Standardization of Geomatics Applications in Cultural Heritage

Mohsen Miri,
mohsen_miri@alborz.kntu.ac.ir

Dr. Masood Varshosaz
varshosazm@kntu.ac.ir
Dept. of Photogrammetry and Remote sensing, K.N.Toosi University of Technology, Tehran, Iran.

KEY WORDS: *Cultural Heritage applications, Geomatics, Standards*

ABSTRACT

Currently Geomatics is used in a large number of cultural heritage applications. The standardization of these applications, therefore, is of great importance. In order to define the required standards, in this paper various fields of Geomatics in cultural heritage are reviewed. These fields are photogrammetry, surveying, laser scanning technology, and some information systems such as GIS (Geographic Information Systems) and APIS (Architectural Photogrammetry Information Systems). Different groups of applications are identified including "Documentation", "Heritage Recording", "Conservation, Preservation and Reconstruction", "Architecture", "Archaeogeology" and "Information management" of cultural heritage tasks. Each group is assessed based on the methods used, equipments required, and the accuracy of the relevant techniques utilized. Proposed essential parameters for standardization of each branch are presented on the side of geomatics.

1. INTRODUCTION

Cultural Heritage institutes and organizations are constituted of different working groups using equipments, methods and professions to measure geometric elements, in traditional or new systems. Creating geometric models to be applied in some tasks such as documentation, conservation, preservation, architectural designs and archaeo-geological researches is of the great purposes in cultural heritage institutes and relevant working groups. With very few exceptions, heritage sites in Iran are paid little attention by the local and international community. Using traditional methods during data acquisition, data storage and representation of final results; culminates in losing time and budgets in such projects. Using rather time consuming, labouring and expensive methods caused to store inaccurate and imprecise data in complicated archives, difficult to manage information required in each field. Sites, museums, galleries, libraries are the main centres where objects, models and other related information of cultural patrimony would be presented. Documentation, conservation and restoration of such sites requires accurate spatial information such as shapes of remaining walls, location and physical extent of eroded surfaces, thickness of walls, dimensions of features such as windows, doors and so forth. A spatial information system of a site will also be required for management of development and restoration projects. Beforehand, subjects defined in cultural heritage committees such as museum objects, buildings and built environments, archaeological sites and excavations, natural environments and cultural landscapes must be classified in geomatics point of view. Thereafter, standards and instructions

of applying geomatic methods in cultural heritage tasks could be identified based on accuracy and precision required, representation data formats, considering time, economy and available equipments.

2. PROJECT OBJECTIVES AND STEPS

Required geometric measurements in cultural heritage could be recognized through cultural heritage definitions and task groups. Beforehand, a literature review has done around the international projects, to evaluate the situation of geomatics in cultural heritage applications and then during the interviewing the researchers and technical groups, working at Research Foundation of Persepolis and Pasargadae, the essential parameters for modeling geometric elements is specified. Each field is evaluated in terms of precision, time and economy. Presenting optimized methods for data acquisition, data processing, equipments, required resulted data formats for storage and representation of models are the fundamental aims of this project to prepare necessary parameters for standardization of applying geomatic methods in cultural heritage tasks.

3. GEOMETRIC MEASUREMENT IN CULTURAL HERITAGE TASKS

The necessity of performing geomatics in cultural heritage applications could be marked by geometric measurements and representation formats identified trough relevant tasks. To achieve where, when and how geometric measurements appears in cultural heritage projects, applicable tasks are classified in several fields due to definitions designated to each. Through definitions mentioned by the organizations and experts, relevant task groups are classified in six general fields including "**Documentation**", "**Heritage Recording**", "**Conservation, Preservation and Reconstruction**", "**Architecture**", "**Archaeogeology**" and "**Information management**" will be defined below.
In cultural heritage point of view some of these tasks are integrated or discrete in definitions but these fields are categorized considering applicable scales and representation formats via geomatic methods and products.

Documentation...information units acquired over time through heritage recording and other research means which constitute the knowledge base for particular sites and objects [2]. Documentation, therefore, is considered as the basic step for heritage recording, conservation and preservation projects which requires precise and proper realistic models to show the situation and condition of historical objects through defined periods or at necessary times, see figure 2.

Heritage Recording...the capture of information relevant to understanding the physical configuration, evolution and condition of heritage sites and objects, at known points in time, and the basis of decisions made to alter or care for such sites and objects [2].
Before any intervention can be performed, a number of steps have to be carried out and where different documentation techniques form a substantial part. Three main purpose of recording plans are:

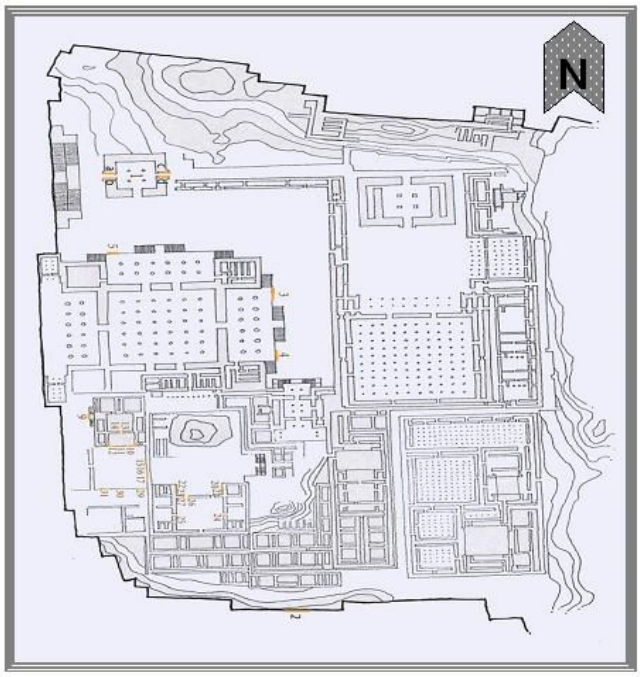

Figure 1: Historical plan of Persepolis, Schmitt 1935.

1-recordings as a *back-up* of historic structures and buildings if they should be damaged or destroyed, or to be used through a valorization process in a societal context;
2-recordings in order to *prepare conservation* contract documents; and
3-recordings as a *monitoring* device in order to detect changes which occur with the passage of time or because of external forces [1].
Position, situation and shape of ancient objects, as significant information of found and excavated objects, are to be mentioned in spatial and geometric records of identification files, shown in figure 1.

Conservation... concerned with the transmission of cultural heritage, with its significant messages intact and accessible to the greatest degree possible. Conservation Process…the analytical decision-making process of ensuring that conservation intervention at all levels will respect heritage values of sites while maintaining functional effectiveness within applicable budget and other constraints [2].
There are some intervention principles trough tactical levels in conservations projects which are a conservation demands and require a minimum of interventions, use of original materials, similarity between substitute material and the original, avoiding damages resulted by new materials, "retreatability" of all interventions rather than "reversibility" and finally documenting all interventions.
Methods required to measure geometric elements need minimum touch with objects, reliable and accessible archiving of data and easy to prepare change models, temporally or permanently.

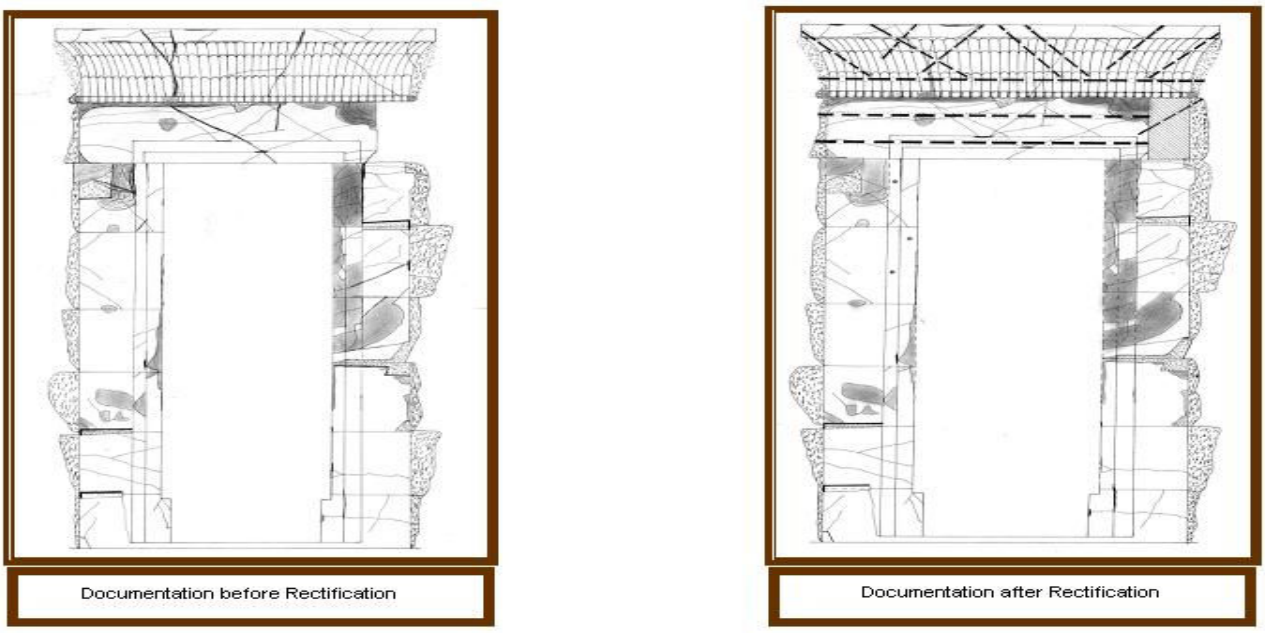

Figure 2: Two rectification models drawn during conservation plan of an entrance door frame in Persepolis modelled by technical conservation group at Research Foundation of Persepolis and Pasargadae.

Preservation… to keep cultural property in its existing state, with repairs when. In another word preservation is the act or process of applying measures necessary to sustain the existing form, integrity, and materials of an historic property. Works should generally be focused upon the ongoing maintenance and repair of historic materials and features rather than extensive replacement and new construction [1].

Models, in several scale and formats, are required indicating the protective regions and limited boundaries to ensure the safety of cultural properties and will be used through different purposes such as architectural plans and municipal designs.

Reconstruction… the act or process of depicting, by means of new construction, the form, features, and detailing of a non-surviving object for the purpose of replicating its appearance at a specific period of time and in its historic location [1]. Thus, virtual models with high precision and qualification are needed to represent models of deteriorated objects in its complete shape. Measuring volumetric models of ruins in large extent regions is of importance of reconstruction projects.

Architecture… the art and techniques applied to study historic architectural designs over time including construction of cities, sites, buildings, monuments and other architectural objects and to create new designs for environmental developments in cultural heritage places, concerning tourism guidance directions, furnishing, landscape managements through conservation and preservation conditions[4]. Required architectural models are identified in three main categories. Historic architectural studies, at first, need 2D and 3D models from medium scales, over cities and sites, to very large scales for constructive elements of structures. Second, architectural development designs preferably require site plans and topographic maps to design tourism paths and situation of facility places. Third, landscape analysis requires 2D and 3D models, usually colored, to manage the environmental features in aesthetics point of view.

Archaeogeology… an integration of some archaeological fields with relevant geological sciences to investigate geological effects on historical sites, monuments and other properties concerning constructive materials (type, situation and position of mines and other natural resources) and destructive geological forces in the environment such as earthquakes, faults, earth movements [4]. Geological maps indicating prehistoric layers of the earth crust, faults, historic and recently found mines, hydrology layers and seismological information are used as basic information in this field, generally in small scale formats.

Information management... is defined as the process of acquiring, storing and sharing site documentation, museum properties and other relevant subjects to ensure the accessibility, security and reliability of presented information for decisional purposes.

Through the definitions mentioned above, geometric parameters could be regularly introduced through propounded tasks in cultural heritage. In this paper, required geometric components are pointed in the view of geomatic methods and products each results.

4. GEOMATIC METHODS IN CULTURAL HERITAGE FIELDS

Geometric and visualization models could be produced by state-of-the-art geomatic methods through relevant applications requiring geometric and spatial data acquisition, management, analysis and representation as optimized methods versus the traditional ones.
Photogrammetry (aerial and close range), laser scanning (aerial and terrestrial), remote sensing, Geospatial Information Systems (GIS and APIS) and surveying methods are the categories investigated through mentioned cultural heritage fields to prepare essential parameters for standardization of these methods and provide required instruction for executive task groups. While all these technologies, with

the possible exception of the laser scanner, are well developed, there are some unresolved problems, specifically in the 3D modelling and virtual reality presentation [3]. In this paper geomatic methods are classified in six ordered classes considering scale of final results each introduces.

4.1 Remote Sensing and Aerial Photogrammetry

Remote sensing images can provide spatial models from very small to large scale formats. In general, remote sensing data are preferred to produce maps covering large extent regions where other data acquisition methods are not optimized on the side of time and economy.
2D maps including layers of vegetations, transportation, building blocks and city plans can help the tourists and researchers to find best accessible paths to sites and other cultural heritage places, which are recognizable in satellite images. Rectified models and Orthoimages as other products of remote sensing images are suited to generate models for tourism guidance. Digital Terrain Models in small scales are also applicable for environmental management of cultural sites and landscapes. As well, archaeologists, as mentioned above, deal with small scale models required for geological analysis. Generally, satellite images in RGB formats are sufficient to provide essential layers to register spatial layers using in archaeological investigations.
Basic dimensions (lengths, areas and volumes) of structure elements are to be mentioned in heritage recording identity files. Aerial photogrammetry as an efficient method to extract lines and boundaries would present such geometric information to heritage recording institutions. Considering the investigations around historic architectures, precise models in CAD or visualisation formats would be available via photogrammetric methods with small or medium scales models. To monitor the condition of historical cities, especially in view of possible illegal destruction, modification or new constructions, detailed city maps are required [3]. In architectural point of view, city plans are needed as basic models to study historic municipal designs, comparing other historic architectural styles, and to find out the environmental interactions of such historic designs. Orthophoto, as a result of photogrammetric processes, represents efficient information for historic architecture researches.

4.2 LIDAR

Since 3D models extracted from aerial laser scanning data, would be generated in less time versus aerial photogrammetry. Volumetric measurements required for restoration tasks and relevant environmental analysis using LIDAR data are in priority on the side of data acquisition and processing time. Topographic models such as DTM, contour maps and elevation control points are referred as basic spatial information to represent excavated and unexcavated areas in archaeological plans. Integrating mentioned geospatial data with other archaeo-geological data, for instance archaeo-geophysical images, will help the archaeologists to determine the considerable places to be excavated prior to others. Moreover, registering geological layers with topographic information, leads the archaeo-geologists to position the historic mines and find out the geological forces have affected/affects ancient regions of interest. But photogrammetry is still needed to produce 3D textured models integrating laser scan elevation data.

4.3 Close Range Photogrammetry

Traditional methods for creating 2D or 3D models are currently used to represent detailed drawings of eroded or broken parts of monuments and small objects of cultural patrimony. Such rather labouring methods require much more time, cost and expert personnel than existing geomatic methods.
Close range photogrammetric or laser scan recording, as proposed for the spatial data capturing process, differ from traditional methods, less complex recording and visualisation techniques in that they provide metrically accurate data. While this is less relevant for education and tourism, it is highly significant for architectural, historical and other scientific research as well as for conservation and restoration projects. Photogrammetric recording of structures results in spatial data which allow precise measurement of dimensions, areas and volumes in CAD and GIS systems on a computer screen or on hardcopy diagrams[3]. Detail dimensions of features such as windows, doors, ornaments, columns, arcs, vaults could be extracted from photogrammetric models to create virtual structures required in virtual museum environments. Accurate dimensions of structure details and decorative elements, for visible or invisible parts, are relevant for architectural research or when destroyed sections of a building are to be restored, as in figure 3. In the latter case dimensions of destroyed components can be derived from remaining portions of buildings, assuming symmetry, and duplicated. 3D models generated from laser scanning process are ideally suited to extract these dimensions in a short part of time. Integrating photogrammetric models with laser scan data, results a 3D textured model, applicable in different tasks.

The preparation and implementation of a conservation plan, mentioned above, can be further divided into a number of steps, where each has its specific requirements of data and information through different representations. At the initial phases where decision on an object to be subject for preservation action is made photogrammetry provides the base for needed data and information: as ”ordinary” photos, photographic stereo pairs, ortophotos, 2D-drawings, 3D vectorized models, or rendered 3D models [1].

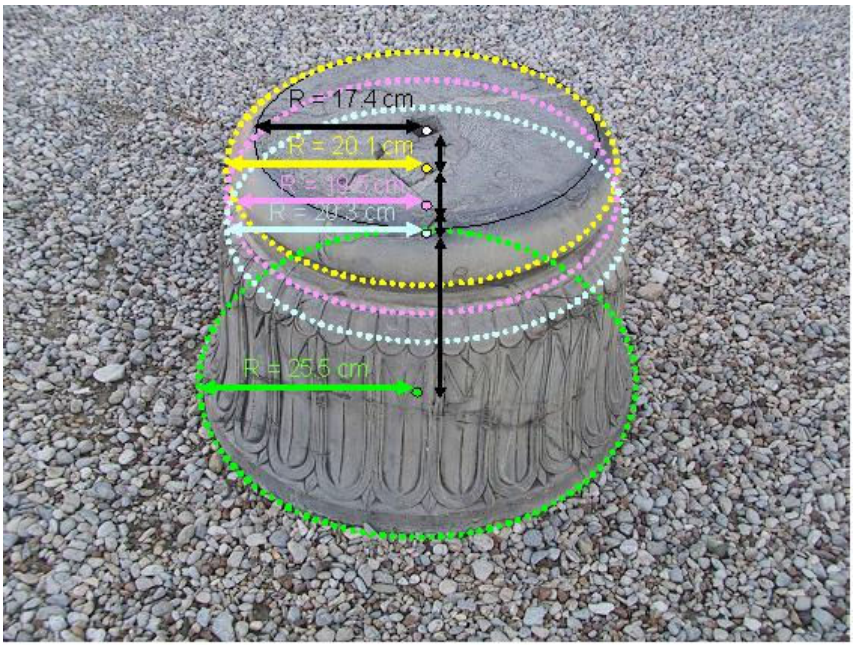

Figure 3: Visible and invisible elements of a pedestal identified by photogrammetric methods can provide models for virtual museums and stored in architectural photogrammetric information systems.

2D models such as site plans as the basic information representing the position of places, objects and paths accessible for tourists, are suited to be generated by photogrammetry (in large scale formats) and modern surveying methods. Also site maps are essential for the planning and management of restoration projects and landscape preserving through architectural designs.

4.4 Terrestrial Laser Scanning

Modelling complex surfaces, with less time and lower cost than photogrammetry and conventional surveying methods, marked up laser scanning technology amongst other methods. In comparison with close range photogrammetry, laser scan technology can produce such models in short time but without real texture of the object. Recording of caves, ancient and historic mines and other dark places requires 3D models representing traces, elevation data and desired sections of caves and mines become possible via laser scan technology. Rectification and reconstruction of cave paintings and historical inscriptions, petroglyphs and pictographs need to be performed by fast, precise, accurate and economical methods. Integrating close range photogrammetry and laser scan technology is of advantageous proposed method representing rather perfect 3D textured model for excavation, documentation, recording and reconstruction purposes. Structural design as one of constructive steps during conservation and preservation plans are based on supporting old structures against dynamic and static mechanical forces [4]. The detailed 3D dimensions of buildings and structures are required to determine stresses and loads and design support structures and shelters [3]. Creating 3D models with laser scanners data is preferred as an optimized method, for deformations and replacement monitoring of rather unmovable objects [6]. Temporal documentation of static structures by laser scan 3D models will identify such changes via change detection algorithms. Also, architectural landscape management will be quite convenient through laser 3D models, representing environmental objects and parameters required for visibility analysis.

4.5 SURVEYING METHODS

Providing control points required for mentioned geomatic methods is possible through conventional and modern surveying methods. As a matter of fact, surveying methods are not proposed to produce maps of large extent areas or modelling complex surfaces of cultural heritage objects. Whereas topographic and planimetric maps are the known products applicable in site development plans and identifying the protective boundaries for municipal designs. Geodetic surveying, can provide models representing deformations and replacement of unmovable objects such as towers, columns, sculptures, with high precision, towards conservation purposes.

4.6 GEOSPATIAL INFORMATION SYSTEMS

All geometric data layers obtained from different methods, mentioned above, need to be archived and managed via relevant information systems to ensure accessibility, security and reliability information [2]. GIS (Geographic Information System) brought together small to large scale data layers to manage archaeo-geological and municipal projects. Also they can store and update information about cultural heritage places through their geospatial databases.

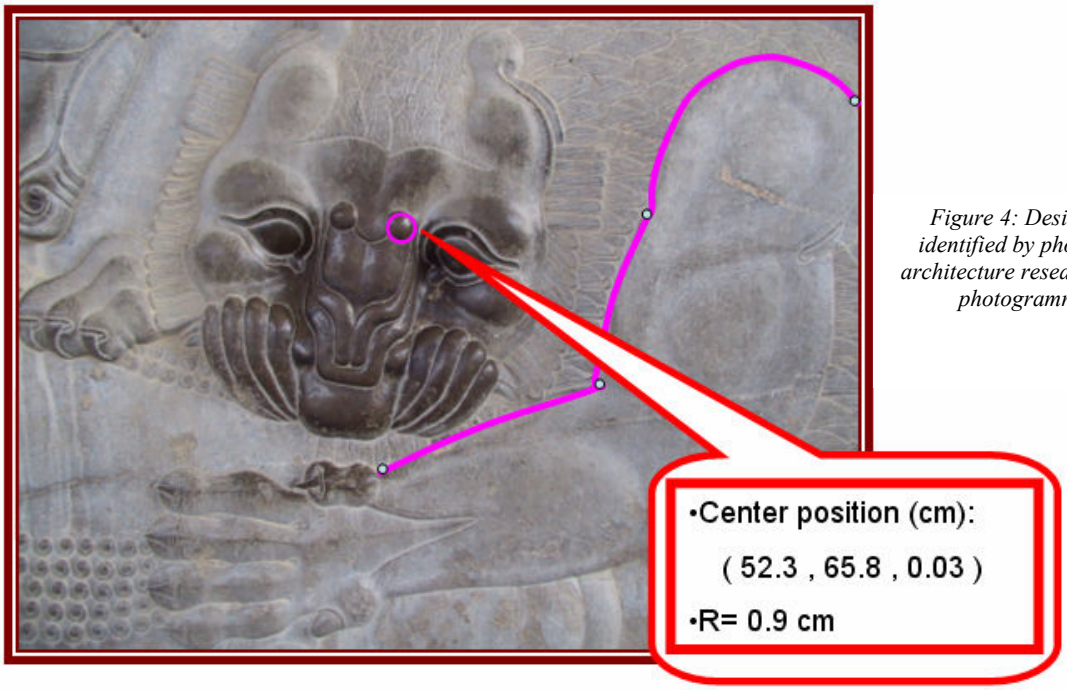

Figure 4: Desired elements of a petrography identified by photogrammetric methods ancient architecture researches and stored in architectural photogrammetric information systems.

APIS is an information system accessible via internet which provides a platform for all who are interested and work in the field of conservation and preservation of cultural heritage. The system, focused on the collection of material about single objects in the beginning, was enlarged by modules which are designed especially for urban data management. APIS accessibility via internet provides the possibility for everyone to take part in the conservation work. APIS provides a service for those who want to make a useful documentation. People interested can copy the instruction for a proper documentation, ask for help, join the discussion about the conservation work, find photogrammetrists who can handle their pictures, read more about photogrammetry and conservation of cultural heritage, find links to related internet-sites, see examples of already applied photogrammetric documentation, provide others with the information they collected by data input into the database. The latter is nothing but a systematic filling in of data sheets. But APIS also provides facts for people who need material about objects [5]. They can search such system for a special object with defined geometric properties, to measure desired parts of each and generating new models and databases, as in figure 4.

5. DISCUSSIONS AND CONCLUSIONS

Photogrammetry has proved its efficiency to create models which texture is of prior importance. Modelling the paintings, eroded and broken portions of ancient objects and very large scale plans of sites are some examples of interest for close range photogrammetric fields of work. Large and small scale models such as site plans, city plans, DTMs and orthophotos extracted from remote sensing images and aerial photographs can present information for historic architecture studies, archaeological researches and municipal designs.

Creating surface models for irregular and complex surfaces is of the superiorities of laser scan technology. Volumetric and complex surfaces could be represented by terrestrial laser scanning (via large and very large scale models) and LIDAR (for medium to very small scales) in less time than photogrammetric processes.

Integrating relevant information layers obtained from different methods (geomatics, archaeo-geophysical images, geological maps, architectural designs etc.) in relevant information systems such as GIS and APIS would ease the accessibility of information in research and executive projects.

In order to perform geomatic methods through cultural heritage fields, standards are needed to define optimized methods for each through data acquisition, processing and presentation procedures. Standards should be designed based on making more contribution between geomatics and current task groups working in cultural heritage organisations. In order to define rather efficient instructions, detailed parameters required for measurement, analysis and representation of historic and cultural objects are to be extracted from definitions and current instructions. As a mater of fact, precision required and quality of visualization models, are the principal parameters, concerning time and economy of each project.

ACKNOWLEDGEMENTS

The authors acknowledge the extremely valuable assistances of Research Foundation of Persepolis and Pasargadae and technical groups working at international heritage site of Persepolis, both in interviews and data acquisitions.

REFERENCES

[1]: Bosse Lagerqvist, "A system approach to conservation and cultural resources management, photogrammetry as a base for designing documentation models"
[2]: Robin Letellier, 2001. "Bridging the gap between the information user and the information provider", Report of Working Group 1, Getty Conservation Institute. page2.
[3]: Heinz Rüther, "The Concept of an Integrated African Heritage Documentation and Database for Architectural and Cultural Landscape Sites"
[4]: Interview task groups at Research Foundation of Persepolis and Pasargadae, February (RFPP)2005.
[5]: Ulrike Herbig, Gernot Gmeinhart, Markus Landerer. "Administration examples for the usage of cultural heritage recordings", Institute of Photogrammetry and Remote Sensing, University of Technology, Vienna
[6]: http://www.univie.ac.at/Luftbildarchiv/intro/aa_mus2.htm
[7]: http://www.univie.ac.at/Luftbildarchiv/wgv/pict/gars.htm
[8]: http://home.t-online.de/home/Fokus-GmbH/
[9]: http://www.apis.org