upgrade of Dr. What-Info, a prototype master multi-agent system asking what information it is. WIAS-- web-services-based information agent system, -supported universal application interface (UAI) technology is analyzed, designed and researched for different data formats, as a way to construct the network service system APIs of desired information with the support of OpenData@Taiwan/Taipei and domain ontology according to local GPS location interception and address conversion. This move not only upgrades the quality of mobile information consultation and sharing, but also enhances the correctness, authenticity and integrity of location-based information provision. Dr. What-Info II is experimentally demonstrated as a successful technology integration, and stands as an innovative piece of work in the literature.*
Keywords*: Open Data; Universal Application Interfaces; Intelligent Mobile Information Systems; Multi-agent Systems.*

1. Introduction

Data economy ranks among the top ten predicted technical trends in 2014 published by Gartner. However, as pointed out by IBM, mass data is characterized as volume, velocity, variety and veracity, the so-called big data 4V's. Therefore, if the latest, correct and complete "Open Government Data" can be imported with the "cloud" technical support, and the "mobile" equipment location technique is able to provide the corresponding information "value added" service, then the "community"-like consultation and sharing of an optimal information solution

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can be performed. However, the data of Taiwan government data open platform are provided mostly in XML (Extensible Markup Language), JSON (JavaScript Object Notation) and CSV (Comma-Separated Values, or xls) formats up to now, and the access modes include file download for either off-line use or on-line direct access through a system application programming interface (API). Therefore, a UAI is developed based on the Taiwan government open data for a variety of data formats and intelligent system APIs. With local GPS location capture and the support provided by OpenData@Taiwan/Taipei as well as domain ontology, suitable information is intercepted as a way to upgrade the location-based services (LBS) of Interest, such as the spots of recommended hotels or restaurants in a journey, etc. All the above will be the major contribution of the presented Dr. What-Info II [22].

In 2014, a prototype Dr. What-Info [21] has been completed with the following outcome summary. 1) A cloud computing interaction paradigm, extensively and seamlessly integrated into the back end of an Internet information agent system, is implemented using network service technology. The cloud operating environment WIAS [16], in charge of cloud information exchange processing, analysis, integrated operation, decision support and network service support, is constructed, such that cloud services are made accessible to mobile devices ubiquitously. 2)Agent technology is introduced to construct the "tourism" related ontology (described later), and to assist users to access appropriate and current cloud information rapidly, accurately and effectively. Developed in this study, OntoIAS (Ontological Information Agent Shell) [15] is used in the cloud tourism information domain in such a way that the EOntoIAS (Extension of OntoIAS), is augmented into CEOntoIAS (Cloud Extension of OntoIAS). As a WIAS-supported cloud platform illustrated in Figure 1, CEOntoIAS is designed to drive cloud information processing, exchange, communication, operation, integration, analysis and three-stage intelligent decision making supported by OntoDMA (Ontological Data Mining Agent) [18], OntoCBRA (Ontological Case-Based Reasoning Agent) [17] and OntoIAS, the target of an optimal cloud information solution searching and sharing by Solution Finder via ubiquitous Interface Agent (Ubi-IA) [14] in Dr. What-Info is reached easily. 3) Using a built-in

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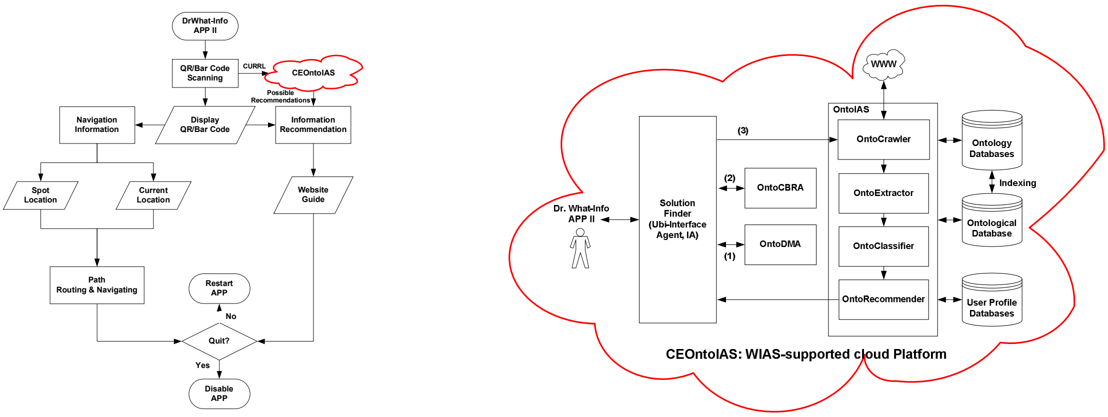
camera or video recorder in a mobile device, an ontology-supported semantic analysis and Chinese/English speech recognition technology [19], an accurate, efficient and effective intelligent mobile "tourism" information consultation and sharing multi-agent prototype system, supported by network and CEOntoIAS, is built. A step-by-step execution procedure is shown in Figure 2.



(a) (b)

Figure 1. Dr. What-Info prototype system: (a) Front-end system operation process; (b) Back-end system framework.

(a) (b) (c) (d)

Figure 2. Execution procedure of Dr. What-Info system; (a) QR/Bar Code reader; (b) to recognize, display decoded contents and recommended information provided by the back-end system; (c) to capture and display local GPS coordinates; (d) to display route planning toward a target.

To sum up, this paper is substantially a piece of extended research work on Dr. What-Info, where the OpenData@Taiwan, particularly OpenData@Taipei, is integrated with the aforesaid UAI technology as a way to enhance the correctness, authenticity and integrity of information provision, and to effectively upgrade the quality of mobile information consultation and sharing. The remainder of this paper is organized as follows: Section 2 introduces the motivation and

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technologies involved. Section 3 illustrates the system operating architecture, and how it is constructed. Section 4 presents the system displays and evaluations. Section 5 offers some conclusions and future works.

2. Literature review and motivation behind this work

Open data is not a completely new term to the general public, although it has not yet been well defined globally. In most cases, open data as such have or can have commercial value after integration, and sponsors claim that open data will be available completely free of charge. There have been a great volume of publications on open data. For instance, as proposed by Perera and Parma [8], a framework is built, which can utilize the Open Information Extraction to extract relations from natural text and these relations are then aligned with triples to identify lexicalization patterns. Curé [2] proposed a self-diagnosis and treatment network application system based on linked open data technology (LOD). Zuiderwijk and Janssen [24] made a systematic comparison on architecture in terms of strategy, implementation and impact of open data. In short, this study presents a UAI technology to support various data formats on a WIAS-supported cloud platform, and the network service system APIs of appropriate corresponding information are constructed with the support of OpenData@Taiwan/Taipei and domain ontology according to local GPS location capture as well as address conversion through a time series analysis technology. Finally, cloud information processing, exchange, communication, operation, integration, analysis and decision support are performed in CEOntoIAS and then presented in sequence.

In addition, data mining techniques had been widely used in the literature, even for open database, to develop relevant information systems. For example, Lausch et al. [5] provided a comprehensive overview of existing data mining techniques and related tools and to illustrate the potential of data mining for different research areas by means of LOD example applications. Based on LOD, Paulheim et al. [7] proposed a FeGeLOD architecture, an automation technology supporting statistical classification and interpretation, and made an investigation into

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relevant issues. Warkentin et al. [12] addressed an issue on a generic agent-based data mining architecture supported decision support management and relevant techniques. All the above-cited references stand as representative conventional data mining tools or mechanisms, based on which improved versions or even novel mining concepts are developed as a way to highlight the significance of self-developed mining mechanisms. A data mining mechanism is built, and WIAS-supported network services are provided by Dr. What-Info II. OntoDMA implements period processing by means of WIAS starting a corresponding network service from the variation of case base in OntoCBRA according to a time series analysis technology, the case variations are compiled, and then the Full Scan with PHP algorithm [13, 18] is used to obtain the corresponding prediction rules. With the support of the UAI technology, OntoDMA can process relevant information prediction services according to the prediction rules, local GPS location capture and address conversion. The information of interest is captured with the support of OpenData@Taiwan/Taipei and domain ontology, upgrading the quality of mobile prediction information. Dr. What-Info II can feature an efficient system operation and an upgraded cloud information forecasting service.

In addition, CBR and learning techniques are frequently employed in the literature to develop open information systems. For example, Platon et al. [9] present the development of simplified, yet accurate models, combined artificial neural networks and case-based reasoning technologies, which can predict the hourly electricity consumption of an institutional building. Monfet et al. [6] proposed a case and reasoning-based technique, and developed energy prediction tools for commercial buildings. Rodríguez-González et al. [10] as well proposed an integrated multi-agent system architecture and a distributed inference mechanism as a way to improve the inference time interval and address relevant issues. In short, the literatures cited above were mostly combined with a traditional CBR technology and a similarity quantification mechanism, based on which improved versions or even new concepts are developed as a way to highlight the importance of the matching mechanisms developed on their own. Dr. What-Info II is developed using a similarity quantification mechanism, namely, a sequence information is recorded according to the network service provided by WIAS using a time series analysis technique, and the differentiation to the information of interest in a case-based system is calculated and then converted as a case similarity. Finally, the OntoCBRA are completed by a WIAS-provided case retrieval, reuse, modification and saving network services. With the support of the UAI technology, OpenData@Taiwan/Taipei and domain ontology, the information of interest is captured according to local GPS location capture and address conversion, hence upgrading the quality of mobile case information directly. Furthermore, using open data, Dr. What-Info II provides an enhanced robust cloud service, besides an efficient system operation, through the network service interface integration and real-time augmentation.

Since a vast majority of the above are special-purpose agent systems, they cannot be made as cross platform. Moreover, special-purpose agent systems are developed mostly using specific programming languages, leading to a poor expandability and a difficulty in maintenance. This work is proposed as an innovative solution to the above-stated problems in a mobile cloud system. There exist a wide variety of mobile cloud architectures in the literature. For example, Bonhomme et al. [1] present TrafficGen, a highly modular platform based on the integration of such open data within a library of rule-based behaviors, in order to provide a versatile decision support tool in traffic. Huang proposed [4] using open data, location information and social tagging for the construction of a mobile APP system to improve the quality of infant health care and growth record. As presented in [23], Zaw and Tun, following the Cloud Computing trend, researched network service-based information acquisition agent system techniques. The cloud network service information agent system WIAS is developed herein as a way to provide the network services of interest for subsystem operations, using multiple flexible system designs, such as standardized and flexible parameter transmission format, rapidly disassembled and reformed SQL IC (Structured Query Language Integrated Circuit) and modular network service function designs. The performance excellence of the proposed network service technique is demonstrated [16], and this cloud (mobile) intelligent information processing and decision support multi-agent system is proposed to address the feasibility of implementing a specific-purpose cloud service system, as a way to realize a multi agent-based network service technique.

3. System Research and Development Technique and Architecture

3.1. UAI Technology

When Open Data is that only a download hyperlink is provided in case the access APIs are not provided. This paper is presented as a solution via Dropbox Cloud storage service, illustrated below by the example of the JSON format of Kaohsiung City government open data platform. Firstly, an access point saves a link as a corresponding .json file; secondly, upload the file to Dropbox Cloud space, and share this access link; than, modify the first half of the shared access link "https://www.dropbox.com/" as "https://dl.dropboxusercontent.com/" for an APP to access an open database directly. Instead of skipping to the Dropbox file download page directly; finally, the corrected access hyperlink is copied to the object corresponding program code of an access interface directly, and the same access mode as in the access APIs of a corresponding database provided by the open data platform is completed for the system to implement subsequent processing, a step-by-step procedure referred in [20].

Therefore, using a UAI to access an open database, a location-based mobile information service can be improved easily, as long as a user's local GPS location is converted into address, a suitable open database is found according to the keywords of user's current event, and a corresponding map is converted according to the data capture of the "address" field. In addition, the back-end system must construct an event-based ontology linked to a suitable open database, as given in Table 1, and a map API is converted from an open database query and a query result, completing the construction of an overall open database UAI. Table 2 gives all the involved partial cloud network service APIs, where the UAIs are designed to provide connect, compute, search and storage services [11]. In addition, with a result of "address" field data capture, the complete address of a query result must be converted to a corresponding map, so as to complete the integrity of a location-based mobile information service. In other words, the indexes are

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classified beforehand, using the three-layer relationship of address and a corresponding location-based mobile open database, as shown in Table 1, and a suitable scenario index is checked by address with the aforesaid tourism event ontology (detailed later) for a system to trigger. The solution via the above-stated Dropbox cloud space is uploaded to provide an open data platform with a complete or fuzzy character string matching function, completing the standard operating procedure of a UAI. Hence, the design objective of an UAI is reached in this extensive study.

Table 1. System back end tourism event ontology versus open database.

TOURISM JOURNAL	GENERAL EVENT	Ask for Food, Clothing, Housing, Transportation, Education, Entertainment aid	Corresponding "Food, Clothing, Housing, Transportation, Education, Entertainment" open data	SOURCE: MANUAL OF RESPONSE TO EMERGENCIES FOR TEAM LEADERS, TOURISM BUREAU, MINISTRY OF TRANSPORTATION AND COMMUNICATIONS, TAIWAN, 2008.
	DISEASE ACCIDENT EVENT	Ask for medical aid	Corresponding "medical institution" open data	
		Call the police for help	Corresponding "regional procurator and police" open data	
		Inform family	Corresponding "regional household registration" open data	
		Report to Tourism Bureau	Corresponding "regional Tourism Bureau" open data	
	LOSS EVENT	Outposted agency asks for help	Corresponding "regional outposted agency" open data	
		Call the police for help	Corresponding "regional procurator and police" open data	
	EMERGENCY EVENT	Ask for medical aid	Corresponding "medical institution" open data	
		Call the police for help	Corresponding "regional procurator and police" open data	
		Inform company	Corresponding "company" open data	
		Report to Tourism Bureau	Corresponding "regional Tourism Bureau" open data	

Table 2. Function outline of partial cloud network service APIs.

SERVICE NAME	SERVICE DESCRIPTION	TO WHOM
UAI_ConnectCrossDomain	Connection of cross-domain Open DB	UAI_Connect
UAI_ConnectAlertReg	Connect registration prompt	UAI_Connect
UAI_ConnectRuleSetting	Connect rule setting	UAI_Connect
UAI_ComputeFileAccess	File access Compute	UAI_Compute
UAI_ComputeTimeSeriesAccess	Time series Compute	UAI_Compute
UAI_ComputeTriggerConfig	Trigger reconfiguration Compute	UAI_Compute

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UAI_SearchTimeSeries	**Time series search**	**UAI_Search**
UAI_SearchBuildIndexFields	**Create index field**	**UAI_Search**
UAI_SearchStatistics	**Search statistics**	**UAI_Search**
UAI_StorageFFStatus	**Data folder and file status**	**UAI_Storage**
UAI_StorageFFManipulation	**Data folder and file manipulation**	**UAI_Storage**
UAI_StorageFTransimission	**Data folder and file transmission and status**	**UAI_Storage**
UAI_StorageFFSharing	**Data folder and file sharing and integration**	**UAI_Storage**
CBR_InsTmpCaseData	**Temporary data for creating solution**	**CBR Agent**
CBR_Solutions	**Solution of case base**	**CBR Agent**
DB_InsCaseBase	**Create Case base Rule**	**Share**
DB_InsPrediction	**Create Prediction Rule**	**Share**
DB_UptCaseBase	**Whether record is converted or not**	**Share**
DB_UptRawData	**Whether record is converted or not**	**Share**
DM_Solutions	**Solution of prediction rule**	**Data Mining Agent**
DM_TransCaseToPred	**Convert case base with semanteme into prediction rule base**	**Data Mining Agent**
DM_ViewCaseBase	**Case Base consultation**	**Data Mining Agent**
IA_InsRawData	**Create original data**	**Interface Agent**
IA_Solutions	**Solution of predefined rule**	**Interface Agent**
Share_DelUniqueTables	**Delete data in independent data sheets**	**Share**
Share_IsNumeric	**Judge whether strNumber is numeric or not**	**Share**
Share_ViewCBR	**Inquire case base summary**	**Share**
Share_ViewDBSDT	**Query system time**	**Share**

3.2. Domain Ontology and Related Ontology Services

The base architecture of domain knowledge is built using Protégé herein. In addition, the Protégé API is used to construct an inference primitive knowledge-based function with ontology application. Finally, an ontological architecture is used to index authentic information to access relevant information rapidly and accurately. As illustrated in Figure 3, an indexing process firstly uses an ontological index to index associated files, a Partial Full-text Index [13] to filter out the files not containing the ontological words, and then a file search procedure is reduced into two stages. As ontology contains the accurate implication of domain words, the useful information can be accurately judged, highly correlated with real data, and then can be filtered rapidly by means of a two-stage indexing, implementing an ontology-supported rapid and accurate access to useful information, as presented in Figure 4. As illustrated in Figure 5, rapid

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modular connection and an access to information of interest can be made in the system as a way to support the overall system operation effectively.

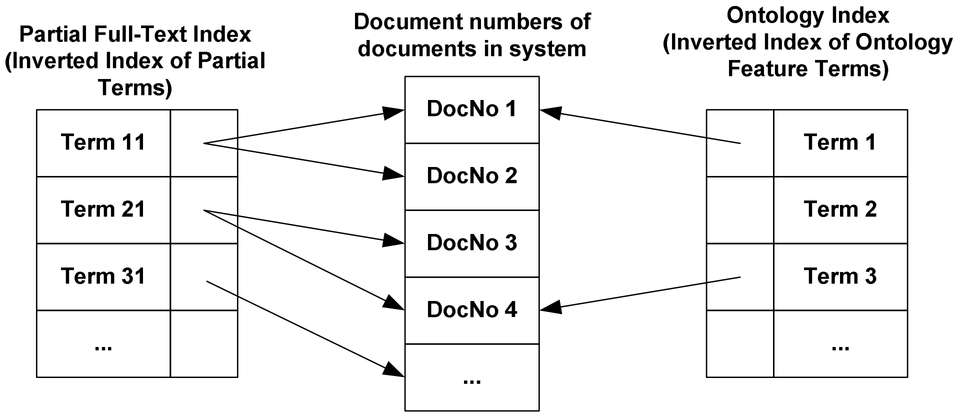

Figure 3. Two-stage index architecture.

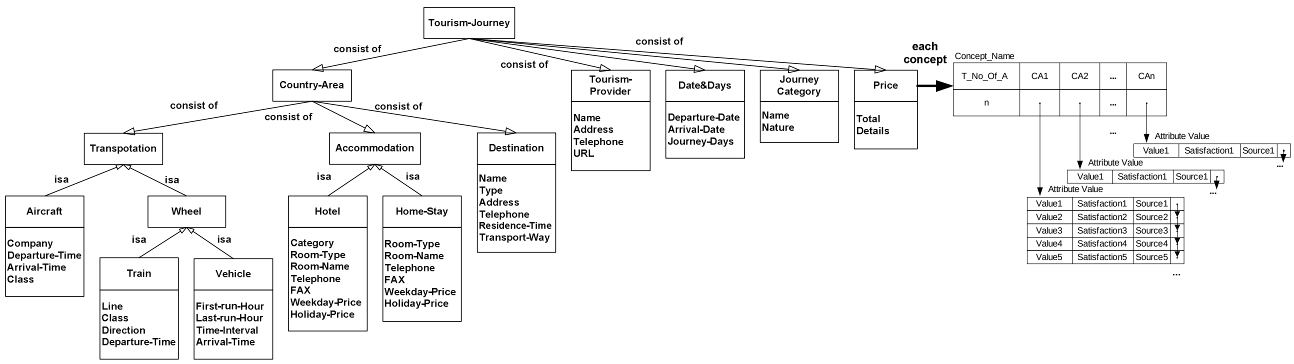

Figure 4. Relationship between ontology index architecture and real data.

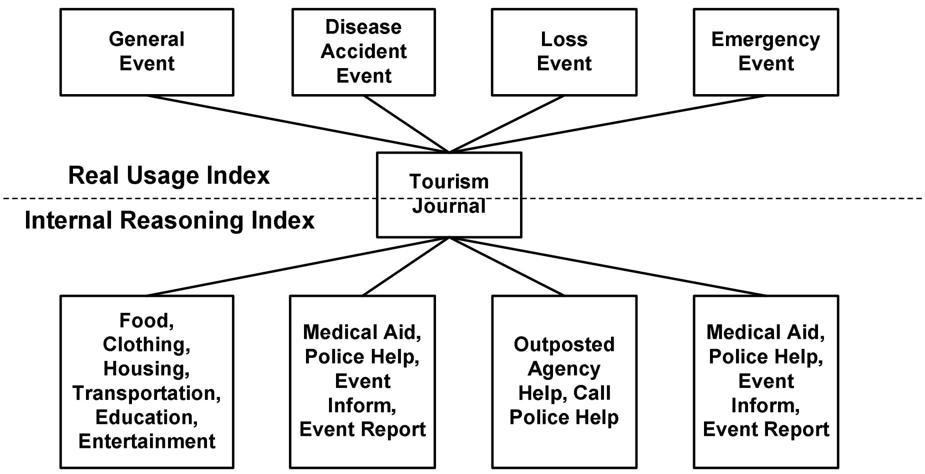

Figure 5. Modular connection and usage.

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The presented "tourism" scenario and a corresponding event message ontological architecture are shown in Figures 4–5. The design object is to provide helpful information as a response to various types of queries for journeys, local events, practitioners, vehicles/lodging available and sightseeing information. As listed in Table 1, the usage scenarios cover the emergency, loss and found, illness and accident affairs. As illustrated in Figure 5, a corresponding scenario handles events including asking for medical aid, calling the police for help, contacting companies, reporting to Tourism Bureau, outposted agency asks for assistance and notifying family members of information services available. The Jaccard similarity is used as a measure of the consistency between ontological concepts. The WordNet database can be accessed, using SQL and Java WordNet Library, due to which an ontology and Java Development System is built by use of a SQL database. The Jaccard similarity J, also known as the Jaccard index, and the Jaccard dissimilarity Jδ, also as the Jaccard distance, are respectively defined as

$$J(A,B)=\frac{|A\cap B|}{|A\cup B|}, \tag{1}$$

$$J_{\delta}(A,B)=1-J(A,B)=\frac{|A\cup B|-|A\cap B|}{|A\cup B|}, \tag{2}$$

Taking OWL/RDF(s) as an example, these relationships are defined as "owl:ObjectProperty", "owl:Functional Property" and "owl:InverseFunctionalProperty". Therefore, relevant analysis rules can be defined to capture the main concept of ontology, e.g.

```
TRIPLE
   (SUBJECT ?P)
   (PREDICATE “HTTP://WWW.W3.ORG/1999/02/22-RDF-SYNTAX-NS#TYPE”)
   (OBJECT “HTTP://WWW.W3.ORG/2002/07/OWL#OBJECTPROPERTY”)

TRIPLE(SUBJECT ?S)(PREDICATE ?P)(OBJECT ?O)

=>RESULT : O IS DESCRIPTION FACTOR FOR S
```

In the aforesaid rules, if the Predicate P is the type of the aforesaid words, then the Subject S has other concepts of Object O. On this condition, Subject S is the main concept related to this

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domain. Afterwards, from a set of the main concepts, the most representative domain concept, i.e. the maximum information content value, is expressed as

$$DomainConcept = \max_{c \in S(C_1, C_2)} [-\log P(c)], \tag{3}$$

In addition, the location of this domain concept in the WordNet ontology is indexed according to the hasURI of hasURI and hasConsistency attributes of the most representative concept, the consistency of the domain concept is evaluated as the Jaccard Similarity, and then stored in the corresponding hasConsistency attribute to complete the corresponding processing of the domain concept. Finally, the location of the domain concept in Ontological Databases (OD), as shown in Figure 1(b), is accessed according to the Synset_ID of concept in WordNet to support the overall system operation.

3.3. Dr. What-Info II System Operation

As illustrated in Figure 1, recognition and conversion are performed in an ontology-supported multimedia semantic analysis subsystem of a Dr. What-Info II APP, using Ubi-IA and a built-in camera, a video recorder in a smart phone. A corresponding query semantic content is completely described using CURRL (Canonical User Request Representation Language) [15], and then the corresponding query data are fed back to CEOntoIAS for related cloud information processing and query decision support operation [19, 20]. As can be seen in Figure 6, CEOntoIAS is a multi-agent system, consisting of Ubi-IA, OntoDMA, OntoCBRA, WIAS, WIAS-supported OntoIAS and Content Databases. Ubi-IA is designed to take charge of cloud query information processing, conversion and intelligent query decision. A 3-stage intelligent query decision mechanism providing a solution to a cloud query is illustrated as follows. In stage 1, OntoDMA processes query information sequentially to judge whether there is a cloud prediction solution, while, in stage 2, OntoCBRA processes sequence query information to judge whether there is a CBR solution, and, in stage 3, Ubi-IA searches the Internet for an external solution by means of OntoIAS in WIAS. Then the query information is processed by the preset rules constructed by domain experts to judge whether there is a preset

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solution. WIAS uses a SQL software IC concept to build a universal SQL access template for information parameter transmission, just as a hardware IC provides a network service function to various cloud information among the aforesaid agent systems for a rapid access to cloud system information via Internet. The Content Databases include system OD constructed by system processed index information, and recommend users related databases supporting information sharing. At the beginning of a Dr. What-Info II operation, the cloud information ontology constructed by domain experts and the corresponding preset rules are used to extract the useful information in answer to the occurrence frequency of a piece of query information, and the support as well as the confidence of prediction rules corresponding to the piece of query information is initialized meanwhile. The case similarity computation of a corresponding WIAS network service support is constructed by cloud information ontology, so as to initialize CEOntoIAS. During Dr. What-Info II operation, the most and the least frequent query information is periodically evaluated using a time series analysis technique in answer to the frequency of query information. OntoCBRA produces related case information, and uses Full Scan together with a PHP algorithm]16, 21] to enable OntoDMA to correct the corresponding prediction rules. With the support of UAI technology, OpenData@Taiwan/Taipei and domain ontology, wanted information is captured according to local GPS location and address conversion, such that the quality of mobile information consultation and sharing can be upgraded effectively and the correctness, authenticity and integrity of location-based information provision can be enhanced accordingly. Moreover, if the aforesaid two agents have no way to provide an appropriate cloud information solution as expected, Dr. What-Info II will enable OntoIAS to seek an appropriate cloud information solution outside Internet by means of information search, acquisition, classification and presentation or ordering, and domain experts can hence augment and modify preset rules, constructing a learning cycle in answer to a piece of query information. This move can not only mine related cloud information operation knowledge or rules to speed up the system process for query information, but also learn related processed

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cases and operation modes to enhance the system robustness for query information processing, implementing an user-oriented and domain related optimal cloud information solution easily.

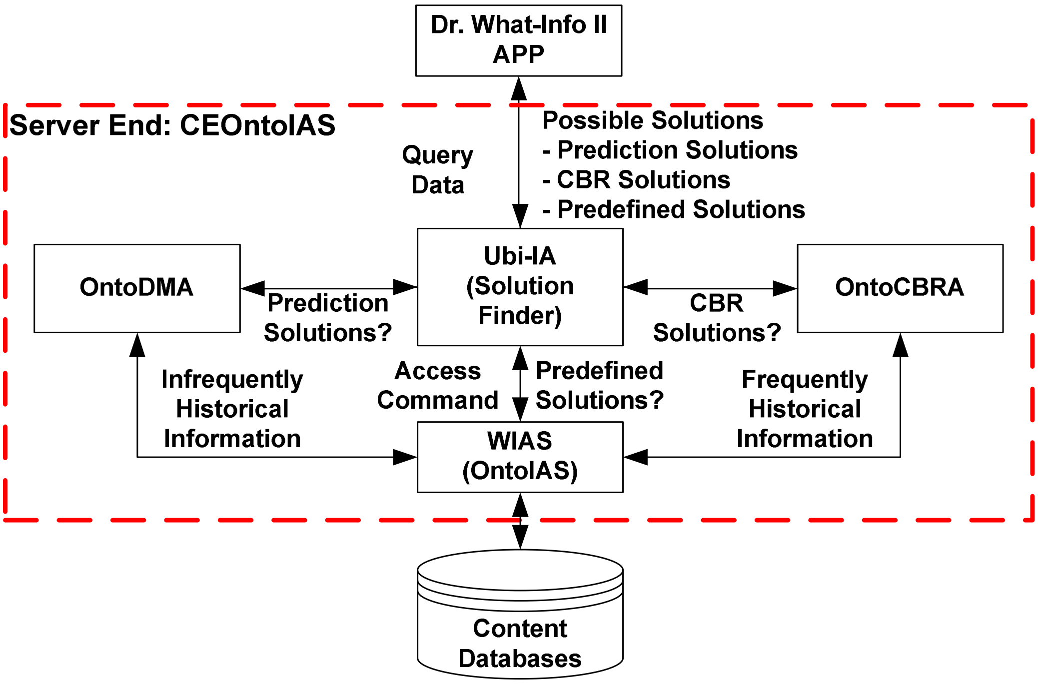

Figure 6. Architecture of the proposed system.

4. System Validation

4.1. System Presentation

Figure 7. Local GPS location.

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Due to a huge progresses in the development of the prototype system Dr. What-Info, as illustrated in Figure 2, UAI is developed in this paper on the basis of Taiwan government open data for different data formats and intelligent system APIs, with the support of OpenData@Taiwan/Taipei, domain ontology and local GPS location capture, say in Figure 7. Information of interest is intercepted, such as the spots of recommended restaurants and parking facilities nearby on a journey based on local GPS location at St. John's University, Taiwan, as shown in Figures 8–9, respectively. A click on a bottom in the lower part of such two figures leads to a website, as shown in Figures 10–11, for a whole picture of searched restaurants and official information on parking lots in advance, respectively. Finally, if a user makes up his/her mind to visit a target, for example, Warehouse II Café (二號倉庫咖啡), a route planner is enabled autonomously, and a suggested route is then displayed, as shown in Figure 12. Meanwhile, such information can be shared on Face Book, as shown in Figure 13. The aforesaid block information recommendation based on a special event-based information provider, as opposed to a general one in Figure 5, is presented as the major contribution of Dr. What-Info II.

Figure 8. Information on recommended restaurants.

Figure 9. Information on Parking lots.

Figure 10. Official website of Warehouse II Café (二號倉庫咖啡).

Figure 11. Parking lot website in the Repulse Bay, New Taipei City, Taiwan (新北市淺水灣停車場).

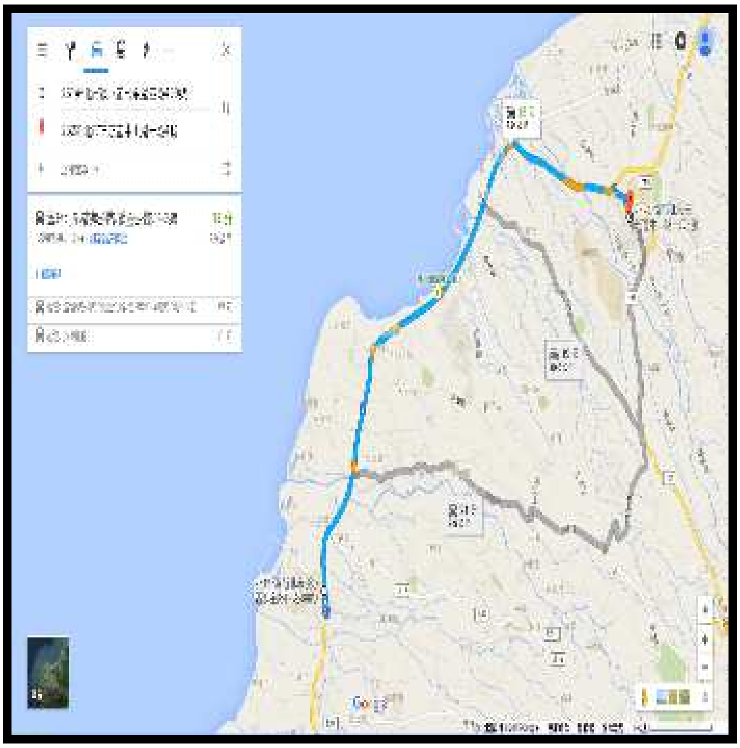

Figure 12. Target route planning and map display.

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Figure 13. Website of Warehouse II Café (二號倉庫咖啡) shared on FB.

4.2. System Rating

User's satisfaction is rated. Both the "usability" of the contents provided on a system webpage and "ease of use" (easy to use) of system operation are analyzed. As requested by ISO 9241, usability is rated in terms of effectiveness, efficiency and satisfaction dimensions. The Whitney Quesenbery (http://www.wqusability.com/, 2009) recommends the so-called 5Es for measuring usability. For the ease of use of system operation, Jakob Nielsen (http://www.useit.com/jakob/, 2005) suggested ten basic principles to a user interface design. However, the presented system user interface receives a collective satisfaction score of 80% (((4/5) + (8/10))/2) in terms of the system usability as well as ease of use rated by the parameters listed in Table 3. This tremendous difference in satisfaction score is caused by superior engaging, including the 1st–8th out of the 10 quantities in a Nielsen rating as a consequence of an intelligent user friendly interface design. However, it must be pointed out that there is still room for the improvement in error tolerant, i.e. quantities 9–10, in both user interfaces.

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Table 3. A collective rating for the satisfaction of the presented user interface

Standard	Items	The presented system
Usability (Quesenbery 5E)	Efficient	O
	Effective	O
	Engaging	O
	Error Tolerant	X
	Easy to Learn	O
Easy to use (Nielsen)	Visibility of system status	O
	Match between system and the real world	O
	User control and freedom	O
	Consistency and standards	O
	Error prevention	O
	Recognition rather than recall	O
	Flexibility and efficiency of use	O
	Aesthetic and minimalist design	O
	Help users recognize, diagnose, and recover from errors	X
	Help and documentation	X
Total comparisons		80%

Legend: "O" means to have this function; while "X" means none.

However, the design concept of this human-machine interface (HMI) uses the "Design preference to Importance Ratio" (DIR), proposed by Ha [3] and defined as Eq. (4), and use "Balancing Index" (BI), defined as Eq. (5), to define the perfection of interface setting. In other words, a zero of BI means that all the HMI elements are balanced, the HMI design conforms to the concept of important design preference and meets the user's operating requirement in system operation. Hence, the value of DIR should approach unity for an optimal balance.

$$DIR_{ijk} = \frac{\dfrac{DP_{ij}}{\sum_{i=1}^{n} DP_{ij}}}{\dfrac{I_{ik}}{\sum_{i=1}^{n} I_{ik}}}, \tag{4}$$

$$BI_{jk} = \frac{\left|\sum_{i=1}^{n} \log_{10} DIR_{ijk}\right|}{n}, \tag{5}$$

where DIR_{ijk} , DP_{ij} and I_{ik} represent the DIR value in the design attribute j and the important attribute k, the design preference in the design attribute j and the design importance in the important attribute k of the HMI interface element i, respectively, BI_{jk} represents the BI in the design attribute j and the important attribute k, and n represents the total number of the HMI interface elements.

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Each design preference DP_{ij} is rated on a scale of 1 to 5: (1) poor, (2) fair, (3) good, (4) very good and (5) excellent. Table 4 gives the scores of all the HMI elements in our design attributes and the informational importance thereof, using an analytic hierarchy process [3], while Table 5 gives the DIR values with BI = 0.003165 (a zero value represents an optimal balance). The verification results show that the presented human-machine interface is experimentally validated not only to meet the design preference, but also to provide a nearly optimal balance.

Table 4. Design preference versus informational importance for each HMI elements

HMI Elements	Description	Design Preference	Informational Importance	Remarks
GMAP	Google Map	5	0.166667	Graphical display and points
GSP	GSP Location	3	0.233333	Label in Text
BOT	Recommendation Bottoms	3	0.233333	Bottom in Text
NAVI	Navigation	3	0.183333	Bottom in Text
FB	Sharing by Face Book	3	0.183333	Label in Text

Table 5. DIR values with BI = 0.003165.

HMI Elements	DIR	Remarks
GMAP	1.266055	A minor improvement is required
GSP	0.904325	A minor improvement is required
BOT	0.904325	A minor improvement is required
NAVI	1.000834	An nearly optimal balance
FB	1.000834	An nearly optimal balance

5. Conclusions and Discussions

Dr. What-Info II is presented herein as an upgrade of a prototype system Dr. What-Info. A cloud intelligent multi-agent system is built for information processing, exchange, communication, operation, integration, analysis and decision support via a three-stage intelligent decision mechanism made up of OntoDMA, OntoCBRA and OntoIAS. In this manner, using Taiwan government open data and Universal Application Interfaces, Dr. What-Info II can be implemented easily to search for and share an optimal cloud (mobile) information solution. Accordingly, the quality of mobile information consultation and sharing is upgraded effectively,

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the correctness, authenticity and integrity of location-based information provision is enhanced, and an accurate, rapid, robust, pervasive and active intelligent mobile information consultation and sharing multi-agent system is built as well.

An in-depth and complete system analysis and experimental results validate the feasibility of the techniques involved and the presented system architecture. Moreover, this Dr.What-Info II app receives a collective satisfaction score of 80% in terms of Quesenbery’s 5Es and Nielsen ratings. However, it must be pointed out that there is still room for interface performance improvement in successive studies, including error tolerance in interface design; Help users recognize, diagnose, and recover from errors; and Help and documentation. In addition, the DIR and BI verification results show that the presented human-machine interface is experimentally validated not only to meet the design preference, but also to provide a nearly optimal balance.

For easy demonstration of the techniques in our system, the current implementation runs on a specific “Tourism” information domain. However, the authors believe that even if the domain is scaled up, our techniques are still applicable. The idea is that we are not directly scaling up our ontology; instead, we can create a complex system by integrating a set of simple systems through a multi-agent design, i.e. OntoIAS [21]. In addition, by exploiting the capability of Protégé, which supports the creation, extension and cooperation of a set of domain ontologies, we do not need to change our system much to transform it into a more complex system. We only need to recollect and reconstruct the related ontological databases for supporting the system operation, rebuild the regular expression rule base for supporting the operations of the webpage crawler and information extractor, and devise a mechanism to ensure that a set of ontology-supported systems can cooperate effectively under our investigation.

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