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LANGKAWI GEODIVERSITY REPOSITORY SYSTEM: THE ACTION RESEARCH-BASED APPROACH

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Abstract: The development of a geodiversity information and repository system is a valuable solution that can assure the management and preservation of geological datasets are more interesting, reachable and shared to the public at large. This research was embarked upon based on the realisation that, with the advancement of information and communication technology, knowledge about geodiversity might be better represented and explored. This research attempted to establish how geodiversity components and their relationships could be modelled into various forms of digital object (DO) to enable access and sharing of geodiversity information. The objectives of this research were (1) to establish a data model for geodiversity repository, (2) to design and implement Geodiversity Repository System, and (3) to capture the Langkawi geodiversity data into a single repository specifically for tourism industries. This development was conducted through an action-research approach which comprised in five phases: diagnosing, action planning, action taking, evaluating and specifying learning. This paper presents the phases in the action-research cycle for the development of Langkawi Geodiversity System, also known as MyGeo-RS. It highlights the theoretical architecture, the design of geodiversity repository and the implementation. The data captured and provided in this system is suitable for tourism industries but gives little contribution to scientific applications. This will be the limitation of current design and architecture and further work needs to be done to accommodate the scientific requirements.

KEYWORDS: Digital Object Model, Langkawi Geodiversity, Geodiversity Repository System, MyGeo-RS System, Action Research

Introduction

All geological and landscape resources have two opposing value sets: extractive and conservative activities (Komoo, 2003). In the conservative concept, a new paradigm, earth physical resource, is regarded as having value in the context of knowledge, history and culture. The geoconservation idea arose mainly from the need to protect heritage resources that are already recognised by the general public (or naturalists and geologists) in the context of preserving the landscape beauty for recreation or outstanding heritage value. The philosophy is embodied in the UNESCO's Geopark approach, which provides guidelines for identifying and assessing natural world heritage sites that have outstanding universal value (UNESCO, 1988). A geopark is defined as an area with a geological heritage of significance, with a coherent and strong management structure and where a sustainable economic development strategy is in place (UNESCO, 2008). Geoparks are not just about rocks but they are also concerned with people.

The foundation of the assessment of geological heritage resources is geological diversity or geodiversity. The concept of geodiversity is a new concept amongst geologists that carries a different meaning to different researchers (Komoo, 2003). It refers to the range of geological (bedrock), geomorphological (landform) and soil features, assemblages, systems and processes. The geodiversity concept takes into account the different dimensions shown by a geological exposure or landform.

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In addition to the variety of characteristics of minerals, rocks, fossils, structure and landform features; time, environment and processes are also incorporated in dealing with geodiversity. It contributes to our quality of life in many ways. Its benefits include appreciation, knowledge, products and natural processes (UNESCO, 1988).

Geoheritage value is strongly linked with the specific geodiversity pertaining to significant scientific records for research, education, tourism, and industry usability. This diversity includes a varied and complex amount of information and data concerning rock, mineral, fossil, structural and landform diversity that can be found in varied forms and resources.

Similar to the necessity and success that derived biologists to represent and deploy their information digitally into biodiversity information systems, the geologist as well has been attracted to this technology according to the nature of the complexity and diversity of geological datasets and their interrelated components. Therefore, providing theoretical and systematic modelling approaches for organising and representing those datasets to global access have become one of the arising challenges that required more attention from the researchers and computer professionals in Malaysia. This need has been derived from the scientific, educational, research, industrial, economic, social, culture and inspirational values that can be gained. In addition, the lack of awareness from the software professionals to the geodiversity domain remains hidden from the global sharing. Moreover, the preservation of geodiversity datasets is semi-or unorganised, as well as the overlook of digital-archiving aims is another issue to be considered.

In our project, an exclusive geodiversity information system was developed that focussed on creating a new digital object model, namely Networked Digital Object (NDO). Our model allows a sharing environment with a knowledge discovery through relating, varied and specific Digital Objects (Dos) among the geodiversity components to produce a new NDO, which represents new information. Together with the input from Langkawi Geopark components and knowledge, GRS can be customised into Langkawi Geopark GRS (LGGRS). With this establishment, further research on geological data and expertise and other DO services can be incorporated into the repository. Finally, GRS can be generalised to offer geodiversity knowledge for other places. Bringing GRS technology closer to knowledge-based, knowledge management and data mining, several models can be proposed for both commercial products and research prototypes.

This paper is organised into four sections. Following this introduction, Section 2 highlights the literature and current state-of-the arts in geodiversity and repository system. Section 3 provides a detailed description of action-research approach for software development. It will discuss in detail all the stages in the action-research cycle. Section 4 provides the discussions and conclusion of this research. It details the specifying learning outcomes from this action research. Section 4 also highlights the limitations of current architecture and future works.

Geodiversity and Repository System

Geodiversity is a term which describes the variety of rocks, minerals, soils and landforms, and the processes that have shaped these features over time. It is important because of its intrinsic value and provides examples of kind, regardless of any scientific or aesthetic potential (Department of Environment and Climate Change, 2008). A more complex definition of geodiversity can be defined as "*the variability of abiotic nature, including lithological, tectonic, geomorphological, soil, hydrological, topographical elements and physical processes on the land surface and in the seas and oceans, together with systems generated by natural, endogenous and exogenous and human processes, which cover the diversity of particles, elements and sites"* (Canadas & Ruiz Flano, 2007). Moreover, geodiversity is a useful concept for geoconservation and management of abiotic heritage. It is a corporation of abiotic elements to the local policies of sustainable development and the assets of natural resources (Canadas & Ruiz Flano, 2007).

For the past decade, organisations, universities and research units from different areas, which include fields such as biology, medicine, chemistry and geology, have witnessed an exponential growth in digital information available for learning and sharing experiences. There are many collections of digital objects, including images, texts, audios, and videos, that have great value in a diverse set of fields. As the quantity of information continues to increase and these collections expand, there is a need for a repository system that can provide appropriate storage and access to all these valuable materials in a flexible and extensible manner for the foreseeable future. This has led many geological organisations and experts to realise the need of a geodiversity information-system solution. This system can assimilate current collections and accommodate new materials by dealing with highly-structured geological data (such as rock, soil, and topographical data) and complex spatial relationships as they become available to global users. In fact, several projects have been developed to handle varied datasets and issues of geological domain based on the developers' interest and needs, such as geological hazard spatial-information system (Lee & Choi, 2001) and web-based geographic information system (Chang & Park, 2004).

Lee and Choi (2001) research work focussed on the datasets that considered the geological hazard management, assessment and prediction in the development of their geological information system. In this work, a geological hazard spatial database (SDB) was designed and constructed. Among the data structures used were coverage (vector data), GRIDs (raster data), and images (raster data). The SDB included geological hazards, basic maps of damageable objects, satellite imaging, meteorological data and terrain analysis data. To use the constructed SDBs, a geological hazard spatial-information system was developed. In this information system, the SDB output can be selected according to scale. The system used GUI that allowed the development of a user-friendly application. It also featured many functions such as retrieval, identification, edit, and help.

The main objective of Chang and Park's (2004) study was to develop a Web-based Geographic Information System (GIS) model for efficient management of borehole and geological data. They claimed that GIS application development adopting internet technology was essential because the efficiency of data usage and knowledge sharing was very important in the developing countries. This project suggested a borehole data standard and corresponding database. More than 10,000 boreholes and other geological data were archived into the database. A prototype for Web-based GIS application was successfully designed to provide systemic interfaces and functions such as geological information search, on-line geological functions, statistical summaries and administrative functions. Geological data from many construction projects should be standardised, structured, archived and properly used through suitable system and applications for efficient management. However, there yet remained many important problems to be solved for advanced GIS applications. One problem came from the requirement of suitable standards for geological data and good design of a geological database. Another problem came from the requirement of a suitable modelling approach that was essential to maximise the sharing of geological information and knowledge to solve problems related to geotechnical engineering.

Haigen Xu and friends developed a query system for China National Biodiversity Information. The objective of this system was to provide metadata to help people to find data and to understand its content and characteristics. The system possessed functions such as information search and queries (Xu *et al.,* 1999).

Repository is defined as a collection of resources that can be accessed to retrieve information. Repositories often consist of several databases tied together by a common search engine (Chapple, 2011). A repository is also defined as a database of information about applications software that includes author, data elements, inputs, processes, outputs and interrelationships. It is used in a CASE or application-development system in order to identify objects and business rules for reuse (PC Magazine Encyclopedia, 2011).

Information systems through various research works have been proved to be an appropriate solution to facilitate the organisation and archiving of varied and complex information concerning such different domains as biodiversity, medicine and environment (Aziz *et al.,* 2005). Therefore, the development of a geodiversity information or repository system is believed to be one of the suitable solutions that can assure the management and preservation of geological datasets to be more interesting, accessible and shared to the public at large. With the advancement of information and communication technology, as well as data mining and knowledge discovery, knowledge about geodiversity can be better represented and explored.

From literature, only a few studies have been carried out with geodiversity and information systems. Thus, our research was focussed on geodiversity information in the Langkawi Island of Malaysia. Langkawi Island is a well-known island with valuable geological sites and rich geodiversity and natural heritage information. Previously, there were several works on creating a geodiversity inventory and individual related projects (Komoo, 2003; Komoo & Leman, 1999). Unfortunately, the information created was not integrated and comprehensive because these works were done mostly for geologists and were scattered. Data was stored in obsolete or inaccessible forms, was poorly standardised and documented. Meanwhile, separated ownership of geology data gave rise to difficulty of information exchange, sharing and comprehensive processing. At the same time, there was no collaboration works done with information-technology experts to integrate the geodiversity information, disseminate the information and monitor the valuable geodiversity and heritage. Therefore, it is necessary to set up an information system for providing geodiversity metadata to assist users in searching location and characteristics of geodiversity data. Furthermore, this project attempts to establish how geodiversity components and their relationships can be modelled into various forms of digital object (DO). These sets of digital objects can then be incorporated into a primary repository of Geodiversity Repository System (GRS) for easy manipulation of DO's information and knowledge.

This research targets to achieve the following objectives:-

- To establish a data model for geodiversity repository
- To design and implement Geodiversity Repository System (MyGeo-RS)
- To capture the Langkawi geodiversity data into a single repository
- To provide geodiversity data for tourism industries

The Action Research Approach

In action research, theoretical and experimental approaches are adopted to finally produce a usable repository. Action research simultaneously assists in practical problem solving and expands scientific knowledge. It is performed collaboratively and enhances the competencies of the respective actors in the research. Another characteristic of action research is to increase understanding of an immediate social situation and complex social setting (Baskerville, 1999). Five main phases in action research are identified as diagnosing, action planning, action taking, evaluating and specifying learning (DeLuca & Kock, 2007). The following sections discuss in detail the five phases in the action-research approach for the development of Langkawi Geodiversity Repository System.

Diagnosing

The first phase was diagnosing the problem. Diagnosing corresponded to the identification of the primary problems that were the underlying causes of the need of the repository system in the geodiversity environment of Langkawi. In this initial stage, discovery of problems involved a series of discussions and observations between researchers and practitioners as well as the main users of the system which in this case were the geologists and public users. In this research, the specific users were the Geological Heritage Group of Malaysia and Langkawi Development Authorities, best known as LADA.

Initial study involved collecting sample data of geodiversity for Langkawi. The samples were collected and analysed in order to understand the complexity of the information needed as well as their relationships. During this phase, our team (which consisted of software engineering experts, geology experts and users) collaboratively worked to develop the repository system suitable for the domain and expert requirements. In this phase, methods were undertaken to establish user needs. Initially, the research team consisted of postgraduate students and researchers from two domains; information technology and geology experts held initial discussions on the research domain areas specifically on geodiversity and system design. The discussion revolved around the understanding of the concept of geodiversity from the perspective of geological heritage research, geoconservation and geographical landscape tourism. The research team visited several geoparks in Langkawi to observe and better understand the information needed as well as their relationships.

Action Planning

Researchers and practitioners then collaborated in the next activity in action research, action planning. This activity specified the user requirements and actions that should relieve or improve these primary problems. The discovery of the planned action was guided by the theoretical framework or architecture, which indicated both the desired future state for the group of users, and the changes that would achieve such a state. The plan established the target for change and the approach to change.

In the action-planning phase, the data representation was structured and formulated. It underwent testing to a certain level of optimisation and the use of data normalisation approach was conducted. With a well-defined DO, a workable conceptual repository structure for Langkawi Geodiversity was developed and tested. The data flow and the architecture of the Langkawi Geodiversity Repository System or MyGeo-RS is represented and shown in Figure 1. MyGeo-RS is a metadatabase that will use geodiversity data as the input to produce or present digital objects of the geodiversity domains. Three categories of the digital objects representation have been identified and selected which consist of Artifacts Digital Objects, Geoparks Digital Objects and Management Objects. The category selection was based on information from our geodiversity experts and was focussed specifically in Langkawi.

The metadatabase consists of three levels of input. The first level contains information on the description of geodiversity types, which were obtained from the geological experts. The second level is the information on description of the data sets that is inter-related from the underlying sources of the geodiversity types described. The third level describes the information on the actual geodiversity data that have been documented and collected in forms of existing databases, files and other digital types, which includes images, reports, maps and video. Geodiversity metadata can then be produced using the data from these three levels of input.

MyGeo-RS accesses the input data through the geodiversity metadata and also the actual geodiversity data, which is processed into the digital objects representation according to the selected categories. One of the modules in MyGeo-RS is the classification module of geodiversity types. At this initial stage, the classification process is categorised into two types; attributes and services. The attributes are described by our geology experts and in accordance to the geodiversity types agreed. The potential services that have been seen to be of interest are tourism, knowledge and products. With regard to toolset design and implementation, a commercial database engine was used to implement the development of MyGeo-RS.

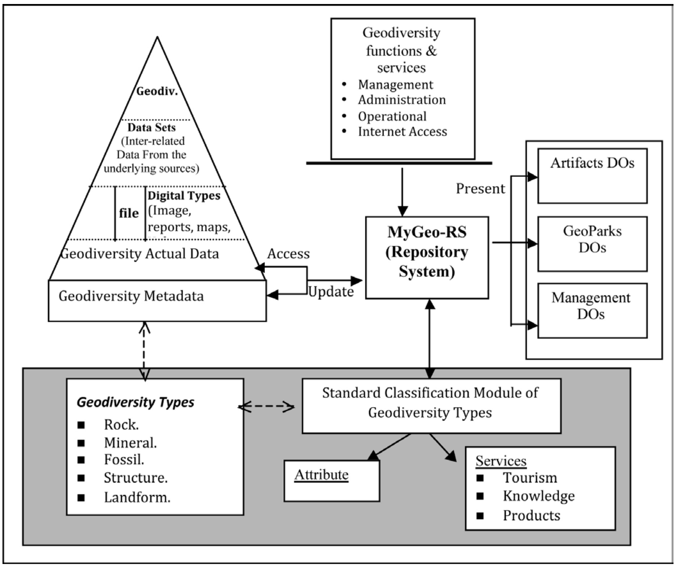

Figure 1: The architecture of MyGeo-RS

Action Taking

The next phase in action research was action taking which implemented the planned action. The researchers and practitioners collaborated in the active intervention into the actual environment causing certain changes to be made. Several forms of intervention strategy could be adopted. The intervention might be directive, in which the research "directs" the changes, or non-directive, in which the change was sought indirectly.

The information required to establish user needs was decided through a number of focus groups and through several methods included structured interviews, group discussion and workshop and collaboration with LADA and Geology Heritage Group of Malaysia. Here, user needs were determined by way of regular consultations between the development teams, led by experienced software engineers, and data designers with the users, who were represented by geology experts through workshops and brainstorming sessions among these three expert groups. This encouraged a sense of participation in the development process by the users.

During the action-taking phase, an issue to be solved was how to realise each task decided in the action planning. There were four steps in this phase and the first step was the identification and classification of data requirements and specification. The second step was the definition of data structure and the third step was the identification and definition of the logical system structure. The final step was the overall system-control design.

An issue to be solved in this phase of the design was how to realise the structure of the data to be kept in the repository. It was difficult to get a mutual understanding and agreement between the computer experts and the geology experts. The process of identification and classification were very complex and time-consuming since it required several expeditions to the study location. The complexity process is also agreed by Paula and Pedro (2004). After a series of long and massive discussions and visits, the requirement specifications and structures were described and documented. At this stage, the data requirements have been mapped into several data structures or tables in one database entity (myGeo repository).

Accordingly, MyGeo-RS has thirteen data tables: Landscape, Artifact, Cultural, Fossil, Geopark, Landform, Management, Mineral, Primary_Structure, Recreational, Rock, Secondary_Structure and Reference. Table of

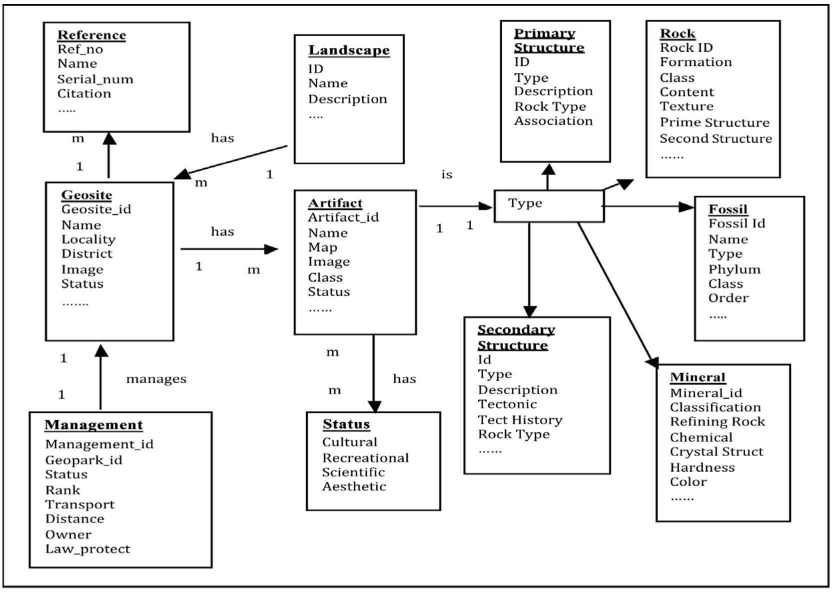

Figure 2: Semantic Data Model of MyGeo-RS database

Artifact holds data of artifacts collected, table of Cultural maintains data of cultural value, table of Geopark holds data of geosites in Langkawi Island, table of Landform contains data about landform and its associated attributes. Table of Management captures data about management of the geopark. In Langkawi, there are 99 geoparks which consists of thousand of artifacts. Table Mineral maintains data of mineral, table Primary_Structure maintains data under primary structure classification and Secondary_Structure holds data of secondary structure. Table of Recreational stores data of recreational value, table Rock contains information on rocks and Reference table holds data on related references of this project. The semantic data model of MyGeo-RS is shown in figure 2. The model demonstrates the main entities and attributes of this system. The semantic model displays partly the associated attributes of the entities.

The MyGeo-RS was implemented as a database Window system. The functional requirements have been identified and can be summarised as follows: -

a) Capture geodiversity data in diversity of data formats which include text, images, photos and videos.
b) Store, update, and delete database content on demand.
c) Display to producing printed output as needed.
d) Import and export database content based on prescribed format.
e) Search for specific content based on "keyword" (full and practical).

Four main functions of MyGeo-RS are: management module, administration module, operational module and Internet-access module. Management module includes functions of detail description of MyGeo-RS and main page of the system. The administration module provides functions of managing user-access control, managing database structure and content, implementing back-up system and managing access-log system. The operation module manipulates multimedia data in this system, which includes functions of input, update, delete, import and export data and reporting. The Internet-access module provides public access based on a simple membership system, query and searching, viewing capabilities based on prescribed format (printer-friendly format) and feedback/comment communication.

Figure 3: Main menu of MyGeo-RS

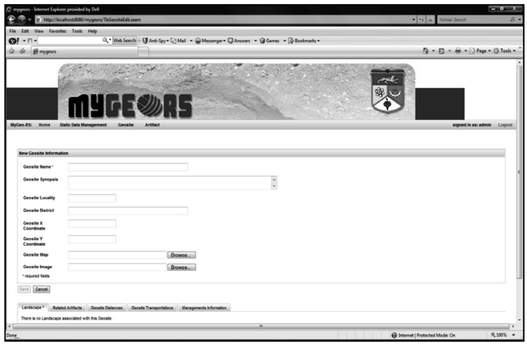

Figure 4: Screen shots of MyGeo-RS – an example of the input screen

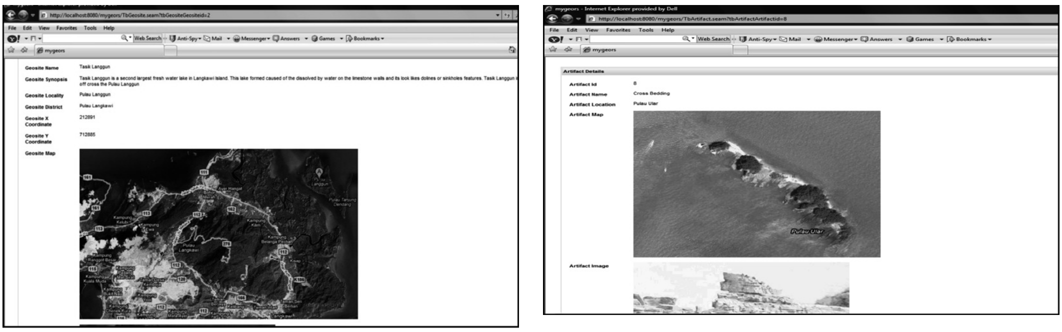

Figure 5: Screen shots of MyGeo-RS – two examples of the output screens

Evaluating

After actions are completed, the collaborative researchers and practitioners evaluated the outcomes. Evaluation included determining whether the theoretical effects of the action were realised, and whether these effects relieved the problems. If the change was unsuccessful, some framework for the next iteration of the action-research cycle should be established.

The system was built using Eclipse and MySql database and operated in Window environment. Figure 3 illustrates the main menu of MyGeo-RS. It shows that there are three categories of users which are site administrator, system administrator and general users (which include general public and scientists). These different categories of users is to ensure integrity and security of the system and the data. The site administrator is the person who is responsible for handling and maintaining the data while the system administrator is the person who is responsible for maintaining the system and users.

Data inputting is implemented at the user side and in this project the user involved is the Geological Heritage Group of Malaysia which is based at the Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia. This group is responsible to coordinate and update the data requirements by this system. Figure 4 shows an example of the input screen of MyGeo-RS while Figure 5 demonstrates two examples of the output screens.

Information provided by MyGeo-RS basically reflects the present status of geodiversity information in Langkawi Island, Malaysia. The system is designed so that it can be applied in other geology parks. In general, the system will be beneficial to the Langkawi Research Centre, Geological Heritage Group of Malaysia, Tourism Industries and general public. As an initial result with initial data provided, MyGeo-RS has been demonstrated to, and received positive comments from, the members of Geological Heritage Group of Malaysia. It can be used for general data queries, tourism and travel planning for the public and tourism agencies as well as geology heritage planning and management. Gaps and priorities in geodiversity conservation can be identified which can support geodiversity planning. The most common uses of the system are dissemination of geodiversity information for the public and data query for scientists. At present, users can have access to the system free of charge.

Specifying Learning

While the activity of specifying learning was formally undertaken last, it was usually an ongoing process. The knowledge gained in the action research (whether the action was successful or unsuccessful) can be directed to three audiences as explained by Baskerville (1999):-

- First, is called 'double-loop learning', the restructuring of organisation's or user's environment norms to reflect the new knowledge gained during the research.
- Second, where the change was unsuccessful, the additional knowledge may be used as the foundation for diagnosing in preparation for future action cycle.
- Finally, the success or failure of the theoretical framework or architecture provides important knowledge to the scientific community for dealing with future research setting. In scope of this research, the setting will be applied in different geoparks environment in different places.

This action-research cycle can continue, whether the action proved successful or not. As the result of the studies, the user groups thus learn more about nature and environment, and collection of theoretical elements of the scientific community continues to benefit and evolve. The learning aspect in this action research is explained in Section 4 which highlights the discussion and conclusion.

Discussion and Conclusion

In Malaysia, information about geodiversity of Langkawi Island is gathered and maintained by several different projects. The information is realised as an important and valuable asset that is needed by the scientists, interested agencies and general public. These groups must have access to this information easily and efficiently. This means that tools are required to help to locate, analyse and integrate the information in order to improve the quality of decision making and in turn the quality of life (Xu *et al*., 1999).

The development of MyGeo-RS, a geodiversity repository system, is a timely effort and a suitable solution that can assure the management and preservation of geological datasets to be made more interesting, accessible and shared by the public at large. This research was embarked upon based on the realisation that, with the advancement of information and communication technology, as well as data mining and knowledge discovery, knowledge about geodiversity can be better represented and explored. This action research attempted to establish how geodiversity components and their relationships can be modelled into various forms of digital object (DO) to enable access and sharing of geodiversity information. The target user groups of this project are mainly public users and tourism industry. This means that the data captured and provided in this project is suitable for these groups but at the same time gives little contribution to scientific applications. This will be the limitation of current design and architecture and further work needs to be done to accommodate the scientific requirements.

From experience, the process of developing the standard geology data can be difficult, complex and expensive. Even under these circumstances, however, geologists and information technology experts appear willing to compromise to achieve data exchange and standard. Although some standards exist, no coordinated and established comprehensive geodiversity standards have been introduced to the community. Some standards must be implemented by the geologists and managers of data. Standards must be kept as flexible as possible to encourage data submission, but should be constructed in such a way that they can be mapped into rigorous standards, and allow inter-operable searching. In this research, data quality is not covered. Subsequent efforts are required to perfect the data and standards.

The current version of MyGeo-RS runs in Window and Internet-based environment. The system is live on the Internet and can be accessed at any time and any place. It is efficiently available and accessible for public users. Data input and updates are an important component for the system of MyGeo-RS and they are still an on-going process.

Future work will focus on generating integration with tourism industries and companies. As has been mentioned earlier, the necessary target of this research was to develop a partnership between system managers and the geology-related community such as the tourism industry. Therefore, this will be the next strategy and future plan of this research which is targeted to have a linking and partnership with tourism operators providing the necessary information infrastructure.

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