SMART EARTH COLLABORATION PLATFORM BASED ON SEMANTIC WEB TECHNOLOGY

Chih-Hong Sun,
Department of Geography, National Taiwan University, chsun@ntu.edu.tw
Hsiang-Hsu Lin,
Department of Geography, National Taiwan University, d04228004@ntu.edu.tw
Joe-Air Jiang,
Department of Bio-Industrial Mechatronics Engineering, National Taiwan University, jajiang@ntu.edu.tw
Jehn-Yih Juang,
Department of Geography, National Taiwan University, jjuang@ntu.edu.tw
Tzai-Hung Wen
Department of Geography, National Taiwan University, wenthung@ntu.edu.tw

Abstract

With over half of the world's population now living in cities, the pace of urbanization has been accelerating. As a result, major cities around the world are faced with multiple challenges, including traffic jam, insufficient infrastructure, rising unemployment, environmental pollution, and deteriorating security. How to cope with those challenges has become an inescapable issue for city chiefs. Fortunately, rapid development of information communications technologies, such as the maturing technologies for cloud computing, the Internet of Things (IoT), wireless sensing network, big data analytics, semantic web, social network, and geographic information system, have opened up opportunities for them to cope with the challenges. Smart earth and smart city that deploy these smarter technologies will provide a brighter future for mankind in the near future; however, it requires the world's governments, academia, and business community to work together to face the challenges. This paper presents the concept of Smart Earth Collaboration Platform (SECP) based on semantic web technology and open data policy. We employ the Open Semantic Framework (OSF) to integrate various kind of structured, semi-structured, and unstructured data. OSF integrates many kinds of open source software on the semantic web forming a useful open framework platform for data integration and knowledge management. Via the employment of SECP, the world of information can be combined into a super big data system for common sharing, and academic research results can also be pooled into a sharable knowledge base. Decision makers only need to raise

decision-making needs on SECP and decision support system developers will take advantage of this sharable super big data system and sharable knowledge base to develop customized decision support system for decision makers.
Keywords- Smart City, Semantic Web, Geographic Information Science, Internet of Things, Linked Open Data, Big Data Analytics

1. INTRODUCTION

With over half of the world's population living in cities, the pace of urbanization has been accelerating. As a result, major cities are faced with multiple challenges, including traffic jam, insufficient infrastructure, rising unemployment, environmental pollution, and deteriorating security. How to cope with those challenges has become an inescapable issue for city chiefs. Fortunately, rapid development of information communications technologies, such as the maturing technologies for cloud computing, the Internet of Things (IoT), wireless sensor network, semantic web, big data analytics, social network, and geographic information system (GIS), have opened up opportunities for them to cope with the challenges. Therefore, smart city built on the basis of those new technologies has become a hot topic in recent years, as chiefs of various cities have hoped to solve problems facing their cities via the pushing of smart cities, thereby assuring their sustainable development [1, 2, 3, 4].

The issue of smart city has received high regard, since it is a key means for solving urban problems. The question now is how to push and materialize the concept of smart city, rather than whether to push it. In recent years, the rapid development of the Internet of Things (IoT) and geospatial information technology has laid a solid foundation for materializing the vision of smart city. In its whitepaper on the development of smart city and the IoT, Cisco proposes an important strategy for materializing smart city [2]. The fast emerging IoT in recent years has triggered construction of a revolutionary smart city infrastructure, eventually will connect every sensor, every enterprise, every government agency, every resident, and every car to a smart network consisting of communications network, energy network, and logistics network in future. In 2007, there were 10 million sensors worldwide connecting various human-invented devices to the IoT and the number had skyrocketed to over 3.5 billion by 2013, which is expected to top 100 trillion by 2030 [5]. Those sensors transmit massive data in real time, forming big data at unimaginable scale, which then undergoes processing of big data analytical technology, greatly boosting human decision-making efficacy and productivity.

Except multiple problems and challenges facing cities, the issues of global climate change and financial tsunami have taken on a global magnitude in recent years, even threatening future development of humanity. Effort by the United Nations pushing the sustainable development concept since 1992 has failed to alleviate deterioration of the problems, which have been complicated by the globalization issue [6]. What's outlet for humanity? Do we have no other choice but watching helplessly increasing deterioration of problems? A good news is that the development pace of science and technology has not let up, as shown in emergence of new science and technology in recent years, such as geographic information science, cloud computing, the IoT, semantic web, linked open data, and big data, which shed light of hope. The development of geographic information system and geographic information science has enabled us to more efficiently collect, process, and analyze geospatial information [7, 8]. The development of cloud computing technology has made data sharing more efficient [9]. The development of the IoT has transformed GIS into real-time GIS, enabling decision makers to grasp trend of changes in space and time [2]. Thanks to the development of linked open data, data sharing and retrieval has become easier [10]. As a result of the development of big data analytical technology, sources of problems can be located and solutions proposed by employing data mining technology to process massive space/time data [11].

In fact, the environmental issue, economic issue, and social issue confronting humanity has a common origin, that is human greed [12]. In order to cut production cost, factories discharge the production process untreated pollutants into rivers or the air, polluting environment. The financial tsunami in 2008 was also caused by the greed of Wall Street bankers, triggering a chain economic disasters worldwide. The Sunflower Student Movement erupted in Taiwan in 2014, partly due to young people resenting the government over aggravation of wealth gap, as financial groups monopolize economic benefits, to the exclusion of massive common people. Since ancient times, power and greed have colluded, resulting many human tragedies. The most effective antidote for the greed problem is information and power transparency, bring all the problems and information under sunlight and baring the corruption and decadence problem. Therefore, the corruption and decadence problem can be minimized via the design of system which opens up information [13].

The opening up of information, however, is confronted with twin barriers, one in technology and the other in administration. In technology, difference in hardware, software, and data format among different information systems creates a barrier for data exchange and sharing. The barrier for data sharing, though, have been gradually overcome in recent years, thanks to the pushing of various international information standards [14, 15]. Administrative barrier for data sharing refers to conservatism and outdated norms of government agencies, which needs review of existing institutions for its removal. The emergence of cloud computing and broadband wireless communications has made it very convenient for data securing and sharing. Plus the emergence of the IoT technology, digital data have been accumulated by leaps and bounds, which, via big data analysis, generates lots of useful information facilitating resolutions by decision makers. Therefore, so long as the administrative barrier can be overcome, data sharing and opening-up will greatly augment the administrative efficiency of government and enterprises, in addition to dampening corruption and decadence problem. Dampening of corruption and decadence problem and enhancement of efficiency for administrative decision making will help humans solve the environmental, economic, and social issues, facilitating the development of the sustainable development concept [13].

Consequently, IBM proposed the "smarter planet" concept in 2008 [16], in the hope of utilizing technologies of cloud computing, the IoT, open data, and big data analysis to help government gradually improve the environmental, economic, and social issues. The "smarter planet" concept calls for application of the IoT technology, establishing global sensing network for real-time monitoring the Earth's environment and humans' economic activities and then subjecting the accumulated huge amount of data to cloud computing and big data analysis, in order to help decision makers improve the quality of their decision making. Therefore, the pushing of "smarter planet" can help various governments improve administrative efficacy and corporate executives more efficiently utilize resources and cut costs, further facilitating creation of new-type job vacancies and making critical contribution to the solutions of the issues confronting humanity.

In the future, smart cities and smart earth will be built on the omnipresent IoT and linked open data and will have smart decision support systems to facilitate high efficiency city and global governance and provide innovative smart services. The paper probes the status of related smart technologies, smart city, and smart earth, in addition to putting forth the conceptual framework of smart earth collaboration platform, as the foundation for developing smart cities and smart earth. The paper explains the development status of smart technologies in section 2 and the development status of smart earth and smart cities in section 3, while putting forth the framework for Smart Earth Collaboration Platform (SECP) in section 4, an application prototype project based on SECP is briefly described in section 5, to be followed by conclusions at the end.

2. REVIEW OF SMART TECHNOLOGIES

In 1992, Michael Goodchild put forth the concept of geographic information science, making GIS a key field of scientific study, rather than a mere tool for problem solution [17]. After near 20 years of development, GIS has become a multi-discipline study, scoring rapid development in both basic and application research [8, 18]. During a speech in 1998, then U.S. Vice President Al Gore put forth "Digital Earth" concept, noting that the development of GIS had enabled humanity to grasp massive geospatial data and calling for various government to share geographic data for use in government, corporate, and academic sectors, thereby jointly solving problems confronting the earth [19].

The IoT is a topic widely covered by media and concerned by the information technology industry. Thanks to rapid development of wireless networks, sensing technology, and ICs, inexpensive RFID chips have been available, capable of tracking virtually every object in real time. Cheap environmental sensors can also transit in real time massive environmental data and a global electronic nervous system is gradually taking shape. The IoT is dubbed a revolutionary smart infrastructure, connecting every sensor, every enterprise, every government agency, every resident, and every car to a smart network consisting of communications network, energy network, and logistics network. In 2007, there were 10 million sensors worldwide connecting various human-invented devices to the IoT and the number had skyrocketed to over 3.5 billion by 2013, which is expected to top 100 trillion by 2030 [5]. Those sensors transmit massive data in real time, forming big data at unimaginable scale, which then undergoes processing of big data analytical technology, greatly boosting human decision making efficacy and productivity.

According to the statistics of Cisco Systems, online information traffic on the Internet topped 23.9EB (Exabyte, 1EB=1018bytes=1 billion Gigabytes) in 2011, 12 times over the amount five years ago, in 2006, which is estimated to hit by 1.3ZB (Zettabyte, 1ZB=1021bytes=1 trillion Gigabytes) by 2016, really stunning figure. As a result, big data analysis has become a hot topic in recent years. Customized decision support system featuring big data application enables decision makers to grasp global dynamic information anytime, anywhere, facilitating optimal decision making [20, 21, 22, 23, 24].

At present, most online data are transmitted in a format which cannot be understood by machines. If the data can be converted to materials capable of being interpreted by machines, users' retrieving and planning capability will be greatly enhanced. The Semantic Web is a knowledge framework for bridging data. Berners-Lee predicted in 2001 that the Semantic Web will become next-generation Internet [25]. The Semantic Web can present concept in online form and utilizes ontology to the relationship, as well as logic rules, between concepts for specific knowledge field. Guarino divides ontology into three categories, upper or top-level ontology, domain or task ontology, and application ontology [26]. What upper ontology presents is the foundation and general rules of objects, mostly general, abstract, or philosophical concepts, for extensive application in different knowledge domains, such as space, time, object, and event. Domain or task ontology involves explicit expression in a specific professional domain (medicine, publishing) or activities or task items in a domain (such as diagnosis, marketing), in addition to presenting relationship between concepts, as well as specific viewpoints, in a domain. Application ontology applies various kinds of knowledge in the realm between upper ontology and domain ontology and therefore is most complicated, often involving two or more related kinds of ontology.

In recent years, various governments have been vigorously opening up public data, facilitating linked data. Technology-wise, linked data involves data in the simplest mode, enabling record or data set to be linked to any place via a Semantic Web under control. Conceptually, linked data offers a brand-new method to consider the construction, publication, discovery, retrieval, and integration of data [10, 27]. Linked data is an unavoidable process for materializing the ideal of the Semantic Web, while ontology is an indispensable core element for linked data.

Linked data employs two fundamental Internet technologies, namely Uniform Resource Identifiers (URIs） and HyperText Transfer Protocol (HTTP). Via HTTP, URI in reference can be located for identification and lookup of objects. RDF is another key technology for data sharing. While HTML is a method for constructing and linking online documents, RDF is used for constructing and linking descriptive data via a data format with general graphic basis. RDF employs a triad of subject, predicate, and object for data encoding (Figure 1). Of the triad, subject and object are both URIs, capable of identifying resources, URI, or character string, while predicate, also in URI form, can depict the relationship between subject and object. Linked data is constructed in the simplest triad data mode, enabling record or data set to be linked to any place via a Semantic Web under control.

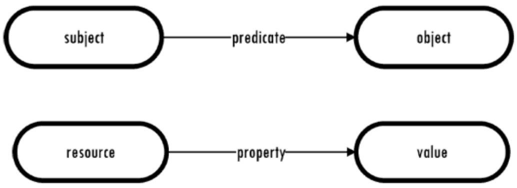

Figure 1 RDF-depicted graphic structure
(source: Yu 2011) [28]

In addition to describing the concept of linked data, Berners-Lee [27] also proposed linked open data (LOD), which means forgoing entitlement so that outsiders can retrieve data freely. Sometimes, linked data can only be accessed by internal units or individuals of an organization or data set cannot be opened to general public, due to copyright. LOD, however, offers free access to outsiders. Berners-Lee employs a five-star deployment scheme to show the extent of openness for LOD, as reference to managers and users (Table 1).

Table 1 Definition of five-star linked open data

★	Available on the web (whatever format) *but with an open license, to be Open Data*

★★	Available as machine-readable structured data (e.g. excel instead of image scan of a table)
★★★	as (2) plus non-proprietary format (e.g. CSV instead of excel)
★★★★	All the above plus, Use open standards from W3C (RDF and SPARQL) to identify things, so that people can point at your stuff
★★★★★	All the above, plus: Link your data to other people's data to provide context

（Source：http://www.w3.org/DesignIssues/LinkedData.html）

3. DEVELOPMENT OF SMART EARTH AND SMART CITIES

Proposed by Samuel J. Palmisano, former IBM chief executive, in 2008, the "smarter planet" concept calls for various governments and enterprises to employ smart technologies developed in recent years in solving multiple predicaments entrapping humanity [16]. At a roundtable meeting convened by former U.S. President Obama in 2009, Palmisano shared the "smarter planet" concept, prompting Obama to launch "open government" initiative, in the hope of opening government data to usage by academia and the private sector and making government operation more transparent and efficient [29]. Li Deren, member of the Chinese Academy of Sciences, believes that smart earth owns the following four features: (1) smart earth contains the IoT; (2) smart earth is oriented toward application and services; (3) smart earth blends with the world of physics; (4) smart earth can form and maintain networks by its own [30].

Globally, more people live in urban areas than in rural areas, with 54 per cent of the world's population residing in urban areas in 2014. In 1950, 30 per cent of the world's population was urban, and by 2050, 66 per cent of the world's population is projected to be urban [31]. Some scholars even raised the idea that "cities are where human future lies."[32]. With urban population having become ever larger, infrastructural facilities for key services, such as transportation, medical treatment, education, and public safety, have been subject to ever heavier pressure. People are demanding quality education, environmental protection plan, convenient government services, housing at reasonable prices, and more welfare for senior citizens, large variety of public needs which pose major challenge to cities in the future. On the other hand, thanks to rapid development in recent years, emerging information communications technologies, such as cloud computing, the IoT, wireless sensor network, big data analysis, social networks, and GIS, have increasingly matured for application and become key tools for solving urban development issues, leading to the proposal of such concepts and ideas as "digital city," "information city," and "mobile city" [33, 34, 35, 36]. In order to integrate Internet technologies and map out an innovative vision for future urban development, IBM and Cisco jointly put forth in 2005 the innovative idea "smart city," for addressing such issues as social change, technological application, green energy/environmental protection, and sustainable development, which elicited warm reception worldwide [32, 37, 38, 39].

Smart city employs omnipresent communications networks, extensively installed wireless sensors, and smart management systems in coping with existing and future urban challenges, in addition to creating new services. It can not only connects citizens and government, facilitating direct participation, interaction, and cooperation, but also offers solutions for the sustainable development of economy and environment, posing as a potential future for every city and township [2]. Smart city aims to optimize the operation of urban services via the development of operational data. Its basic concept features instrumentation, interconnection, and intelligent application. Instrumentation calls for collection of real-time data on the real world via physical and virtual sensing devices; interconnection for the integration of those data into a corporate computing platform and data communications among various urban services; and intelligent application for the incorporation of complicate analysis, mode building, optimization, and visualization into business operating process, thereby facilitating better decision making [37]. The Intelligent Community Forum (ICF) highlights the importance of broadband networks in smart city, especially for economic development and public welfare, and lists broadband connectivity, knowledge workforce, digital inclusion, innovation, and marketing and advocacy as the five major criteria in evaluating smart city [40, 41].

IBM believes that smart city involves application of new-generation IT technologies in grids, railways, bridges, tunnels, among others, at every corner of the world, facilitating the integration of the operations of governments, airports, and harbors, so as to make resources utilization more efficient and cities smarter [42]. Cisco depicts a vision of interconnected smart cities, where networks function like nervous systems linking up various urban aspects, capable of rapid data transmission, facilitating high-tech applications in citizen services and urban management and formation of a convenient, energy-conserving, and humane living environment, which can satisfy citizens' needs anytime, anywhere. In planning smart cities, information technology and Internet companies, such as IBM, Cisco, and Hitachi, believe that energy conservation and carbon abatement must be incorporated into the objective in the development of smart cities, to facilitate the establishment of the foundation for sustainable development of cities. In addition to putting forth corresponding constructions for smart cities and calling for development of related high-tech and system-application industries [43]. The European Union believes that smart cities involves the utilization of information communications technologies in making traditional networks and services more efficiency, augmenting the welfare of residents and enterprises. The concept of smart city covers not only efficient utilization of resources and reduction of emission but also smart transportation networks, upgrading of water-supply and waste-water treatment facilities, efficient lighting and air conditioning for buildings, more interactive and responsive urban management, safer public sites, and capabilities to meet the needs of aging population [44]. To push the development of smart cities, the EU joined hands with European cities, industrial leaders, and private-sector representatives in launching "European Innovation Partnership on Smart Cities and Communities (EIP-SCC) in 2012, an initiative which has attracted 3,000 participants with 370 commitments, pledging to subsidize the development of smart solutions in such fields as energy, information-communications, and transportation, which will make cities more attractive and create bigger business opportunities.

Except some plans with the vision of low-carbon city and objective of city of sustainable development, focus in the current stage is on planning of application technologies and provision of innovative services. In the future, in reference to foreign related studies and planning, efforts can be extended to integrated urban planning and the development and application of professional and technological industries, as well as integrated development of low-carbon and energy-conserving cities [32], innovative information services [36,45], and the establishment of knowledge systems [46], which feature cross-discipline perspective with the objective of cities of sustainable development.

4. SMART EARTH COLLABORATION PLATFORM BASED ON SEMANTIC WEB TECHNOLOGY

We propose a concept of Smart Earth Collaboration Platform (SECP), as shown in figure 2, which is based on the open semantic web technologies, related smart technologies and our previous work MAKOCI [47, 48]. SECP is designed to function as a collaboration platform among government officials, academics, private industry, and decision makers, helping government's open data attain LOD five-star service level, research results and forecast simulation models accumulated by academic institutions over the past years become useful API, so that private industries can utilize government's open data and academia's forecast models in developing various early warning systems and decision support systems for smart applications.

Figure 2 Concept of Smart Earth Collaboration Platform

In addition, SECP can carried out in-depth indexing of data and service. At present, many crowdsource data and government's open data have reached LOD three-star level but most of them are for physical-data downloading and value-added utilization, not suited to the Semantic Web and smart-city management, which need open data without restriction online, or those attaining four-star or five-star level on LOD standard. The problem is that neither government units nor the private sector is likely to invest corresponding fund, manpower, and time in ontology established by themselves. Therefore, SECP will employ open sources semantic web software for data testing and publication and use user feedbacks to locate major tagging of data sets, in preparation for the establishment of ontology, thereby shortening the establishment time of data sharing and integration.

4.1. MAKOCI

MAKOCI (Multi-Agent Knowledge Oriented Cyberifrastructure) aims to develop a platform for geospatial cyberinfrastructure, a Web-based environment for the integration of geospatial knowledge, data, and technologies [47]. MAKOCI adopts multi-agents and ontologies to entail GI services (as geospatial data) with geospatial knowledge for the collaboration of domain experts to contribute their domain knowledge, Web service providers to publish and semantically annotate their GI services, and Web service consumers to semantically search and use their required GI services. Ontologies are used for semantic interoperability and knowledge sharing while registering or searching GI services. And multi-agents can be intelligent to assist users to automatically discover GI services in ontologies in response of users' queries, and can be autonomously communicated each agent for exchanging information.

4.2. Ontology and linked open data

Ontology is a tool of expression for the interrelationship between concepts and is used mainly for knowledge categorization in a specific field of study and the relationship between different categories. It can present not only the complicated relationship between objects but also the definition of the relationship, which is lacking in the current information systems. Via conceptualized, regular, and explicit definition, ontology enables mutual collaboration and sharing between data sets, thereby attaining data and knowledge exchange.

Guarino divides ontology into three different levels (1998): upper or top-level ontology, domain or task ontology, and application ontology. What upper ontology presents is the foundation and general rules of objects, mostly general, abstract, or philosophical concepts, for extensive application in different knowledge domains. Domain or task ontology involves explicit expression in a specific professional domain or activities or task items in a domain, in addition to presenting relationship between concepts, as well as specific viewpoints, in a domain. Application ontology applies various kinds of knowledge in the realm between upper ontology and domain ontology and therefore is most complicated, often involving two or more related kinds of ontology. As shown in figure 3, visualized data relationship facilitates understanding by users of the linkage between data sets and difference of between different levels.

Ontology is the foundation for the linked data and via the complete depiction of OWL and other standards, data can be available for inquiry, analysis, and citation via URI on the Internet. We collect smart city-related ontologies, convert it into Chinese-language version, and then apply Open Semantic Framework (OSF) open source software and related technologies in linking data connected by sensors and government's open data, in addition to understanding key tagging of various data via analysis of user feedbacks, thereby proposing suggestions for data providers in charge adjusting and revising ontology, to facilitate application of data sets.

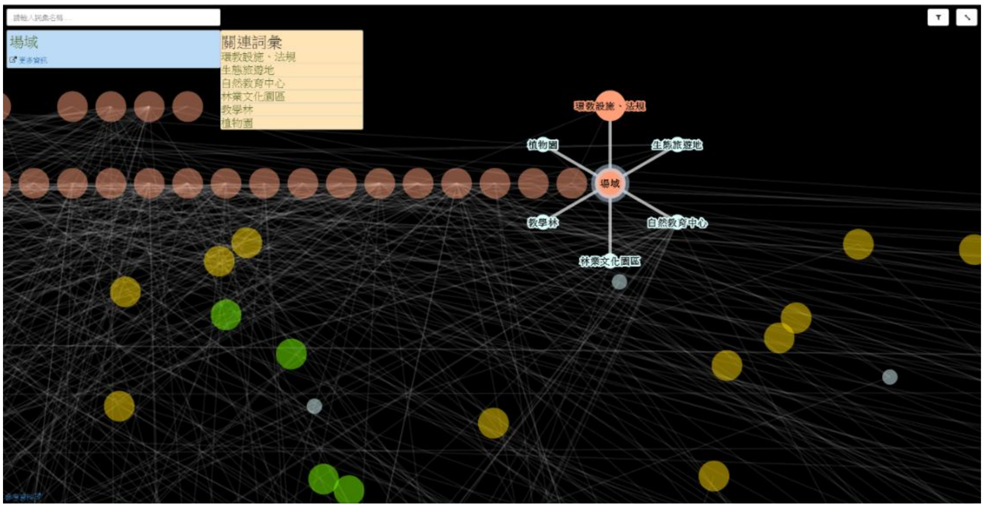

Figure 3 Visualized linkage between ontology concepts

4.3. Open semantic framework

Open Semantic Framework (OSF) integrates many kinds of open source software on the Semantic Web forming a useful open framework platform for data integration and knowledge management. It has evolved to 3.x version after six years of development (http://opensemanticframework.org/).

OSF is constructed on the foundation of the data format of RDF (Resource Description Framework), which facilitates integration of structured data in relational databases, semi-structured data on websites, and non-structured data, such as writings, photos, and multi-media materials. In addition, OSF irons out semantic differences in database via ontology, including similar data with different designations in a database, such as temperature and weather degree and similar designations with different contents, in addition to defining the interrelationship between different data. Therefore, OSF can effectively integrate heterogeneous databases and establish the structure for the sharing of open data, thereby solving longstanding technological problem barring data sharing between the information systems of different formats. For sharing of the data of different formats, users only have to agree to the establishment of ontology for mutual compliance, without changing their existing information systems.

The OSF is an integrated software stack using semantic technologies for knowledge management (Figure 4). It has a layered architecture that combines existing open source software with additional open source components. OSF is designed as an integrated content platform accessible via the Web, which provides needed knowledge management capabilities to enterprises. OSF is made available under the Apache 2 license.

OSF has a variety of applications from enterprise information integration to collaboration networks and open government applications. The system provides:

- Data integration across all content and data types
- Knowledge management
- Semantic search across the enterprise
- Distributed, differential data access and permissions, and
- Publishing and managing your information.

OSF can integrate and manage all types of content — unstructured documents, semi-structured files, spreadsheets, and structured databases — using a variety of best-of-breed data indexing and management engines. All external content is converted to the canonical RDF data model, enabling common tools and methods for tagging and managing all content. Ontologies provide the schema and common vocabularies for integrating across diverse datasets. These capabilities can be layered over existing information assets for unprecedented levels of integration and connectivity. All information managed by OSF nodes may be powerfully searched and faceted, with results datasets available for export in a variety of formats and as linked data.

Thanks to those features, OSF has very high expansibility, capable of expanding the contents of data services, according to the needs of users. Consequently, OSF is suited to be the development platform for smart earth and smart city application systems, capable of integrating heterogeneous data of different departments of city government via OSF to become a smart city collaboration platform with a common architecture.

OSF employs Drupal as the development software for front-end application system. As an open-source software, Drupal is the most popular free software for website contents management. After 10 years of development, Drupal has evolved to 8.0 version, with hundreds of free application modules ready for use, and is the best choice for developing web 2.0 and social network websites with close interaction with users. Many government agencies and even enterprises in the private sector have employed Drupal as their websites' development software, such as the White House, U.S. professional football team Dallas Cowboy, and Harvard University. Drupal enables users conveniently managing website contents, registering accounts, and uploading sharing data, such as photos, films, and writings, as well as geographic information with the coordinates of longitude and latitude. As a result, Drupal is suited to be a development tool for the application systems of SECP. Since Drupal embraces Html5 standard, application systems using Drupal as development tool can be smoothly applied in different mobile phones, tablet PCs, and desktop PCs.

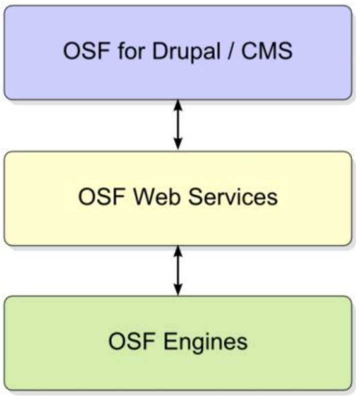

Figure 4 Architecture of OSF system

4.4. Drupal and front-end application systems

As the open-source content management system (CMS) employing PHP program language, Drupal offers users the functions for the addition, programming, and deletion of contents on the website, is applicable in Linux, Windows, and Mac OS, and supports databases MariaDB, MySQL, PostgreSQL, and SQLite, as well as deployment in web servers Apache, Nginx, and IIS (https://www.drupal.org/).

In its operating concept, Drupal treats various kinds of contents as a node and controls the display, arrangement, and categorization of contents via modules, in addition to providing display templates with multiple system interfaces, facilitating establishment of simple system websites by common users. Thanks to the module-based architecture, users can choose proper modules according to different contents and needs, controlling contents display and handling permission and thereby generating multiple custom-made website applications (Figure 5):

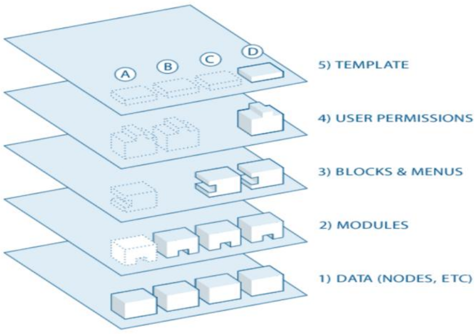

Figure 5 Drupal hierarchy architecture

1. Data

   In Drupal, various data and contents are treated as respective nodes, which are the foundation for constructing system.

2. Module

   As inserts for expansion of functions, modules are mainly provided by Drupal's in-house developers (for core modules) and members of open-source communities (for application modules). Drupal's preset core modules allow users to define the categories of and sequence nodes, as well as display of contents. At present, there have been over 10,000 modules in the application modular inventory.

3. Blocks and menus

   In order to exhibit their set functions in interface, blocks can undergo design for interface deployment, in tandem with theme templates at the uppermost level. Menus can be regarded as the navigator in Drupal, defining the contents of the URL for every node and webpage and providing linkage for all the webpage.

4. User permission

   Permission for addition, revision, website management, and browsing, role distinction for user types and permission, facilitating management of heavy users.

5. Template

   Theme template is a descriptive document defining the appearance of website, often in the formats of XHTML and CSS, including exhibition contents (such as uploaded texts and pictures) and deployment method. Presently, there are over 2,500 templates for choice in template inventory.

The SECP employs MAKOCI and OSF as the technical architecture for application bottom layer, collecting various sensing data and open data, which are announced via URI as interlinked notes in the Semantic Web. The front end streams, via Drupal technology, OSF engine and communicates with various nodes of registered data stations at the bottom layer, thereby securing contents of blocks and facilitating the establishment of decision support systems by system developers. Since OSF is a free open-source software, any data hosting unit can employ OSF in establishing linked database, manage data usage permission itself, or upload data to linked database set up by other hosting units. As linked databases built via OSF have common format and API, facilitating data accession and registration, thereby enabling system developers to obtain raw data easily for the development of decision support system for use by decision makers.

4.5. Functions of SECP

Smart Earth Collaboration Platform (SECP) is developed to promote collaboration among smart city and smart earth service providers and decision makers. SECP contains four portals, which are data portal, tools portal, application services portal, and portal for decision makers respectively. SECP users include data providers, tools providers, application service providers, and decision makers on various smart city and smart earth application subjects. SECP data portal contains data and data hyperlinks submitted by data providers and SECP users. Users of SECP can submit and download data from data portal. SECP tools portal includes hyperlinks of related data management, data mining, data analytics, and data visualization tools submitted by tools developers and SECP users. SECP application services portal includes application services hyperlinks submitted by SECP application service developers and SECP users, including application areas such as smart tourism, smart water, smart health, smart disaster management, smart transportation, smart agriculture, smart building, smart governance, and smart business etc. SECP decision makers portal provides a platform for decision makers to submit their problems and decision making needs so that SECP application service developers can build services to fulfill decision maker’s needs.

5. APPLICATION PROTOTYPES BASED ON SECP

Technologies and applications of Internet of Things（IoT） and big data analytics are the key emerging issues in academia and industries. Understanding and shaping the theories of environmental sensing and the protocols of multiple-source spatial data collection, communication, sharing and analytics for better environmental monitoring and management are the key issues in geographic information science. Therefore, the objective of the prototype project is to establish an urban environmental sensing infrastructure with crowdsourcing and spatial big data for early warning of critical conditions based on SECP that we propose in this paper. Using SECP, we emphasize on innovative applications for detecting urban critical conditions, including street-scale heat environment and near real-time population flow in urban settings. We propose the framework of the project which is composed of four sub-projects, including: 1. a crowdsourcing decision support platform for multiple-source sensor data fusion and analytics; 2. establishment of intelligent wireless environmental sensing and traffic monitoring systems; 3. conducting the application for analyzing temporal-spatial patterns of urban street-level thermal environmental and physiological equivalent temperature; and 4. establishment of a multilayer urban population flow modeling framework for assessing spatial transmission risk of contagious disease. In summary, this project establishes an urban environmental sensing infrastructure to further understand the interactions between physical and social environment for detecting early warning signals of urban critical conditions in Taipei city.

With growing popularity of smart mobile devices, broadband internet and the cloud computing services, changes of environment and human activity will be monitored and collected, forming a huge amount of data space. Through the establishment of the sensor web, users can be automatically sensor from multiple sources, capture and use of appropriate information. The sensor data in a simple and easy way to be understood, accessible for the public will be able to enhance the manager and citizen understanding of the status and trends, establish new urban governance, become more efficient, sustainable, and productivity city. In the Web 2.0 era, the information provided voluntarily by the user or the community, often more extensive and immediate, but also more in line with the needs of users. Crowdsourcing has become a field of environmental monitoring, disaster prevention, industry analysis, an indispensable source of information. To integrate data from different sources to sense, users need to rely on the construction of semantic web and ontology, logic rules define the relationship between concepts. This project uses software tools from SECP, open data, plus onboard sensing devices to the crowdsourcing information collected, the use of ontology technology and establish sensor data integration and query system, and combined analysis model and visualization tools to develop decision support system.

The second sub-project proposes to develop a smart environmental monitoring system for traffic management. In the proposed system, micro-sensing devices are installed in cars to monitor the roads that each car takes, and the environmental parameters around the roads, including temperature, humidity, illumination, suspended particulates, carbon monoxide, to fulfill the goal of ‘smart city’. In this project, several sets of low-power micro-sensors and micro-sensing devices for environmental monitoring are built. The sensed data directly transmitted to a decision support platform for traffic-related analysis to improve the use of roads. Following the concept of ‘smart city’, this project also construct an adaptive warning system to increase road safety and reduce traffic congestion by using the micro-sensing devices that deliver the sensing data to a back-end server. With the sensing information, drivers can make smart traffic decisions. The proposed intelligent micro-sensing monitoring system provides drivers with important information, so they can avoid traffic bottlenecks and further reduce energy consumption and costs of cars. Moreover, the proposed system is capable of detecting damping coefficients, car speed, tire pressure, and oil consumption, and it can also provide information about potholes or road repaving as a preventive measure, so drivers can drive their cars in a more comfortable way. The proposed system is not only a safety and environmental monitoring system but the implementation of the concept of smart city. Combining the adaptability analysis with information and communication technologies, this project is able to generate accurate information regarding major roads in Taiwan and provide better solutions to the improvement of road safety and conditions and the reduction of traffic congestion, and eventually helps the development of the smart cities in Taiwan.

The third project dealing with urban heat island effect (UHI) caused by the regional-to-global environmental changes, dramatic urbanization, and shifting in land-use compositions. The topic has becoming an important environmental issue in recent years. The strengthen of UHI effect significantly enhances the frequency of high temperature, and influences the thermal environment in urban area. According to the meteorological data from Central Weather Bureau (CWB) frequency of high temperature (greater than 27 ° C) in the major metropolitan areas in Taiwan (Taipei, Taichung, and Kaohsiung) have increased in the past 50 years from 1960 to 2010. In this study, we characterize heat environment in the greater Taipei metropolitan area by using the meteorological data collected from CWB and Environmental Protection Administration (EPA). In addition, we apply RayMan model to quantify the physiological equivalent temperature (PET) and characterize of the spatial and temporal distributions of the heat environment over different scales in the Taipei metropolitan area. The results can be integrated into the management and planning system, and provide sufficient and important background information for heat stroke early warning systems for metropolitan area.

The fourth project is dealing with human movement within city. In the scale of within city, human movement system includes four types of transportation modes, rail transit, automobiles on streets, non-motorized transport, and walking. In Taipei city, using the combination of the four types of transportation modes could generally bring a person from one place to any destination. The understanding of human movements within a city requires a system which integrate all of the four transportation modes, that involving the usage of the real-time data and open data. Congestion is an important issue that will influence the everyday life of the people who live or work in the city. Congestion is a spatial-temporal process, which would happen while a lots of people appear at the same place in the same time. So, congestion is an issue that include the temporal dimension and spatial dimension. Congestion usually happens on the morning peak and evening peak, when the people are commuting to their working places and going back to their home, respectively. On the other hand, the question of where the congestion will be happening involved the three aspects of the street system, the design of street network, the density of vehicle, and the diversity of streets. These problem require further analysis to reveal the occurrence of congestion. Therefore, in the first year, this study collected the human movement related open data from the Taipei’s open data portal, and constructed a visualization platform for the observation of the human movement data. In addition, this study also tried to understand the influences of built environment on the streets moving speed.

These four sub-projects are dealing with different research topics within city, however, they are all benefited by using SECP as a platform for collaboration. Experience shows that through collaboration among government, academia, private industries, and citizens based on SECP; customized decision support system can be developed much faster and cheaper, enabling decision makers to improve their quality of decision making.

6. CONCLUSIONS

Smart Earth Collaboration Platform (SECP) is proposed in this paper based on semantic web technologies and related smart technologies. SECP is mostly based on open source software so it can be deployed easily in many cities and countries. Data sets managed by SECP can easily be searched and shared by many developers and research institutes. Smart applications can be developed easily and quickly to help decision makers solving complex problems. Humans have to take advantage of all kinds of wisdom to cope with enormous problems confronting them for their future development. After 50 years of development, GIS, plus maturing of the IoT, cloud computing, big-data analysis, and the Semantic Web, among others, has shed some light on the solution of the problems. SECP offers a direction for humans' development, which, though, needs concerted efforts among governments, academia, and business communities worldwide. The paper puts forth the concept of Smart Earth Collaboration Platform, facilitating worldwide data and knowledge sharing, via collaboration, to combine into an ultra-big distributed data base for sharing by all people and incorporate research results of academia into a convenient and useful distributed knowledge base. Decision makers only have to put forth decision making needs and problems confronting them on SECP, which will prompt information technology firms to take advantage of big data and knowledge base on SECP to rapidly develop a customized decision support system for use by decision makers via cloud computing service lease. Since big data in SECP is mostly free of charge and lease of knowledge base is inexpensive, decision makers can then lease cutting-edge smart decision support system at low cost. Therefore, even the poorest countries can benefit from the applications of SECP in gradually improving their environmental, economic, and social problems. Humanity's sustainable development is no longer a dream beyond reach. Everyone can contribute to smart earth big data via smartphones and share the big data. Government and people can partner in establishing smart communities quickly, which can be linked paving the way for the materialization of smart city and smart earth.

Funding

This work was supported by the Ministry of Science and Technology of Taiwan [grant number MOST104-2627-M-002-019-] and [grant number MOST105-2627-M-002-017-].

REFERENCE

[1]Wu, Y. and Ai, H. 2001. "Smart City-Modern Urban Construction Under IoT." Publishing House of Electronics Industry, Beijing

[2]Clarke, R. Y.. 2013. *Smart Cities and the Internet of Everything: The Foundation for Delivering Next-Generation Citizen Services. IDC Government Insights.*

[3]Deakin, M., & Al Waer, H. 2012. "*From Intelligent to Smart Cities*", Routledge, *Taylor & Francis Group*.

[4]Chen, J. 2013. "Green Smart City." *Zhejiang University Press*.

[5]Rifkin, J. 2014. *The Zero Marginal Cost Society: The Internet of Things, the Collaborative Commons, and the Eclipse of Capitalism*. Business Weekly Publications, Cite Publishing Ltd.

[6]IPCC, 2014. "Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change ," *Cambridge Univ. Press. Cambridge, United Kingdom New York, NY, USA*, p. 1-32.

[7]Kennith, F., Myra, B., Qianjun, M., Huayi, W., Wenwen, L., Jing, L., . Hongwei, Y. 2010. "Vision for Geoinformation Science." *Advanced Geoinformation Science* (CRC Press): 415-451.

[8]Raper, J. 2009. "Geographic information science." *Annual Review of Information Science and Technology* 43(1): 1-117.

[9]Buyya, R., Yeo, C. S., Venugapal, S., Broberg, J., & Brandic, I. 2009. "Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility." *Future Generation Computer Systems* 25：599-616.

[10]Bauer, F., & Kaltenbock, M. 2012. *Linked Open Data: The Essentials A Quick Start Guide for Decision Makers.* url:http://www.semantic-web.at/LOD-TheEssentials.pdf

[11]McAfee, A., & Brynjolfsson, E. 2012. "Big Data: The Management Revolution." *Harvard Business Review(October).*

[12]Yu, C. L. 2006. "Promotion of Honesty, Crackdown on Corruption, and Democratic Governance." Taiwan Democracy Quarterly: 165-176.

[13]Sun, C. H., Shan, J. K., Lien, M. F., and Wong, Y. H. 2015, "Smart City and Smart Governance." *Taiwan Law Journal* 15.

[14]Villa, F., Athanasiadis, I. N., & Rizzoli, A. E. 2009. "Modelling with knowledge: A review of emerging semantic approaches to environmental modelling." *Environmental*

Modelling & Software 24(5): 577-587.
[15]Wellen, C. C., & Sieber, R. E. 2013. “Toward an inclusive semantic interoperability: the case of Cree hydrographic features.” *International Journal of Geographical Information Science* 27(1): 168-191.
[16]Palmisano, S. 2008. *Smarter Planet 2015*. url:http://www-03.ibm.com/ibm/history/ibm100/us/en/icons/smarterplanet/
[17]Goodchild, M. 1992. “Geographical Information Science.” *International Journal of Geographical Information Systems* 6: 31-46.
[18]Sui, D., Elwood, S., & Goodchild, M. 2013. *Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice*. Springer Science + Business Media Dordrecht.
[19]Gore, A. 1998. The Digital Earth: Understanding our Planet in the 21st Century. 2015, url: http://www.isde5.org/al_gore_speech.htm
[20]Chen, H., Chiang, R. H. L., & Storey, V. C. 2012. “Business Intelligence and Analytics: From Big Data to Big Impact.” *MIS Quaterly,* 36(4): 1165-1188.
[21]Mayer-Schonberger, V., & Cukier, K. 2013. *Big Data: A Revolution that Will Transform how We Live, Work, and Think: Houghton Mifflin Harcourt.*
[22]Sawers, P. 2015. *How Microsoft's using big data to predict traffic jams up to an hour in advance*. url: http://venturebeat.com/2015/04/03/how-microsofts-using-big-data-to-predict-traffic-jams-up-to-an-hour-in-advance/
[23]Silverman, A., Costa, T., Johnson, C., Gill, M., Witcher, B., Varon, L., & Katz, R. 2014. Analyze This: Web Style Analytics Enters The Retail Store. https://www.forrester.com/report/Analyze+This+Web+Style+Analytics+Enters+The+Retail+Store/-/E-RES115390
[24]Vesset, D., Morris, H. D., & Gantz, J. F. 2014. *Capturing the $1.6 Trillion Data Dividend. IDC White Paper*.
[25]Berners-Lee, T., Hendler, J., & Lassila, O. 2001. “The Semantic Web. *Scientific American”*, 29-37.
[26]Guarino, N. 1998. “Formal Ontology and Information Systems.” Paper presented at the FOIS'98, Trento, Italy.
[27]Bizer, C., Heath, T., & Berners-Lee, T. 2009. “Linked Data - the story so far.” *International Journal on Semantic Web and Information Systems* 5(3)：1-22.
[28] Yu, L. 2011. A Developer's Guide to the Semantic Web. Berlin, Heidelberg: Springer-Verlag Berlin Heidelberg.
[29]Whitehouse. 2009. Open Government Initiative, from https://www.whitehouse.gov/open
[30]Li, D., Gung, J., Shao, Z. 2010. "From Digital Earth to Smart Earth." *Wuhan University*

Journal 35 (issue 2)

[31]United Nations 2014. World Urbanization Prospects The 2014 Revision Highlights. Published by the United Nations ISBN 978-92-1-151517-6

[32]Harrison, C. and Donnelly, I. A. 2011. “A theory of smart cities.” Paper presented at the The 55th Annual Meeting of the International Society for the Systems Sciences, The University of Hull, Hull, U.K.

[33]Chen, T. M. 2010. “Smart grids, smart cities need better networks [Editor's Note].” *Network, IEEE* 24(2): 2-3.

[33]Ishida, T. 2002. "Digital City Kyoto.” *Communications of the ACM* 45(7): 76-81.

[34]Van den Besselaar, P. and Beckers, D. 2005. “The life and death of the great Amsterdam Digital City.” *Digital Cities III*: 66-96.

[35]Qiu, L. 2007. “Life and death in the Chinese informational city: the challenges of working-class ICTs and the information have-less.” Paper presented at the Living in the Information Society: The Impact of ICT on People, Work and Communities in Asia, 2007.

[36]Evans-Cowley, J. 2010. “Planning in the real-time city: the future of mobile technology.” *Journal of Planning Literature* 25(2): 136.

[37]Harrison, C., Eckman, B., Hamilton, R., Hartswick, P., Kalagnanam, J., Paraszczak, J., and Williams, P. 2010. “Foundations for smarter cities.” *IBM Journal of Research and Development* 54(4): 1-16.

[38] Chen, T. M. 2010. “Smart grids, smart cities need better networks [Editor's Note].” *Network, IEEE* 24(2): 2-3.

[39]Filipponi, L., Vitaletti, A., Landi, G., Memeo, V., Laura, G., and Pucci, P. 2010. “Smart city: an event driven architecture for monitoring public spaces with heterogeneous sensors.” Paper presented at the Sensor Technologies and Applications (SENSORCOMM), 2010 Fourth International Conference.

[40]ICF. 2014. The Broadband Economy. url: https://www.intelligentcommunity.org/index.php?src=gendocs&ref=TheBroadbandEconomy&category=AboutUs.

[41]Chang, C. J. 2013. “Relationship Between Spatial Information System and Smart City.” *National Geographic Information System Newsletter*, 86:2-9.

[42]Su, K., Li, J., and Fu, H. 2011. “Smart City and the Applications.” Paper presented at Electronics, Communications and Control （ICECC）, 2011 International Conference.

[43]Kohno, M., Masuyama, Y., Kato, N., and Tobe, A. 2011. “Hitachi: smart city solutions for new era of urban development.” *Hitachi Review* 60(2): 79.

[44]European Commission. 2015. Smart Cities. url: https://ec.europa.eu /digital-agenda/en/smart-cities#Article.

[45]Pantsar-Syvaniemi, S., Simula, K., and Ovaska, E. 2010.” Context-awareness in smart

spaces." Paper presented at the Computers and Communications (ISCC), 2010 IEEE Symposium.

[46]Ergazakis, K., Metaxiotis, K., and Psarras, J. 2006. "Knowledge cities: The answer to the needs of knowledge-based development." *VINE* 36(1): 67-84.

[47]Jung, C. T., Sun, C. H., Lien, M. F., Chang, C. S., Chung, W. J., Lin, H. Y., & Tsai, P. Y. 2013. "MAKOCI: A Web Portal for Integrating and Sharing Geographic Information Services." *Geography, Environment, and Sustainability, 6*(1): 37-54.

[48]Jung, C. T., Sun, C. H., & Yuan, M. 2013. "Ontology-enabled Framework for a Geospatial Problem-solving Environment." *Computers, Environment and Urban Systems* 38: 45-57.