Asian Conference on Computer Vision (ACCV-2014), Nov 1-5, Singapore

USE OF LASER SCANNING FOR 3D MODELLING OF HERITAGE SITE AT HAMPI, KARNATAKA, INDIA

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Key words: Digital heritage, Laser scanning, 3D rendering, GIS, GPS, ICT

ABSTRACT :

Digital reconstruction of heritage sites offers several advantages to promote historical research, research on architecture, virtual tourism, restoration, reconstruction etc. Hampi one of the UNESCO World Heritage Sites, is an open museum, having numerous monuments offering immense information for research and inquisitive tourists.

This paper aims to generate a high resolution 3D Model of important world heritage monuments through terrestrial laser scanning and digital Geo-spatial database generation on various themes of core area of Hampi Heritage site using Remote sensing and GIS. This initiative is aimed at rendering support to the various other Research groups with information to learn, analyse and reconstruct the history through different periods of time, as well as trace the developments that had taken place with regard culture, engineering, technology, trade, etc. by enabling the researchers to interact with the monuments from their own labs and also for improving the tourism and reconstruction/ restoration of monuments by the custodians of the heritage site.

1. INTRODUCTION

The ultimate objectives of Digital heritage are to enable students, conservators, documentation specialists, museum curators, heritage managers and members of the general public to plug in anywhere in the world and study and work together in the cultural heritage sector which is striving to preserve the common heritage of mankind. Digital heritage therefore achieves consistency in documentation at more cost-effective levels, it helps create new research opportunities where these did not exist beforehand, it enables fast, easy and cost-effective collaboration in research projects and also resource-management on a scale previously unthinkable. It also enables the public and the research community to access a wealth of knowledge and information that has lain hitherto untapped. The objectives of Digital heritage and integrated software and hardware systems in the heritage sector are understandably very closely linked to various forms of systems that exist or are being introduced for the purpose of documentation/management of heritage sites and artefacts. This information is crucial for further analysis with regard to the temporal sequence of development, nature of spread of the township, track the engineering skill developed through ages etc. Further such information is extremely useful in computer rendering and reconstruction purposes.

It is the way that digital has ousted analogue during the last 15 years of the 20th Century that is changing documentation in a fundamental manner. The cultural heritage documentation specialist is now faced with an ever-growing array of tools made available by the information communications technologies (ICT) which are the hallmark of the information society. Some of these tools may be used in a stand-alone manner while others achieve their true potential when linked up to other ICT tools. The new digital tools include various forms of 2D imaging (photography, X-ray), 3D imaging (Laser scanning, photogrammetry), relational databases, the Internet, web-based systems, the very nature of these tools helps define the objectives of Digital heritage most specific to documentation.

Laser scanning provides highly accurate, three-dimensional images enabling designers to experience and work directly with real-world conditions by viewing and manipulating rich point-clouds in computer-aided design software. By sweeping a laser beam over a scene or object, the laser scanner is able to record millions of 3D points. These X, Y, Z measurements can be imported into CAD or 3D application software and displayed on a computer monitor as a “point cloud” which has photographic qualities portrayed in gray-scale or true color. A point cloud is a set of vertices in a three-dimensional coordinate system. These vertices are usually defined by *X*, *Y*, and *Z* coordinates, and typically is intended to be representative of the external surface of an object.

Keeping this in view, a Programme on Indian Digital Heritage (IDH) has been evolved to capture the rich heritage of India on a digital platform using modern advanced technologies for reconstruction and recreating through ages and also to use the information for holistic analysis. This initiative is aimed at rendering support to the various other groups with information to learn, analyse and reconstruct the history through different periods of time, as well as trace the developments that had taken place with regard culture, engineering, technology, trade, etc. by enabling the researchers to interact with the monuments from their own labs and also for improving the tourism and reconstruction/restoration activities by the custodians of heritage sites.

2. OBJECTIVES

- 3D rendering of world heritage monuments of Hampi heritage site using high resolution Terrestrial Laser scanning
- Generation of high resolution Geo-spatial framework for the Hampi Heritage site

3. STUDY AREA

Hampi is situated on the banks of the river Tungabhadra in Hospet taluk of Bellary district in the State of Karnataka, India. Geographically it lies between 76^0 25’ 47’’ to 76^0 29’ 40” longitude and 15^0 17’ 24” to 15 20’ 24”longitude. The name "Hampi" is an anglicized version of the Kannada *Hampe* (derived from *Pampa*) which is the old name of the Tungabhadra River on whose banks the city is built. Hampi, was the medieval capital of the Hindu empire Vijayanagara *(the City of Victory)* from 1336 to 1565, till it was laid siege, plundered and destroyed by the Deccan Muslim confederacy. The Vijayanagara kings chose Hampi because of its strategic location, bounded by the torrential Tungabhadra River on one side and surrounded by defensible hills on the other three sides. Hampi is associated with mythology and identified with the mythological Kishkindha, the Vanara (monkey) kingdom mentioned in the Ramayana. It is important due to its history and architectural marvel.

Hampi is surrounded by the hills and valleys and it has 500 plus monuments located spread across an area of about 50 sq kms. Among them are beautiful temples, statues, Gate ways, basement of palaces, remains of aquatic structures, ancient market streets, royal pavilions, bastions, royal platforms, treasury buildings etc. Out of these 500 plus monuments, 56 monuments have been recognized by UNESCO and identified them as world heritage monuments. The core area of heritage site where majority of world heritage monuments are located is having 41.8 sq kms area covered in 12 villages in Hospet taluk of Bellary district. Hampi is charismatic even in its ruined state and is listed as one of the UNESCO World Heritage Sites. Every monument hides more than what they reveal. As an open museum, Hampi has numerous popular sites to offer for the research oriented and inquisitive tourists who visit regularly, every year. The topography abounds with large stones which have been utilized to make larger than life statues of Hindu deities. The Archaeological Survey of India continues to conduct excavations in the area, to discover additional artifacts and temples.
The location of Hampi heritage site is shown in figure no.1

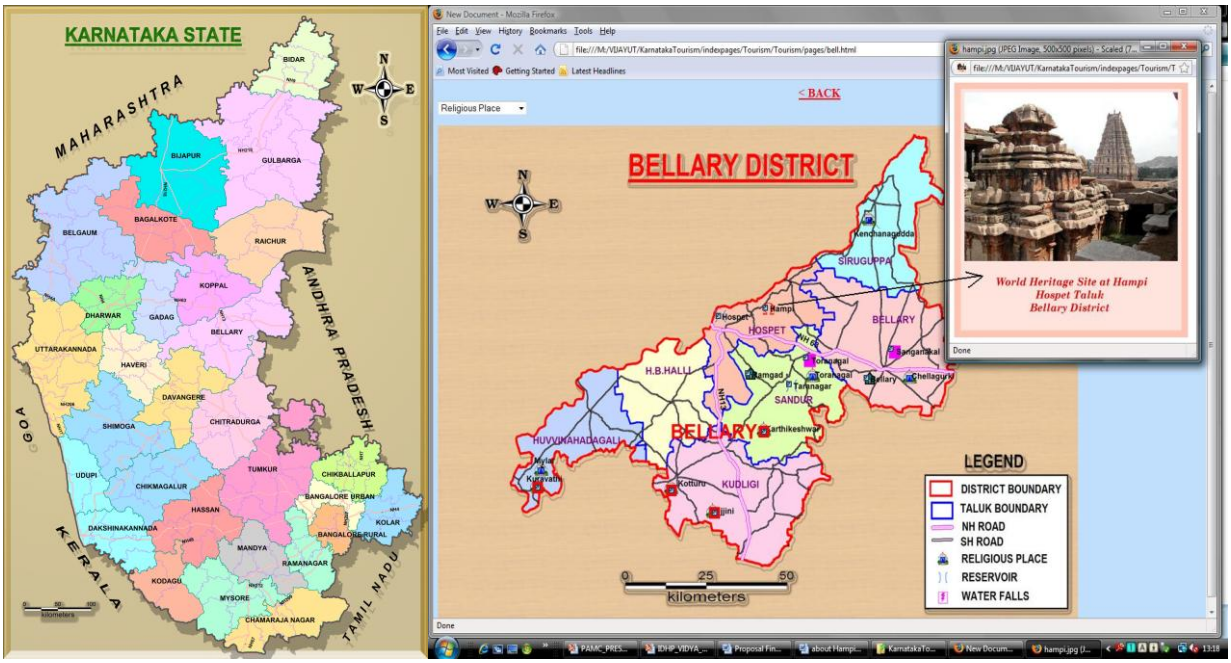


Fig.1. Location Map of Hampi heritage site in Bellary district, Karnataka state, India

4. METHODOLOGY

The methodology was adopted for the project work includes control surveying and re-establishment of control points on the existing high resolution topographic maps prepared by Survey of India to locate the monuments geographically in the GIS environment. Capturing of surface geometric details of world heritage monuments of Hampi heritage site has been carried out by following steps as detailed below. Rendering of 3D Model of heritage site has been planned to create in GIS environment for Geo-visualisation and virtual tourism. The detailed approach is described in the following stages.

4.1 Selection of monuments for Laser scanning

- It was decided to carry out the Laser scanning and 3D rendering of 4 selected world heritage monuments using different Laser scanners to test the Proof of Concept (POC) of different Laser scanning technologies under pilot scale.
- Reconnaissance survey was carried out and interacted with local custodians of the monuments to select the monuments
- World heritage monuments such as 1.Stone Chariot 2. Laksmi Narasimha statue 3, Hajara Rama Temple and 4. Varaha Temple in Hampi heritage site have been selected for Laser scanning and 3D rendering with consultaion with Archaeological Survey of India(ASI)

4.2 Laser scanning of monuments

- Terrestrial Laser scanners were put up in the site to capture surface geometric details of monuments
- Laser Scans were taken from different locations and at different angles to have maximum coverage of monuments and minimum of five targets (reflectors) were placed around the scanner. The scanner reads all the five targets and moves to the next location for new scan.
- Another five new targets were placed at the new location. The scanner does not establish connections between these individual scans.
- All the targets at each scan locations are surveyed using total station and are connected through Project coordinate system which links each individual scans during the process of registration to create one single 3D view known as model space.
- Random dimension checks are performed for most of the scan worlds to ensure accuracy for the registration process. Measurements from Laser Scan data with Total Station data is matched to know the deviation and accuracy of the survey.

4.3 Registration

- Pre-processing was carried out to merge the different scans taken from different angles
- Registration is a process of merging different scans taken from different position into a single scan to get the full 3D view of the area. Target's in individual scans were linked to tie-points capture by Total station which is linked to the local co-ordinate system. All the scans for 4 monuments were registered separately within an accuracy of (+/-) 2 to (+/-) 4mm.

4.4 Linking Digital Photographs to Point Cloud data

- High end digital camera is used to capture digital photographs, and they were linked to individual scans to create a colour point cloud data of the sites.

4.5 Post-processing

- After registration, scans were cleaned and broken down into different clusters which were imported into post processing software such as Geomagic Studio / Point tool/ Mesh lab to create a point clouds and mesh models.

4.6 Rendering 3D models

- After creating wrap (mesh) model of each objects, the data was imported into Blender Software to create Photo rendered model with actual colours. colour schemes were derived from the digital photographs taken at the site.
- 3D mesh solid and wire mesh model were created using post processing software

4.7 Creation of 2D Engineering drawings

- 3D Mesh model data was processed and converted in to 2D engineering drawings
- 2 Dimensional Engineering drwawings containing plans, cross sections at different points were created which can be directly imported into AutoCAD.
- Validated the different dimensions of monuments taken from CAD drawings with the actual dimensions of the monuments measured physically in the field which were quite encouraging

4.8 Generation of high resolution Geo-spatial data

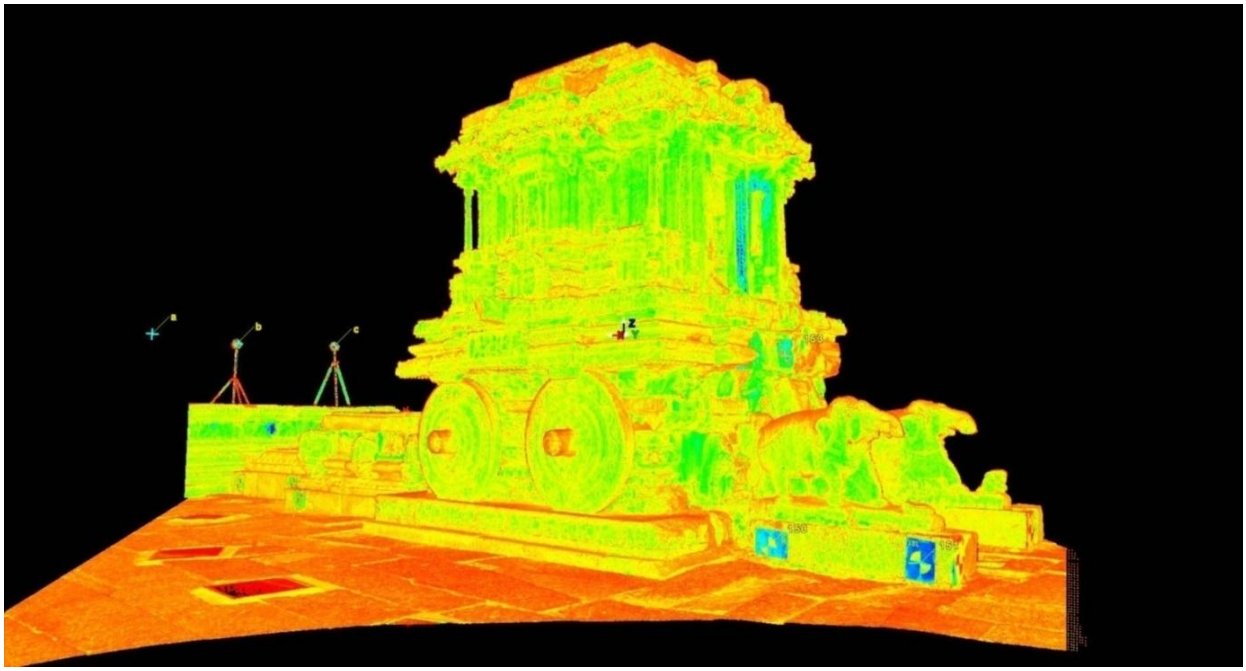
- Collection, collation and digitization of existing topo maps prepared by SOI were carried out.
- Geographic co-ordinates of each monuments were captured using Global Positioning System(GPS)
- Thematic layers like Location of monuments, transportation network, surface water bodies, Land use/Land cover etc., were created in Geographic Information System (GIS) environment.
- Non spatial data on different monuments was collected and linked in GIS environment
- Photographs taken for each monuments from the field were Geo-tagged to respective monuments in GIS environment
- Geographic locations with attribute data on different infrastructure facilities available in Hampi heritage site were collected and created in GIS environment using GIS software

5. RESULTS AND DISCUSSIONS

As laser scanning captures the surface geometric details of an object, it provides the data in an automatic way a large number of points on the surface of an object, and often output a point cloud as a data file. The point cloud data for all 4 monuments have been generated and saved in .las format. The point cloud represents the set of points that the device has measured. These set of points have been converted in to 3D mesh models. Since all laser scan points are 3D, the files can be viewed, navigated, measured and analyzed as 3D mesh models and saved in .obj format. A polygon mesh model or unstructured grid is a collection of vertices, edges and faces that defines the shape of a polyhedral object in 3D computer graphics and solid modelling. The faces usually consist of triangles, quadrilaterals or other simple convex polygons, since this simplifies rendering, but may also be composed of more general concave polygons, or polygons with holes. Engineering drawings were generated for all monuments in 2Dimentional CAD format using mesh data. Drawings of Plans, cross sections and elevations of monuments were generated. Various cross sectional views were also generated at different positions of monuments.

The point cloud data and mesh models of these monuments helps in revealing the intricate details of artefacts, carvings, sculptures, materials used with different ages of the monuments. The Engineering drawings generated will be used for recreate or reconstruct the monuments in future by the custodians of the heritage site.

The laser scan output results of Stone chariot and Lakshmi narasimha statue have been shown in the following figures. The point cloud data of these 2 monuments shows the set of 3 dimensional points captured through laser scanning technology.



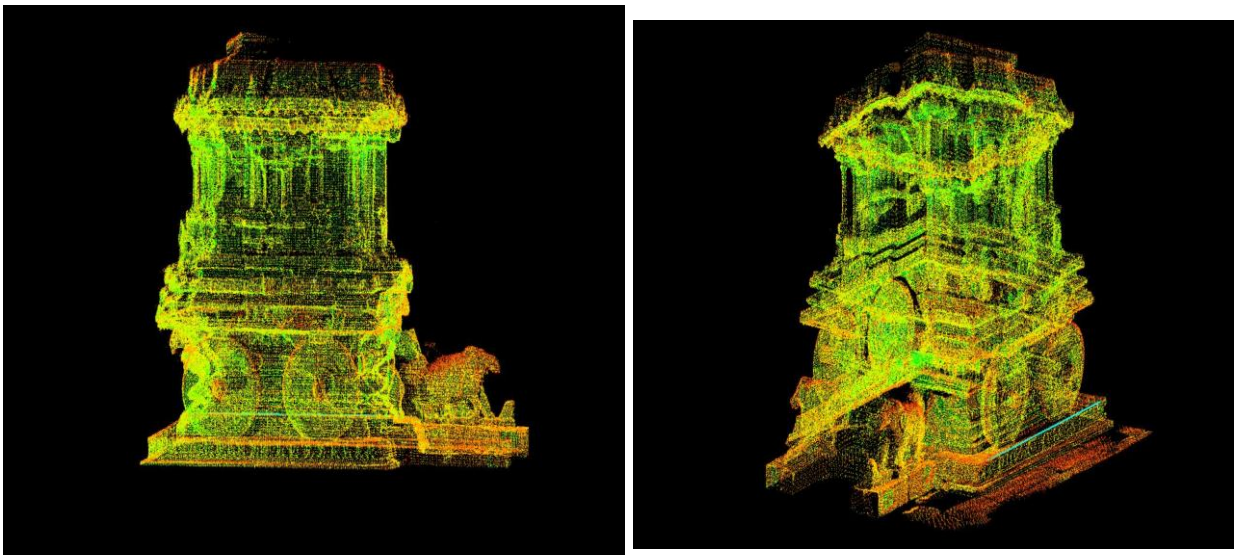


Fig 2: Point cloud data of Stone chariot with different angles

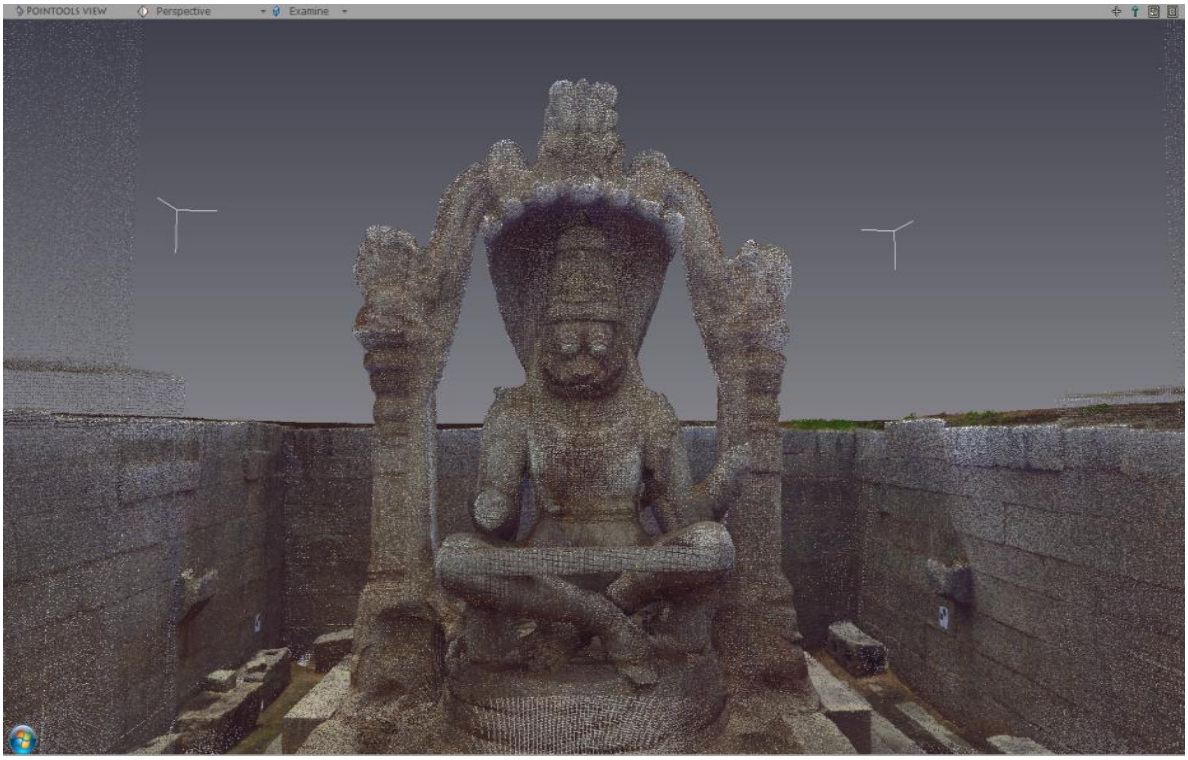


Fig 3: Point cloud data of Lakshmi narasimha statue with different angles

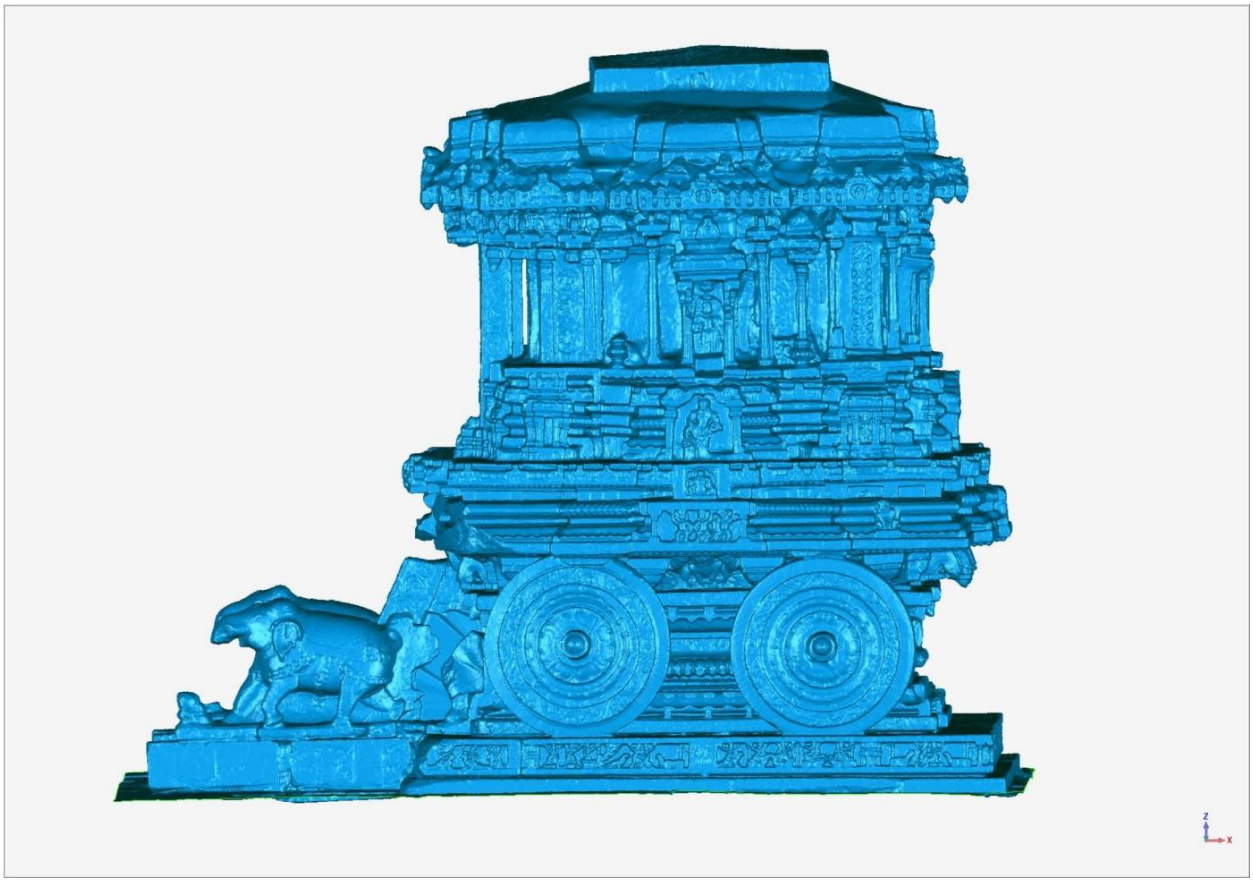


Fig 4: 3D mesh model of Stone Chariot

Fig 5: 3Dimensional wire mesh and solid mesh model of Lakshmi narasimha stattue

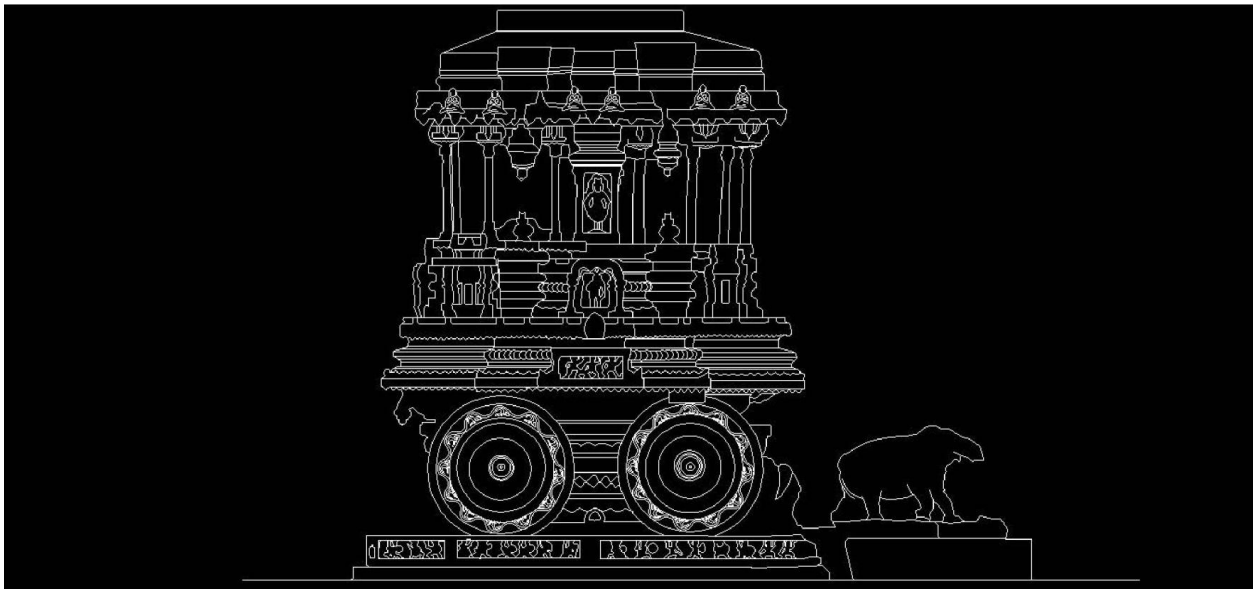


Fig 6: Engineering drawing-Cross section of Stone chariot

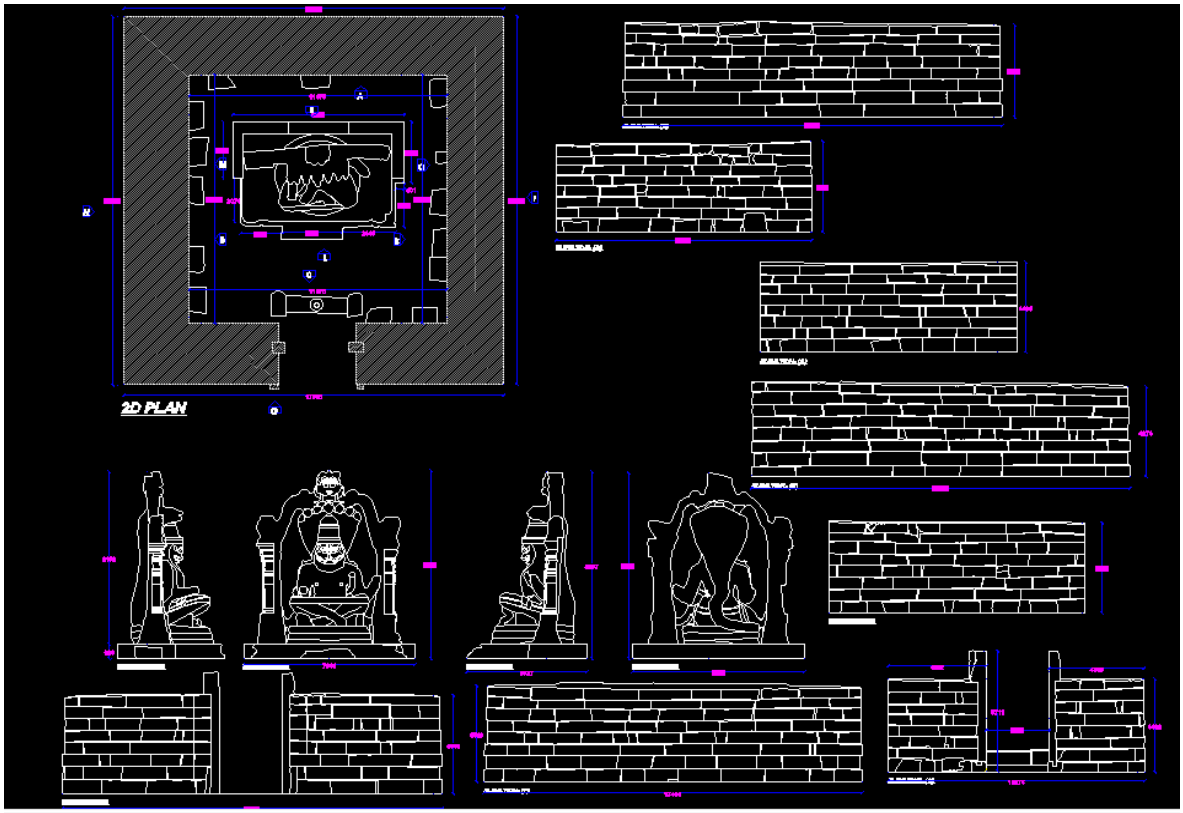


Fig 7: Engineering drawings- Plan and cross sections of Lakshmi narasimha stattue

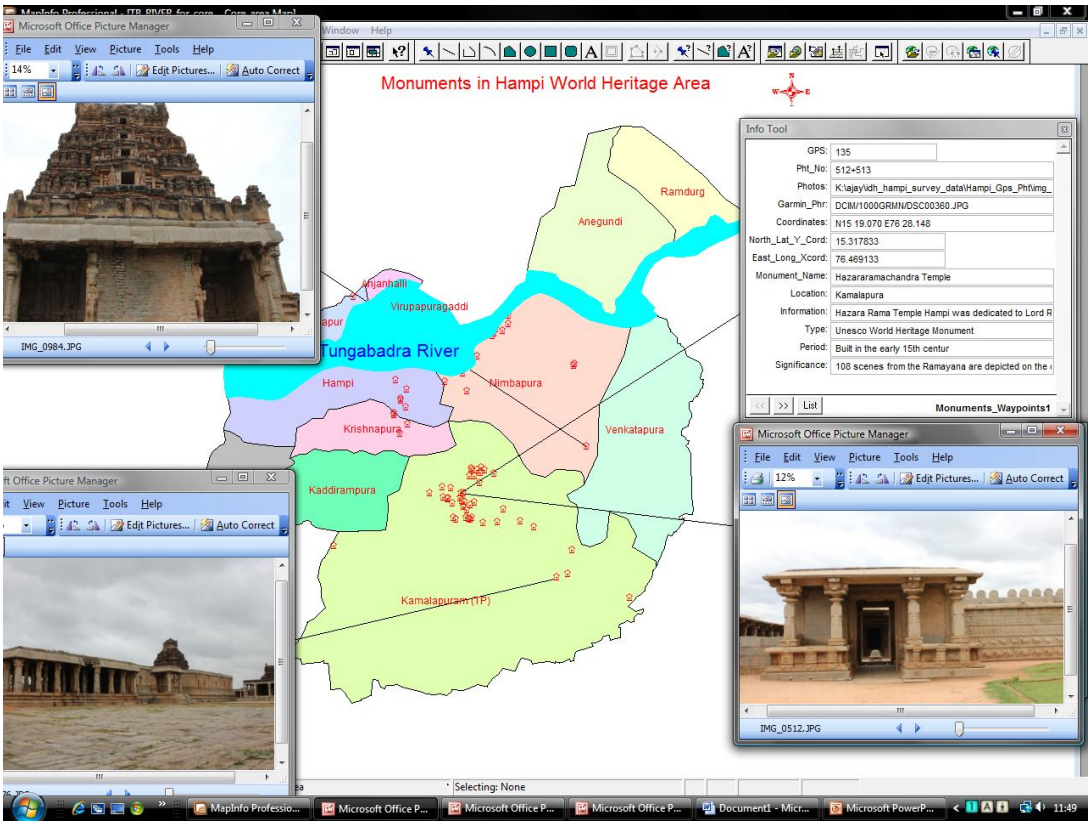


Fig.8: Geographic location of Monuments with Geo-tagging of photographs

6. CONCLUSIONS

Through this project enough 3D models through Laser scanning and Geospatial digital data pertaining to the terrain and the monuments could be generated for future research, preservation, reconstruction and tourism promotion etc. The data would further enable to draw suitable solutions to the problems identified in the heritage site, documentation, restoration, visualization and reconstruction or recreation of the cultural monuments all over the country.

- The outputs would become global visualization of historical monuments of Hampi which helps in virtual tourism of World heritage site at Hampi
- Helps in up gradation of infrastructure facilities and socioeconomic conditions of the local population
- Digital documentation of Hampi heritage site facilitates the Government and UNESCO for preservation, protection, restoration and reconstruction of monuments
- Enables the Researchers and Historians to learn and carryout research to reconstruct the history of existing, ruined and hidden sculptures of monuments of different ages

The outputs of the project will be highly useful for computer visualization and creation of virtual Hampi to support tourism, and also for planning protection, restoration, reconstruction of this cultural heritage site. The Archaeological Survey of India, UNESCO, Hampi World Heritage Management Authority(HAWAMA) and Department of Tourism, Government of Karnataka will have a comprehensive Geospatial database of the various monuments along with the geographic location, topography, LU/LC, water bodies and other details of Core area of Hampi world heritage site at the end of the project. In addition, various institutions involved in development of visualization tools, virtual reality models will also be provided with the base data required for their research and restoration work.

Such Visual rendering and publishing it on internet would help in increasing the tourism of the area. This would help in upgrading the socio-economic condition of the local population, help in infrastructure development and bring about a general betterment in the living condition of the people of this area. This type of projects may also help the historians to visually create the conditions that existed in the past and analyze the nature of development and its implications on the society and vice-versa. Further, proper documentation of the heritage sites facilitates the governmental and non-governmental organizations working for preservation and restoration of the heritage sites and help in understanding the intricacies and implications of the anthropogenic activities on the sustenance of the monuments.

Through this project perhaps we may formulate the guidelines and standards for 3D documentation of the cultural heritage sites in India. Also this would pave the way for uniting the Technical and cultural fraternity in the study of the history of this great country.

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