A Taxonomy on Knowledge-based Geographical Information System (GIS) for a Cloud-based Disaster Management Environment

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***Abstract*— Recent trend shows that the cloud computing is making an impressive impact to the computing world. This is due to its features that are in favor with the complex and vastly expandable field in Information and Communications Technology (ICT) and networking systems. Other advantages of the cloud are including its mobility, scalability and elasticity. Scholars had cited on its definitions, attributes, applications to name a few. On the other hand, the study on the cloud computing with reference to the disaster management environment has yet to be explored thoroughly by available sources. The emergence of Geographical Information System (GIS) to provide and support the geospatial and mapping data in ICT world had improved the tasks of geographical sciences tremendously. GIS has found its way to be programmable and dynamic in conjunction with the knowledge based age evolution. Due to this fact, this paper is prepared to derive the knowledge representations in the field of GIS to suit the cloud-based facility. As a result, a taxonomy for knowledge based GIS in the cloud-based disaster management environment is deduced. A review of the technology is made before coming up with the taxonomy.**

Keywords*— Cloud GIS, GIS Emergency Response, Grids, Knowledge Based GIS, Semantic Web of GIS, Taxonomy of Cloud GIS

I. INTRODUCTION

The computing development evolves quite rapidly. Most people would find that whenever they are trying to get to know a new jargon, there will be a new emerging terminology in the market. The development most of the time is significant especially to aid people in their work deliveries. Nevertheless, it always comes with unbounded issues of privacy, security and validity. It has been the talk of multi-disciplinary engineering, sciences or even the business industries. Nonetheless, this includes technological advances in the field of Geographical Information Systems (GIS) which had utilized all the edges put forth by this facility since the past decade. With the aim of simplifying the storage problems within information access, the GIS are trying to find its compatibility with this cloud computing issues. This is regardless the debates that might supports or contradicts the function and its significance to the GIS applications in the broad view of societal needs.

The study on cloud computing has been made tremendously for the past decades. However, the study of this facility in the environment of disaster management with the geospatial applications is yet to be explored. Therefore, this article is proposing on the development of a taxonomy for cloud-based GIS applications with the enhancement by using the method of knowledge based representations and semantic networks.

II. THE EVOLUTION OF THE CLOUDS FROM THE GRIDS

A. *Reviews on the Clouds*

The appearance of the Cloud is quite hype. It shows that the emergence of this new paradigm has brought more benefits than likewise. The society has begun to learn and adapt their businesses with this edge to the optimum level they might get. Besides making sure that the systems are up-to-date, they are hoping for the best of returns on investment. In fact, the utilization of this facility might to the extent would have created complexity in their organizational structure and brought more opportunities for employments and learning experiences.

A number of scholars' reviews had been written on this topic. The National Institute of Standards and Technology (NIST) has been studying over 15 years on the correct illustration for cloud computing. They have defined that "cloud computing is a model for enabling ubiquitous, convenient, on demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction [1]."

The cloud was claimed to hit the market as early as the 1990s. However, it has only found its popularity in the early 2010s. This is when it has found its way within the applications of ubiquitous and mobile computing. It was seen within public's reach due to its applications in smart mobile phones and computing. In addition, the numbers of mobile telecommunication users keep increasing with the new generation dependencies on these gadgets' development.

Scholars had discussed a rigorous text on cloud computing such that they have derived on the development of the cloud from other existing technology to something more practical to current Internet world. In their texts they have included the cloud architecture, its classification and comparison, the terms of cloud services such as Platform-as-a-Service (PaaS), Software-as-a-Service (SaaS), Infrastructure-as-a-Service (IaaS) and all the flexibility of building the XaaS (everything as a service) [2].

There are other sources that had defined the cloud computing in a quite comprehensive manner by comparing the distinct characteristics of the Cloud with the Grid. Given that the definition of the cloud computing is, "A large-scale distributed computing paradigm that is driven by economies of scale, in which a pool of abstracted, virtualized, dynamically-scalable, managed computing power, storage, platforms, and services are delivered on demand to external customers over the Internet [3]". A narrow definition yet opens to a wide utilization among the World Wide Web users.

B. *The Transformation of the Grids to the Clouds*

The computing world had shown consensus that the Cloud was evolved from the Grids. This is perhaps due to a number of their features which have similarities and coincidences. Scholars has made this comparison against other computing major development which includes supercomputers, web 2.0 and distributed systems. It has seen that all of the computing technology developments still fall under the subset of the distributed systems. They have also illustrated that the Cloud may have been a part of the Grid's service orientation, while the supercomputers are the latter's application oriented. Figure 1 is showing the Grids and Clouds Overview [3].

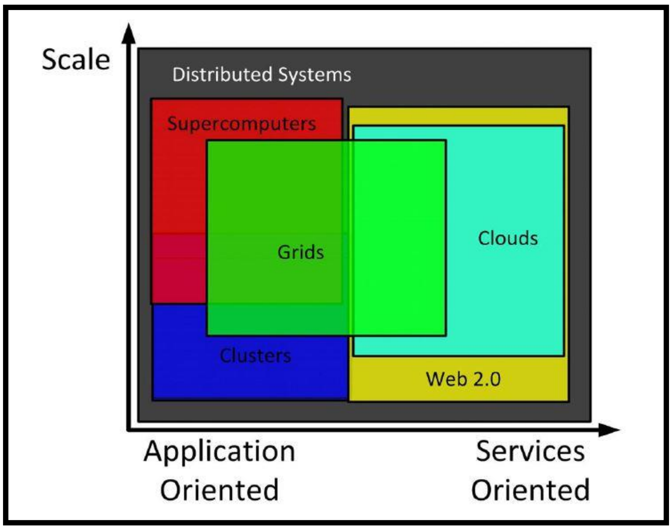

Figure 1. Grids and Clouds Overview [3]

In addition, it was found that the development of the Grids to the Cloud is in a number of paradigms that it favours the latter to prosper for a better service to the user. This includes in the aspects of architecture, business model, resource management, programming model, application model and security model. Nevertheless, the main point that had been highlighted is that the Clouds are progressing much better in all aspects of Internet of Things (IoT).

III. THE DEVELOPMENT OF KNOWLEDGE-BASED GEOGRAPHICAL INFORMATION SYSTEM (GIS)

A Knowledge Based Geographical Information System (GIS) is a computer program that reasons and uses knowledge based representations to solve the GIS complex problems. GIS has a long history perhaps for the use of secret services and military purposes more than half a century ago. As the Internet has also evolved to the use of commercialization and home uses, so did the GIS. GIS has the main function of providing the geospatial and mapping Information to the user. However, challenging the GIS to be part of the knowledge based societal development is not that rapid due to its functions, which is most of the time for the use of certain focus groups.

Today, ever since Google had commercialized its Google Map, or the Microsoft Network had introduced its Bing Application, the interest on GIS knowledge had increased. Even a layman would like to know more on the physical attributes at certain point on the Earth. In addition, the use of spatial information and mapping had been of great aid in the field of meteorological and transportation. Hence, the emergence of GIS within the knowledge based system is very significant.

A. *The Semantic Web of GIS*

To place the GIS within the knowledge based system is to define its ontology and the semantic web that complements it. Transforming the human language to something that machine can understand is never an easy task. On the other hand, ever since the computer has made its debut to the market, it has marked the beginning point of human computer interaction and the commands that between the two entities can understand. This is also marked the era of the Artificial Intelligence in the area of GIS computing.

ODGIS was introduced as a mean of GIS ontology which has made an extensive use of object oriented techniques and combining the use of objects and ontologies to provide a rich model for geographic representations. Among the practical software to program the ODGIS are CORBA IDL, CORBA and Java [4].

As the computing era has evolved rapidly in the Internet world, the need for transforming the ontology to the semantic web had also developed. Semantic web had supported various engineering and sciences researches, findings and applications to something accessible through the application of the World Wide Web. Hence, initiatives had also being taken to support the GIS to be within reach through the Internet browsers.

Figure 2 is illustrating an example of the semantic networks for our study. The field of Spatial Analysis of GIS is shown to have connections to other bigger disciplines including Cloud-based system architecture, machine learning tools and knowledge based disaster management. The illustration is showing the components needed when doing analysis of the geographical information as the properties of the Spatial Analysis with GIS. Among the listings are: the slope and aspect, data analysis, hydrological modelling, cartographic modelling, geometric networks, topological modelling, multi-criteria decision analysis, geostatistics, map overlay, address geocoding and reverse geocoding. From the figure, it is also learned that the component of knowledge based disaster management has, at least, the following properties: Disaster occurrence, Disaster detection, Disaster knowledge based clouds and Disaster management.

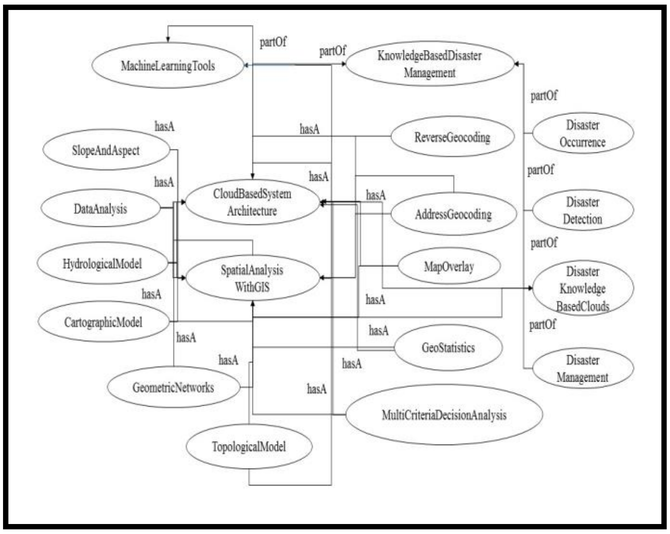

Figure 2. The semantic web for the spatial analysis with GIS in reference to cloud-based system architecture and machine learning tools.

In addition, we have found that over the past decades, GIS has found its way through the World Wide Web. Among the GIS software are the GRASS GIS, gvSIG, MapWindow GIS, Capaware, TerraView and FalconView. Perhaps, among the prominent GIS applications with high market share includes the product of Integraph, Autodesk, MapInfo and Esri. These applications are accessible through their distinct Unified Resources Locator (URL) on the Internet.

B. The Adaptation of the Cloud

With recent economic worldview of cloud computing, GIS has seen its way to be of compatible with this new environment. The cloud's strong attributes which include service-based, scalability, shared services, usage metrics, and the use of Internet technology [5] had stimulated the GIS to be part of the Cloud too. For example, even Esri Inc. has launched its ArcGIS application to be available with the use of cloud servers. According to the company, with the use of the cloud servers for their geospatial Information activities, the software comes with ready-to-use high-quality imagery and topographic and street basemaps. In addition, through cloud ArcGIS users can share their maps and data and collaborate with others [6]. The user interaction features had been incremented. The benefits that this application has brought are that it has increased in productivity, cost effectiveness, and flexibility.

C. Emergency Response and Rescue with Cloud GIS

When discussing the good attributes of a software and the benefits of the GIS, the capacity of its effectiveness should be measured on its contribution towards societal development. The GIS provides major Information in various aspects of human's activities. Nonetheless, when GIS has made its way through the Internet, we have seen that many activities had been supported by this application. This is including giving the Information for the occurrence of natural disaster.

Figure 3 is showing the basic structure of GIS technology utilizing the cloud facility in support of the disaster management processes. The structure is illustrating on the fact that we can translate the knowledge based data with the amalgamation of geographical data within the cloud GIS application to aid the disaster management. In the disaster management, the main important thing is to ensure that warning system is functioning accordingly and problem mitigation can be carried out within proper length of time.

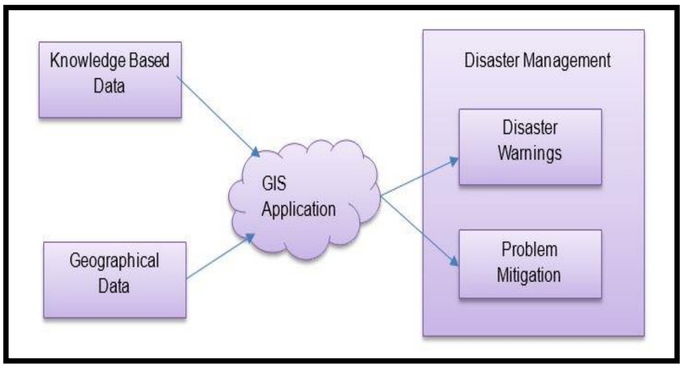

Figure 3. Disaster Management Structure by Utilizing the Cloud GIS

Until today, this feature is yet to be further improved. Most probably this is because the occurrence of the disaster is not of common routine. But, certain applications had been doing research on this matter and developed relevant features for the emergency aid and management. This is for example, ArcGIS software by Esri Inc. has its proposed procedures for using this software in the activity of emergency response and assistance. This is including the planning phase, logistics, operations, commands and public information. However, the customary act for specific disaster, location, country, or perhaps certain community had to be defined within the remote organization itself.

This is a healthy motion one can utilize. There was a study that has put up a good discussion on the safety confirmation system especially for warnings on the occurrence of the earthquake in the campus of University of Shizuoka, Japan. In fact, they have a cloud based system that communicates through the Internet and is accessible to the applications not only on the desktop computers but also the mobile phones, and smart phones. They also had illustrated that while for the type of Note Personal Computer, the Information on the incident is sent through satellite based mobile phones [7].

D. The Derivations of Knowledge Representations and Taxonomy of Cloud GIS on Disaster Management

After much comprehension on the background of the existence of cloud technology, it is feasible to construct the taxonomy of the knowledge based disaster management within the Cloud GIS. This is with reference to the graphical representation of semantic networks as illustrated in Figure 2. Elaborations on its predicate calculus are made including its eXtensible Markup Language (XML) and Document Type Definition (DTD) [8] which are as follow:

Example of predicate calculus from the semantic networks:

hasA (CloudBasedSystemArchitecture, DataAnalysis)
hasA (CloudBasedSystemArchitecture, HydrologicalModel)
hasA (CloudBasedSystemArchitecture, TopologicalModel)
…
partOf (DisasterOccurrence, KnowledgeBasedDisasterManagement)
partOf (DisasterDetection, KnowledgeBasedDisasterManagement)
partOf (DisasterKnowledgeBasedClouds, KnowledgeBasedDisasterManagement)
partOf (DisasterManagement, KnowledgeBasedDisasterManagement) (1)

In addition, the knowledge representation of the above semantic had also produced several relationships in the predicate calculus derived. This is including the inverse proportionality such as the following example:

hasA (CloudBasedSystemArchitecture, SlopeAndAspect) is <u>inversely proportional</u> with *partOf* (Slope and Aspect, Cloud-based system architecture) (2)

hasA (KnowledgeBasedDisasterManagementDisasterOccurrence) is <u>inversely proportional</u> with part of (DisasterOccurrence, KnowledgeBasedDisasterManagement) (3)

…

In conjunction with the above developed knowledge representations, predicate calculus and relationship formulas, the XML and DTD were derived. This is particularly to deduce and conclude the findings of our semantic networks that we have previously constructed. The DTD is in particular to aid the decision making process besides breaking down the elements contained within the tree structure of the developed semantic. The example of the XML is as follow:

<u>XML representation</u>: (4)

<KnowledgeBasedDisasterManagement>

<DisasterOccurrence> List of disasters </DisasterOccurrence>

<DisasterDetection> List of detection systems </DisasterDetection>

<DisasterKnowledgeBasedClouds> List of applications using clouds </DisasterKnowledgeBasedClouds>

<DisasterManagement> List of emergency management methods </DisasterManagement>

</KnowledgeBasedDisasterManagement>

While the DTD was also constructed of which other than to help in the process of decision making, it is also meant to highlight on the taxonomy of the knowledge based in disaster management.

<u>DTD representation:</u> (5)

<!ELEMENT KnowledgeBasedDisasterManagement (DisasterOccurrence, DisasterDetection, DisasterKnowledgeBasedClouds, DisasterManagement)>

<!ELEMENT DisasterOccurrence (Flood, Earthquake, Tsunami, VolcanoEruption, Tornado, Hurricane, Typhoon, Cyclone, Landslide)>

<!ELEMENT DisasterDetection (SatelliteSignal, RemoteSensing, RadarSignal, MeteorologicalForecast, TopologyReading, GISAnalysis)>

<!ELEMENT DisasterKnowledgeBasedClouds (Architecture, Authentication, DataGovernance, Security, CoreServices, ManagementServices, VirtualizationManagement)>

<!ELEMENT DisasterManagement (PlanningPhase, Operations, Logistics, Commands, PublicInformation)>

Therefore, the taxonomy for this study is deduced on the basis of the knowledge representations that have been formulated. Figure 4 illustrates the proposed taxonomy of Cloud GIS for disaster management.

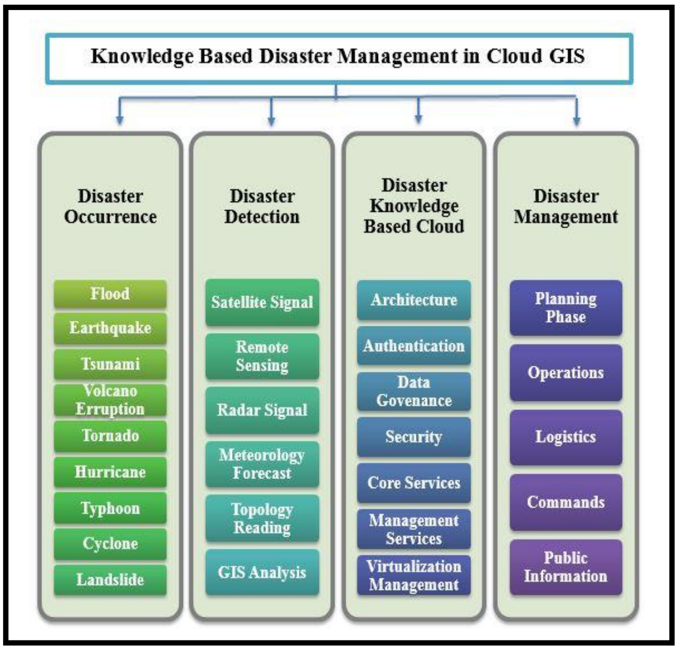

Figure 4. Taxonomy of Cloud GIS for Disaster Management

Within the taxonomy, inherently we regard that all of possible subroutines of the cloud will function accordingly. The taxonomy consists of four (4) pillars, they are: (a)

Disaster occurrence, (b) Disaster detection, (c) Disaster knowledge based cloud, and (d) Disaster management. In the pillar of Disaster Occurrence, the knowledge is everything about the disaster incidence. This is for example the flood, earthquake, tsunami, volcano eruption, tornado, hurricane, typhoon, cyclone and landslide. In addition, these incidences might come with different profiles. They may also carry names in accordance to geological standards.

In the pillar of Disaster Detection, the knowledge that contained is everything about the geomatics engineering. Hence, the calculations will involve all form of geographical sciences, computer and civil engineering. This includes the analysis of the satellite signals, remote sensing, radar signals, meteorology forecast, topology forecast and GIS.

In the pillar of Disaster Knowledge Based Cloud, the knowledge is built by its respective components. The components of this pillar include the architecture, authentication, data governance, security, core services, management services and virtualization management. For the cloud's architecture, it is everything about XaaS features such as Platform-as-a-Service (PaaS), Software-as-a-Service (SaaS), Infrastructure-as-a-Service (IaaS) and Hardware-as-a-Service (Haas) [9]. In addition, in data governance component, the function of interoperability and data migration is carried out translating the GIS data to the desired output of warning system.

E. Testing the Cloud GIS Decision Making for Disaster Management

The most crucial part of making this Cloud to work accurately in the GIS environment especially for the purpose of disaster management is constructing its architecture and algorithm to fulfill the required specifications. As previously shown in the taxonomy, it is expected that once a disaster is about to occur, some detection system will alert our knowledge based cloud server to trigger the actions for problem mitigation.

However, among the main trait for this system to trigger the desired output from the input detected is certainly the process of decision making. On the other hand, due to the architecture of the Cloud which is not built at a certain point or server location, this disaster management system needs to define and verify the types of Cloud data it receives. Basically, the Clouds fall under three main types: public, private and hybrid [10]. For this system to work well, the hybrid type is expected to be much appropriate to use due to its requirement of retrieving public data at one point, filtering it and processing it at some private point for security and authentication purposes before producing the desired output.

Hence, the structure of decision making process in disaster making by the application of Cloud GIS is as illustrated in Figure 5. The figure is highlighting the condition on which the disaster might occur and needs some knowledge based platform to transform its data for computational program before some alert system is activated and actions for problem mitigation are carried out.

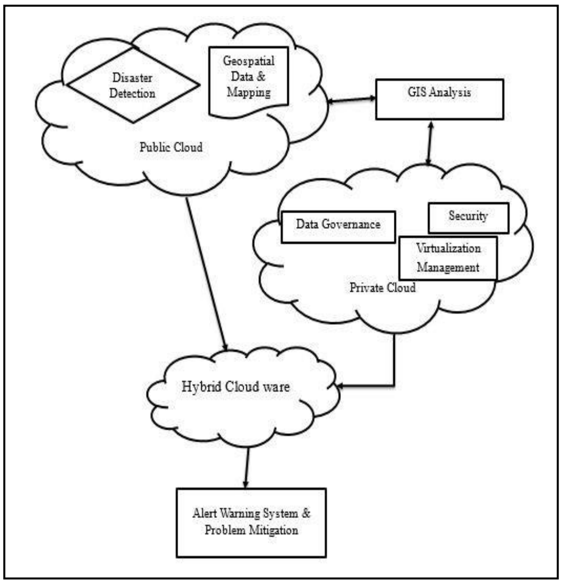

Figure 5. The Decision Making in Cloud GIS for Disaster Management

From this Cloud arrangement, the authors are suggesting that both the public and private clouds are being used and translated within the 'Hybrid Cloudware'. Thus, the Cloudware is the special setup defined for the architecture of this alert warning system to aid the appropriate actions in mitigating the problems.

As a result, the main aim of building the GIS application running through the Cloud is that, it is expected to help people in a number of aspects and industries including the local government, economic development, facilities, meteorological, public works, urban and regional planning, land administration, surveying and even in election and redistricting.

IV. FUTURE WORKS AND ISSUES

We had been served by the facility of the Internet for quite a long time now. The free flow of Information superhighway demanded unrestrictive access to the provisions of data and Information acquired by the user. This has opened the gates to unending computing developments which resulted with new jargons and terminologies.

As people keep opening to more researches and innovations, it is expected that this area of engineering sciences will continue to grow. If GIS has found its way on the Internet, optimizing it by using the Cloud, the call for rigorous development in emergency alerts and warnings are not impossible to be carried out. Nonetheless, as we are discussing the attractive of the Cloud services, the Big Data wave is on its way making a good impression.

Big Data is a phenomenal. How we define it is also on how we explain the Cloud. On contrary, Big Data is about how we are able to handle large amount of data. It is also on how much we can manage the storage, adding, updating and retrieving

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them. A scholar said that it is easier to get the data in than out. He also added that "what makes a big data *big* is repeated observations over time and/or space" [11].

Hence, Big Data is favorable for future work of this study in the essence that we might handle a large amount of data from different types of engineering studies such as being depicted previously in the Taxonomy of Cloud GIS in Disaster Management in Figure 4 above. From the vast information and knowledge of the geographical sciences to computer and civil engineering, Big Data might complement the Cloud features for the action plans of emergency response and rescue.

V. CONCLUSION

The study on the knowledge-based GIS in a cloud-based disaster management has resulted on the development of its taxonomy by the method of knowledge representations in semantic networks, predicate calculus, relationship representations, XML, DTD and the decision making structure for this process. We have proven that the facility that the cloud computing brought had given an advantage to the GIS applications. Hence further research from this taxonomy and its methodology is hoped to be expanded in the near future especially when the Information world is challenged with the wave of Big Data.

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