Digital Preservation of Borobudur World Heritage and Cultural Treasures

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Abstract

In 1972 UNESCO adopted World Heritage Convention, aimed at identifying, protecting, and preserving the world⅃s cultural and natural treasures. Today there are 851 World Heritage Sites in 184 nations, and Indonesia currently has 7 heritage sites, including Borobudur temple. Borobudur is also known as one of the Wonders of the World, besides the great-wall of China, Egyptian pyramid, and others. Considered as the biggest ancient temple of the world, this famous Buddhist shrine was built in the 8th century in central Java of Indonesia during the Golden Age of Sailendra dynasty (old Mataram or Medang Kamulan kingdom). This magnificent stepped pyramid style of volcanic stone monument has an overall height of 42 meters, and dimension of 123 x 123 meters (15,129 square meters) with overall 2500 meters length of stone relief.

This magnificent monument is not well known to many English speaking people, because most of the documentation is written in Indonesian and Dutch languages. The main purpose of this paper is to identify, and gather research works on Borobudur as well as to study on archived projects related to manuscript, text and images of relief on this world heritage. A combination of digital archiving and virtual reality technology will be proposed as a concept of "Digital and Virtual Borobudur" which will help preserving this cultural heritage site and objects by taking this temple and its relief into the virtual world. With such technology, the original masterpieces and site will be preserved and protected from subsequent destructive human influence, and at the same time it will be available through the Internet to all audience and "global virtual tourists".

Key words: Borobudurtemple, Cultural Heritage, digital archive

1. Introduction

Natural and cultural world heritage is the legacy of physical artifacts around the world that are inherited from our past generations, and need to be maintained in the present and bestowed for the benefit of future generations. Due to various reasons such as climate change, natural disasters, wars, etc, these valuable world heritages are continuously destroyed from time to time. Natural

heritage such as rain forests with its valuable flora and fauna, for example, are being damaged in one way or another because of very dry climate, because of huge number of tourists which comes to visit them, or as a result of other human activities for city planning and developments. Once those natural and cultural heritages are destroyed, they cannot be recovered or restored back to its present state. Therefore, it is important to preserve them for the benefits of our future generations.

UNESCO, in 1972, adopted World Heritage Convention to identify, protect, and preserve the world's cultural and natural treasures. The cultural and natural heritage covers the qualities and attributes of places that have aesthetic, historic, scientific or social value for past, present or future generations. Worldwide, there are currently 851 heritage sites located in 184 countries (state parties) up to June 2007. Of these, 660 are cultural, 166 are natural and 25 are mixed properties. All of these sites are classified into 5 geographic zones: Africa, Arab States (northern Africa and Middle East), Asia-Pacific (including Australia and Oceania), Europe and North America (USA and Canada), and Latin America & the Caribbean. Out of 851 sites, 174 are located in Asia-Pacific area, as shown on Table 1.

Most of natural heritages are places related to countryside and natural environment, including flora and fauna that are irreplaceable sources of life and inspiration. Whereas, cultural heritage sites include buildings and historic places, ancient monuments, artifacts, etc., that are considered worthy of preservation for the future. The cultural sites also comprise objects significant to the archaeology, architecture, science or technology of a specific culture. Both kinds of heritage treasures often serve as an important part for country's tourist industry that contributes and attracts many local visitors as well as tourists from abroad.

Table 1: Statistics of World Heritage Sites (WHS) in Asia-Pacific Region

* Source: http://whc.unesco.org/pg.cfm?cid=31

Country	Natural WHS	Cultural WHS	Mixed WHS	Total
Afghanistan		2		2
Australia	11	1	4	16
Bangladesh	1	2		3
Cambodia		1		1
China	4	23	4	31
North Korea		1		1
India	5	21		26
Indonesia	4	3		7
Iran	1	7		8
Japan	3	11		14
Kazakhstan		2		2

Laos		2		2
Malaysia	2			2
Mongolia		1		1
Nepal	2	2		4
New Zealand	2		1	3
Pakistan		6		6
Philippines	2	3		5
South Korea		7		7
Solomon Islands	1			1
Sri Lanka	1	6		7
Thailand	2	3		5
Turkey		7	2	9
Turkmenistan		2		2
Uzbekistan		4		4
Vietnam	2	3		5
TOTAL =				174

The basic concept and criteria for world heritage (both natural and cultural) is exceptional and universal in nature. These world heritage sites in general belong to all the peoples of the world, irrespective of the territory on which they are located. In Indonesia, as an example, natural and cultural world heritage sites include Borobudur Temple Compounds (1991), Komodo National Park (1991), Prambanan Temple Compounds (1991), Ujung Kulon National Park (1991), Sangiran Early Man Site (1996), Lorentz National Park (1999), and Tropical Rainforest Heritage of Sumatra (2004); number inside the parentheses represents the year when the site is recognized by UNESCO. Although these sites are located in Indonesia but they represents past history and culture of the region, especially in South East Asia zone.

When we look at Japan, 11 cultural and 3 natural heritage sites have been recognized for a total of 14 locations on June 2007. The complete list is shown here:

- Buddhist Monuments in the Horyu-ji Area (1993)
- Himeji-jo (1993)
- Shirakami-Sanchi in northern Honshu (1993, natural)
- Yakushima in the south of Kyushu (1993, natural)
- Historic Monuments of Ancient Kyoto (Kyoto, Uji and Otsu Cities) (1994)
- Historic Villages of Shirakawa-go and Gokayama (1995)
- Hiroshima Peace Memorial (Genbaku Dome) (1996)

- Itsukushima Shinto Shrine (1996)

- Historic Monuments of Ancient Nara (1998)

- Shrines and Temples of Nikko (1999)

- Gusuku Sites and Related Properties of the Ryukyu Kingdom (2000)

- Sacred Sites and Pilgrimage Routes in the Kii Mountain Range (2004)

- Shiretoko in the northeast of Hokkaido (2005, natural), and

- Iwami Ginzan Silver Mine and its Cultural Landscape (2007).

2. Borobudur Buddhist Temple

Borobudur temple in Indonesia is one of the greatest Buddhist monuments in the world, located about 40 km north of Jogjakarta city in central part of Java island. This colossal relic of Borobudur was built by Sailendra dynasty between 778 to 842 AD; 400 years before Cambodia's Angkor Wat and any other works on great European cathedrals were created. Little is known about its early history except that a huge workforce - sculptors, artists, statue and carving experts - must have been labored to move and carved tens thousands cubic meters of volcanic stone and lava-rock. Therefore Borobudur temple is an outstanding cultural heritage and legacy and becomes major sources of Indonesian history and culture nowadays (Miksic and Tranchini, 1990).

Sir Thomas Stanford Raffles first revealed the temple in 1814. He found the temple in wined condition and buried under volcanic ash. He ordered an archeologist, H.C. Cornelius to excavate and clear the site from undergrowth and do thorough investigation. More than 200 laborers were occupied for 45 days to uncover and remove earth, bushes, and trees which buried the historic temple. Raffles, motivated by his admirer of history and culture of the country, laid the foundation for actual archeological research. Many theories and works were written on the subjects, including "The History of Java" by Raffles himself, "The Borobudur Monograph" by C. Leemans and J.F.G. Brumund, and many other publications (Dumarcay, 1978).

Figure 1. Top view of candi Borobudur

Most Buddhist temple was built and dedicated to Buddha in the need for peoples to make concrete worship and relationship to the God (Tamura, 2000). The word temple is derived from templum, the Latin word for a sacred place, or worship/ ceremonial space. Around these the ceremonies of worship were elaborated, and in many societies the attendant priests became very powerful. Temples or candi (in Indonesian term) were often built in a magnificent size to accommodate all their priests and followers to gather and worship. As Buddhist center, candi Borobudur was built as a single large stupa, and when viewed from above it takes the form of a giant tantric Buddhist mandala, with 123 m by 123 m in size. It is erected on a hill in the form of a stepped-pyramid of six rectangular levels, three circular terraces and a central stupa forming the summit. The whole structure is in the form of a lotus, the sacred flower of Buddha (Krom, 1927). Some detail facts and figures of candi Borobudur is shown here:

- Monument base: 123 m by 123 m
- Height: 42 m
- Narrative reliefs: 1,460 panels
- Decorative reliefs: 1,212 panels
- Buddha Statues in open niches: 368 (originally 432)
- Buddha statues on the terraces under circular stupas: 72
- Number of galleries: 4 (each has 2 wall panels: main wall and balustrade)
- Total length of visual panels: circa 2500 meters
- Hidden basement: circa 13,000 cubic meters of stone
- Total volume of stone used: circa 55,000 cubic meters
- Time to build Borobudur: perhaps 66 years, and
- Usage period: almost 200 years.

As one of major centers of Buddhist scholarship in South and South-East Asia during that time, Borobudur temple was built with an overwhelming mass of images and galleries on its walls depicting the activities of Gods (Swearer, 1995). There are more than 1,400 narrative panels illustrating the life of Buddha and Buddhist texts, the largest and most complete collection of Buddhist relief in the world. These religious illustrated texts consist of 6 different Mahayana Buddhist doctrines: Karmavibhangga, Lalitavistara, Jatakas, Avadanas, Gandavyuha, and Bhadrachari (Soekmono, 1976).

All of these six manuscripts are carved on 2500 meters long of stone inscriptions on 4 consecutive galleries' walls. The very first engraved image of the manuscripts starts from east gate on gallery 1 circulating to the left, following round 1, 2, 3, …, 10, as shown in Table 2. Among Buddhist monks it is devotional practice in this way to proceed on their ritual ceremony during their Buddhist holy festival day (Vesak Day), and to walk around the galleries and terraces always turning to the left

and keeping the edifice to the right while either chanting or meditating. In total, Borobodur temple represents the ten levels of a Bodhisattva's life which they must develop to become a perfect and full enlightenment of a Buddha (Primadi, 1998).

The highest level called arupadhatu has no relief or decorations but has 3 terraces, circular in shape with round walls: a circle without beginning or end. Here is the place of the seventy-two Vajrasattvas or Dhyani Buddhas tucked into small stupas. Each of the statues in the temple has a mudra (hand gesture/position of Buddha) indicating one of the four directions: east, with the mudra of calling the earth to witness (Bhumisparca mudra); south, with the hand position symbolizing of charity and blessing (Vara mudra); west, with the gesture of meditation (Dhyana mudra); north, the mudra of fearlessness (Abhaya mudra); and the centre/zenith (Witarka and Dharmacakra mudra) with hand gesture of teaching (Marzuki and Heraty, 1982).

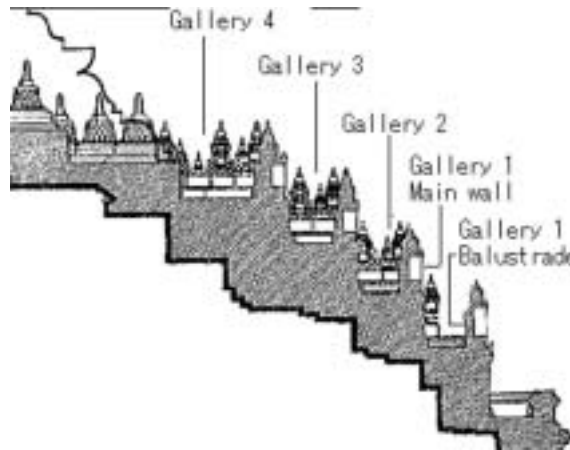**Figure 2. Galleries in which narrative panels of Buddhist text are located**

Table 2: Location of all 1460 Relief and Manuscripts

Round	Relief's Location	No. of Panels	Manuscripts
-	Hidden Basement	160	Karmavibanggas
-	Main wall of Gallery 0	1212	Decorative panels
1	Gallery 1, upper main wall	120	Lalitavistara
2	Gallery 1, lower main wall	120	Jatakas & Avadanas
3	Gallery 1 Balustrade, upper wall	372	Jatakas & Avadanas
4	Gallery 1 Balustrade, lower wall	128	Jatakas & Avadanas
5	Gallery 2 Balustrade	100	Jatakas & Avadanas
6	Gallery 2 main wall	128	Gandavyuha
7	Gallery 3 main wall	88	Gandavyuha
8	Gallery 3 Balustrade	88	Gandavyuha
9	Gallery 4 Balustrade	84	Gandavyuha
10	Gallery 4 main wall	72	Bhadracari

Karmavibhangga is the first manuscript describing the doctrine of cause and effect (karma) as well as good and evil (Moertjipto and Prasetyo, 1993). The pains of hell and the pleasure of heaven are illustrated on the Karmavibhangga manuscript. There are also praiseworthy activities that include charity and pilgrimage to sanctuaries, and their subsequent rewards on this relief. The complete series of 160 panels on Karmavibhangga relief is not visible as it is hidden and surrounded by broad base of stone walls. Only parts of the southeast temple wall were dismantled for visitors, which are represented by panel numbers: 19, 20, 21, and 22.

Second visual manuscript, Lalitavistara represents the life of Buddha Gautama from his birth until his first Sermon at Benares. The relief story of Lalitavistara starts from the glorious descent of the Lord Buddha from the Tushita heaven prior to Gautama's birth, and ends with his first sermon in the Deer Park in Benares. The most famous relief on the Lalitavistara story is the birth of Buddha as Prince Siddharta, son of King Suddhodana and Queen Maya at Lumbini park outside the Kapilavastu city (Nepal, in present-day). One full round on the first Gallery (upper main wall) was dedicated to this manuscript with total number of 120 panels.

Jatakamala or Garland of Jatakas is a collection of poems consisting of 34 Jatakas. Based on manuscript written by Aryacara in the 4th century, these Jatakas contain stories on great deeds performed by Buddha (Bodhisattva) in his former lives, preparing for Buddhahood. These episodes of reincarnations serve as example of self-sacrifice. Similar to Jatakas, Avadanas narrative is also devoted for Buddha, but the main figure is not Bodhisattva (Prince Siddharta) himself. The saintly deeds in Avadanas are attributed to other legendary persons. Both Jatakas and Avadanas are treated in one and the same series of 720 relief panels.

The most important part of Buddhist text is written in the Gandavyuha, the longest manuscript described in 3 galleries: gallery 2, 3, and 4. Gandavyuha, sometimes referred to as a Mahayana pilgrim's progress, describes Sudhana, son of a rich merchant, who meets several Bodhisattvas, in his aim to reach the highest wisdom. Two of these spiritual teachers of Bodhisattvas are Maitreya (future Buddha V) and Samantabhadra (the Lord of the Truth in Buddhism who represents the practice and meditation of all Buddhas). A total of 388 panels represent the Gandavyuha text.

As concluding of Gandavyuha, Bhadrachari doctrine is represented in the 4th gallery. It comprises panels with the pledge of Sudhana to follow examples and teaching of the Bodhisattva Samantabhadra. The narrative panels on Bhadrachari end with the Sudhana's achievement of the Supreme Knowledge and the Ultimate Truth. All 72 panels on main wall of gallery 4 are dedicated for the Bhadrachari.

3. Candi Borobudur Restorations

During brief British administration in Indonesia from 1811 － 1815, Sir Thomas Stamford Raffles found Candi Borobudur (Borobudur temple) from its slumber for almost 10 centuries. Raffles, motivated with the temple mystery, started the groundwork for actual archeological survey and research works in 1814 right after its discovery. He commissioned H.C. Cornelius, an officer of the Royal Engineers, to institute further investigations. Later, in 1835, the structure and basic dimension of Borobudur were first investigated by Hartmann, and a German artist, A. Shaefer, made the first daguerreotype photos. Afterward, between 1849 to 1853, F.C. Wilsen together with Schonberg Mulder, was given the task by Dutch Government to make drawings of all relief.

The first monographs of Borobudur temple was created in 1873 by C. Leemans, director of Leyden Museum of Antiquities, in cooperation with J.F.G. Brumund and Isidore van Kinsbergen. An important aspect of Borobudur relief hidden in the base of Candi was discovered by J.W. Ijzerman in 1885. In 1890 the concealed reliefs was entirely revealed and photographed by Indonesian Kasijan Cephas for documentary purposes. Later on, in 1900, J.L.A. Brandes formed a committee together with Theodoor van Erp, a Dutch army engineer officer, to restore the deteriorated conditions of this great monument. Actual renovation began in 1907 with 50,000 Dutch guilder of cost, which took 4 years of hard work until 1911 (Erp, 1931).

Due to the limited budget, the restoration had been primarily focused on cleaning the sculptures, and excavating the grounds around the monument to find missing Buddha heads and hidden panel stones. This 1907-1911 restoration project did not address and solve the drainage problem. Within few decades, the gallery walls were sagging and the relief showed signs of new cracks and deterioration. Theodoor van Erp used concrete from which alkali salts and calcium hydroxide are leached and transported into the rest of the construction. This has caused some problems that a further thorough renovation is urgently needed (Soekmono, 1973).

Second restoration was established from 1973 to 1983 under the aids of UN. In the late 1960s, the Indonesian government had requested a major renovation to protect the monument to the international community, and a master plan to restore Borobudur was created in 1973. Due to natural and destructive chemical processes over time, the relief and statues had fallen into decay. Besides the dampness, the sagging of the temple walls threatened candi Borobudur to collapse. Therefore, an urgent restoration of the monument was started in 1975.

The Indonesian government and UNESCO undertook a complete overhaul of the monument in a big renovation project from 1975 to 1983. Under the chairmanship of R. Roseno and Soekmono, Indonesian engineer and archeologist, the northern and western balustrades were partly

dismantled and restored. Many UN experts and archeologist in the field of stone preservation were also invited to solve the serious problem of damage to these relief and statues. The overall foundation was stabilized and all 1,460 panels were cleaned. The restoration involved the dismantling of the five square platforms/galleries and improved the drainage by embedding water channels into the monument. Both impermeable and filter layers were added (Parmono, 1988).

Exactly 10 years this colossal project took place, and in 1983 Candi Borobudur was restored as seen to its present state. After the renovation and restoration project finished, it is officially acknowledged by UNESCO and becomes World Heritage and Treasures in 1991. Considered also as one of the Seven Wonders of the World, this ancient monument is a cultural legacy and source of historical research of Indonesia. This beautiful and magnificent temple and Tourist Park located at Borobudur District, south of Magelang city (40 km north of Jogjakarta) now becomes famous tourist attraction and destination, among local people and foreign visitors from many parts of the world.

Preserving this precious tangible and intangible cultural heritage of Borobudur became national and international attentions in order to protect them from further natural destructions. One of possible solutions is through digital archive project effort. Such digital project may offer a virtual tour to provide all information about Borobudur as well as its valuable Buddhist text to public. The digital Borobudur archive may also attract people and tourists coming to visit Indonesia. Additionally, such digital Borobudur project will lead and guide to other heritage sites and temple research in the region. The implementation of digital Borobudur will be proposed and enhanced mainly by modern IT and web technology.

Figure 3. One of the deteriorated narrative panels on Lalitavistara

4. Digital Archives of Candi Borobudur

Digital archiving means creating heaps of archived information using the digital technology. An archive usually refers to an electronic collection of records, and also refers to the computer system/server in which these records are kept for that particular subject. The purpose of digital archiving on cultural heritage is to preserve and protect them and also to make the information available to the Internet audience. Therefore there are lots of basic IT technologies need to be considered and prepared in creating a digital archive, including the Internet infrastructure as basic means for data traffic on the digital archived database.

Over the past ten years, Indonesia has emerged and grown in the journey towards a digital technology. It is currently ranked considerably high-level in the development of Internet infrastructure, with the high penetration rate of broadband Internet in recent years. As of 2003, 5 million users and 1500 universities/ colleges were connected to Internet. Indonesia is also in rapid progress among other neighboring ASEAN countries in Internet use; supporting people on e-commerce, e-banking and stock online trading. Internet is also widely used to promote tourism among people and its citizen with increasing number of Internet access from private lines and Cyber cafes.

The development of Information Technology in Indonesia is closely related to the shift in the national development strategy from agriculture to industrialization and information. Since the 1980s, Indonesia has emphasized industrialization as top priority national agenda and achieved rapid growth significantly, expanding real Gross Domestic Products by 4 times during 1970 – 2000. Driven further by current paradigm shift towards Information Technology and knowledge-based economy, the main concern for Indonesian government now is to enhance its competitiveness through productivity increase via digital technology for its society as a whole.

The Indonesian economic crisis in 1997 helped accelerate the transition to a knowledge-based economy. The government responded very strongly to the crisis by expanding its IT investment and promoting the use of IT. As a result, Internet use sharply increased starting from 1999. The number of Internet subscribers was only 320 thousands in 1999, but it rose to 512 thousands in 2001, and reached up to 740 thousands by the end of 2003 (23% yearly growth). Broadband Internet and Wi-Fi access had demonstrated a similar pattern of growth. The number of active and operational Internet Service Providers (ISPs) connected to broadband Internet reached 30 nationwide in 1999.

With the recent progress in telecommunication networking, digital divide has been narrowed considerably in Indonesia towards a digital technology and knowledge-based economy. Many

commercial business and communities have been creating, delivering, organizing, and preserving digital collections for years. Individual institutions have taken the initiative to digitize their collections, and create web exhibits and databases, all in the desire to use the power of the Web to share valuable resources. Digital archives, in which cultural heritages are stored and preserved in digital form, are also expected to grow in promoting tourism in Indonesia. Sharing and distributing digital contents over the Internet will contribute to the widespread use of tourist network in ASEAN countries and Asia Pacific region, including Australia and New Zealand. For this purpose, the Indonesian government has established the portal website providing links to the digital archive websites of many national tourist spots (Indonesian Department of Tourism, 2007).

Constructing digital heritage requires substantial resources in materials, knowledge, expertise, tools, and cost. Projects supported by governments and academics can only cover a small part of the world's heritage in both time and space dimensions. The preservation coverage problem is most serious in domains where sources of intellectual and cultural heritage may diminish or disappear over time. A central notion that helps resolve these issues is to facilitate global reach of digital technology to sources of valuable heritage. A proposed approach is to exploit non-institutional resources for wider participation and coverage in digital heritage effort. The approach attempts to replicate institutional digital heritage work by teaming up public resources and providing standard practice (Liu and Tseng, 2004).

Many digitization projects have been introduced around the world in recent years. In early 2004, Chinese government established a foundation and mission to protect and preserve the Great Wall of China that emanates from 3,000 years of history (Hylton, 2005). An image-based rendering (IBR) technique was also proposed to create virtual city images with the aid of omni-directional camera and special illumination methods (Katsushi, Sakauchi, Kawasaki, and Sato, 2004). A virtual tour of the Beethoven Museum and Beethoven's life and music was funded recently by city office of Bonn. For candi Borobudur, a preliminary digitalization of the temple was started by Australian National University in 2002 (Greenhalgh and Limaye, 2002).

Based on the initial projects and the network infrastructure available in Indonesia, the 'Digital Borobudur' project effort can be planned and scheduled further. The digital archives of Borobudur will be a digital library project on Borobudur temple in co-operation with Indonesian government and other partners. The digital archive effort will consist of two parts. The digital archive contains digital copies of all documents and objects in the Borobudur temple with meta data on the collection of the temple. Secondly, a digital Borobudur project will offer easy access to the whole collection and visualization facilities about Borobudur and its visual Buddhist manuscripts. Therefore, cyberweb access will allow and contribute to the global visibility and virtual tour of candi Borobudur.

In general, multimedia (video, audio, graphics) and textual information on digital Borobudur are initially unstructured data which normally do not contain indexing information. For fast searching purpose, indexing on structured data has to be added manually by administrators in the form of keywords like title, image description, and its panel location. Most conventional search methods only allow searching for objects by these keywords. However, more sophisticated tools and methods will be developed and implemented in the digital Borobudur's context. The search results are presented in a user-friendly way. The ranking of search results provides a list of documents sorted by rank values that can be easily understood by users.

5. Virtual Reality Technology

Today, Cyberspace and Internet has emerged as global information infrastructure, as well as high-speed access in which the digital archive information is transmitted and received. Further development of digital archive is Virtual Reality (VR) technology that may be used as possible realization to support digital and virtual Borobudur. VR describes a real environment that is simulated by a computer. Most virtual reality environments are basically visual experiences, displayed either on a computer screen or through special stereoscopic goggles with additional sensory systems and sound effects through speakers/headphones. Users can often interactively manipulate a VR environment, either through standard input devices like a handheld instrument or specially designed devices such as cyberglove.

The term virtual reality was introduced in 1989 by Jaron Lanier, founder of Virtual Programming Languages (VPL) research-based company. Similar term, artificial reality has been in use from 1970s and became publicly known when cyberspace was popularly introduced in 1984. The first hypermedia technology on virtual reality system was the Aspen Movie Map program which was created by MIT in 1977. The program was a simple virtual simulation of Aspen city in west central Colorado, in which users could wander the city streets in one of three modes: summer time, winter time, and polygons. The first two were based on actual photographs of every possible tour and movement through the city's street grid in both seasons, and the third mode represented a very basic 3-D model of the city.

In the past, virtual reality has been heavily criticized for being an inefficient method for navigating non-geographical information. At present, the idea of pervasive computing is very popular in user interface design, and this may be seen as a reaction against VR and its problems. In practice, these two terms of VR/VRML and Pervasive computing have totally different goals and requirements. Most pervasive or ubiquitous computing goal is to bring the computer into the user's world to support any kind of applications. Therefore, new trend in VRML is to combine the two paradigms

together to create a fully immersive and integrated experience.

Basically, visual information is easily absorbed by the human mind than the information presented in text format (Katsushi et al., 2003). For this, Internet is a good media to post and publish such visual information because the Internet users are huge in numbers. We should also keep in mind that there are other visual information resources available on the Net which is competitively interesting to users. Therefore to make the digital archive attractive, it should be presented using computer vision technology in a user friendly and easy access to aim variety of users from students, scholars to common people and citizen.

There are some advantages in using virtual reality on digital heritage sites. The users will get information in a very effective way. They will be able to experience the cultural heritages virtually, and there is no need for users to move physically to various places to visit actual heritages sites. This technology gives users a chance to experience and to understand the cultural heritages that they might have even never knew before. Using Internet, this VR technology will help to transmit the information of the archived data to the users effectively. A real-time and interactive ability of this VR will give distinct features over three-dimensional images. And, the sensory experience of this environment can be provided through the output devices, which are designed to match the person's mode of perception.

Using VRML, person can control the position of the viewpoint and interact with a three dimensional Virtual Environment (VE) through the input devices, which are similarly designed to come close to the individual's natural communication. The Internet network provides a means of communication with the computer server through their own computers. Creating a VE gives the users absolute and total control over what he or she will perceive. It also provides easier and safer alternative to reality, and it is cheaper to visit and watch a computerized model than a real trip to the site. Quite often, many people use VRML to experience a real environment before they go the actual site.

The digital and virtual Borobudur aim is to provide a comprehensive learning platform which is motivating, fun and simple to operate so the user may immerse quickly into the content by using full multimedia Internet possibilities like text, picture, audio and video. It is planned to make it the most complete Internet offer on Borobudur temple. Another feature of the digital and virtual Borobudur is its ability to connect students, scholars, and other learners who study Borobudur via the Internet so they can communicate and exchange idea and information rapidly and easily. Through this, they can form online working groups and their discussion results will contribute and amplify the quality and quantity of the studies.

6. Challenges

Although everything in the virtual Borobudur will be based on the digital archive, several related problems have to be overcome to establish it. The information scanning system is one of them, and it must be comprehensive and of high-quality as there are photographs, pictures, 3-D compositions and objects, books, magazines, and even microfilms or microfiches to scan. The main challenge is that primary material is either from original relief on the temple wall, or as copies of old and fragile photographs. To lessen all these tasks outsourcing the digital archival of documents can be employed, especially in case of lack of technical people with appropriate knowledge/expertise (Tiitinen, Tyrvainen and Palonen, 2006).

Having digital copies of the Borobudur manuscripts has several disadvantages. Content authentication, intellectual property, and copyright protection are the major issues. It is technically not possible to prevent an unauthorized manipulation of the document, and distributed by unauthorized users. Although watermarking, visible or invisible, is part of solution to this problem, some questions still have to be solved in this context during the implementation of the project. There is no standard method to embed and proof watermarks in digitized documents which browser and image processing software can detect easily (Venkataramana and Raj, 2007). There is also no standard registration procedure for document watermarks so far.

Another issue in distributing digital objects is the granting of access rights to registered users all over the world ('pull technology'). Modern compression technologies and scalable coding can be applied here to limit the bandwidth usage during the transmission. More sophisticated model transformation approach that implements a preservation-centric view can be utilized in the virtual Borobudur (Triebsees and Borghoff, 2007). All this emphasizes the high innovation potential of the project and its importance for our communities.

7. Conclusion

As conclusion for this paper, Borobudur temple was a magnificent Buddhist pilgrimage center、during almost two hundred years of its existence. With the fall of old Mataram kingdom in the central Java around 950 AD, most probably due to Mount Merapi volcanic eruption, religious and cultural life moved to Eastern Java (Mpu Sendok reign near present city of Jombang). Volcanic ashes which accelerated the temple decays, and ever-growth of tropical vegetation added to Borobudur's deterioration into unknown and forgotten for almost 10 centuries, until 1814 when Sir Thomas Stanford Raffles first discovered it. Due to natural degradation of Borobudur temple and its valuable 2500 meters' length of visual Buddhist text, conservation and preservation of the temple is needed to follow the 1973-1983 restoration project.

Efforts towards preservation of this world heritage through digital technology are underway world-wide. Indonesian Government through Department of Tourism already setup an initial website, museum, library and research center in the temple site. Just recently, Australian National University also set up a website that shows some digitized pictures of Borobudur's relief in the effort towards conservation and preservation of this magnificent monument. Another small project initiative was also done at APU to collect and archive manuscripts and images of Borobudur relief that can be used further by APU students as source of cultural studies in the future. These pictures will be stored and arranged into a database system, and be made available to our global community (Gunarto, 2007).

However, there are also problems and challenges in implementing such archives for digital and virtual Borobudur. Some of them are lack of people with appropriate knowledge/ expertise, difficulties in technical distribution, and copyright protection of the archived data to the Internet users. Resolving all of these, it is expected that the objects and its valuable Buddhist relief still exist even when the real candi Borobudur is destroyed one day. Therefore, the digital archive and VRML on virtual Borobudur represents the best approaches to preserve and protect the Borobudur heritage for the future.

References

Dumarcay, Jacques, 1978, *Borobudur*, Oxford University Press, Kuala Lumpur.

Erp, Th. Van, 1931, *Beschrijving van Barabudur II*, Bouwkundige Beschrijving.

Greenhalgh, Michael and Ajay Limaye, 2002, *A VRML model of Borobudur,* Australian National University, http://rubens.anu.edu.au/htdocs/bycountry/indonesia/borobudur/, accessed June 7th 2007.

Gunarto, Hary, 2007, *Study of Borobudur and Digital Archive Project Plan,* Ritsumeikan Center for Asia Pacific Studies (RCAPS) Research Report, APU, April 2007, http://www.gunarto.org.

Hylton, Eldon C., 2005, *China great wall digital cultural heritage,* Computers in Entertainment (CIE), pp.318, March 2005

Indonesian Department of Tourism, http://www.konservasiborobudur.org, accessed on June 30th 2007.

Katsushi Ikeuchi, Atsushi Nakazawa, Kazuhide Hasegawa, and Takeshi Oishi, 2003, *Digital Presentation and Restoration of Cultural Heritage through Computer Vision Techniques,* 13th International Conference on Artificial Reality and Telexistence, December 2003

Katsushi Ikeuchi, Masao Sakauchi, Hiroshi Kawasaki, and Imari Sato, 2004, *Constructing Virtual Cities by Using Panoramic Images,* International Journal of Computer Vision, Vol. 53, No.3, pp. 237-247, March 2004

Krom, N.J., 1927, *Barabudur: Archeological Description,* The Hague Martinus Nijhoff.

Liu, Jyi-shane and Mu-Hsi Tseng, 2004, *Mediating team work for digital heritage archiving,* Proceedings of the 4th ACM/IEEE-CS joint conference on Digital libraries (JCDL '04), pp.

259-268, June 2004.

Marzuki, Yazir and Toeti Heraty, 1982, *Borobudur,* Penerbit Djambatan, Jakarta.

Miksic, John and Marcello Tranchini, 1990, *Borobudur: Golden Tales of the Buddhas,* Shambhala Pub., Boston.

Moertjipto and Bambang Prasetyo, 1993, *Borobudur, Pawon dan Mendut,* Kanisius Publications, Yogyakarta.

Parmono, Atmadi, 1988, *Some Architectural Design Principles of Temples in Java: A study through the buildings projection on the reliefs of Borobudur temple.* Yogyakarta: Gajah Mada University Press.

Primadi, 1998, *Messages from Ancient Walls,* Penerbit ITB Pub., Bandung.

Soekmono, 1973, *Satu Abad Usaha Penyelamatan Candi Borobudur,* Kanisius Publications, Yogyakarta.

Soekmono, 1976, *Chandi Borobudur - A Monument of Mankind,* The Unesco Press, Paris.

Swearer, Donald K., 1995, *The Buddhist World of Southeast Asia,* State University of New York Press.

Tamura, Yoshiro, 2000, *Japanese Buddhism: A Cultural History,* Kosei Publishing Co., Tokyo.

Tiitinen,Pasi, Pasi Tyrvainen, and Osmo Palonen, 2006, *A Model for Digital Archival of Municipal Documents,* 10th IEEE International Enterprise Distributed Object Computing Conference Workshops (EDOCW'06), pp. 64, October 2006.

Triebsees, Thomas, Uwe M. Borghoff, 2007, *A Theory for Model-Based Transformation Applied to Computer-Supported Preservation in Digital Archives,* 14th Annual IEEE International Conference and Workshops on the Engineering of Computer-Based Systems (ECBS'07), pp. 359-370, March 2007.

Venkataramana, A., P. Ananth Raj, 2007, *Image Watermarking Using Krawtchouk Moments,* International Conference on Computing: Theory and Applications (ICCTA'07), pp. 676-680, March 2007.