DOCUMENTATION OF CULTURAL HERITAGE TECHNIQUES, POTENTIALS AND CONSTRAINTS

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ABSTRACT:

Cultural Heritage is known as an invaluable asset of human being, which portrays his achievements over centuries. The need for identification and preservation of cultural heritage is well understood and experts' attempt is to exploit any possible method to fulfill this aim. There are several published literatures and documents, which emphasize on the importance of the documentation of the cultural heritage such as Burra Charter. However, with the development of human and invention of new tools and technologies, the concept of the conservation of cultural heritage has changed considerably. The new technologies such as computers and digital tools have opened new windows and bestowed new opportunities in the process of conservation of cultural heritage. In this regard, it is important to review different technologies in order to make the best advantage of these tools in the cultural heritage field. The focus of this paper would be on the non-technical users who need to gain an overall comprehension of these new emerging tools. The foundation of this paper will be on the existing literatures published by various experts in addition to the author's experience and research in the conservation field.

1. INTRODUCTION

According to the Burra Charter and in view of the fact that conservation process of cultural heritage is composed of three phases of 'understanding the significance, developing policy, and managing in accordance with the policy'. (Burra Charter, 2013) the fundamental need of any conservation project is understanding the object and gathering data about its physical condition prior to any action and intervention that might change the object. Furthermore, cultural heritage is threatened by various factors such as natural hazards, vandalism, development of cities, and aging, which in a pragmatic view, one cannot guarantee their eternality and each moment there is the possibility of their loss. Thus, we should make sure that they are well documented, which in case of their loss we could pass the documentation and recording archives to the future generations or if needed use them for reconstruction purposes.

In this regard, the use of digital technologies in data acquisition and recording the object condition could be very substantial. Digital technologies can considerably ease and expedite the documentation process, while ensuring a precise result and an accurate output for establishing the conservation phase. Nevertheless, the documentation stage cannot be terminated only in the first phase of conservation process; on the contrary, since keeping the archives up-to date and monitoring the object needs gathering more data, it goes hand in hand with other phases of the project. In fact, in any phase of conservation process, there is an essential need for documentation and in each attempt digital technologies can assist the conservation team by providing appropriate data according to the project needs.

The applicability of digital technologies in the conservation process of cultural heritage has been studied, experimented and analyzed by numerous scholars and experts. However, there is still a knowledge gap between cultural heritage experts and surveyors, IT and computer experts, especially in developing countries. Moreover, the rapid advancement of the electronic means has made the process more complicated since cultural heritage experts should update their knowledge in order get to know the new achievements, which are efficacious in preparing conservation plan and developing policy.

In order to cope with this problem there have been published many different literatures, especially by surveyors. Nevertheless, the problem as yet exists and Cultural Heritage experts are not well familiar with the fast emerging technologies that can help them in the process of documentation and conservation of cultural heritage. 'In certain cases large amounts of money are invested without first considering the purposes and aims of a project at hand. Subsequently large amounts of records are produced, which may end up stored in an archival room and forgotten.' (Quintero, 2003:3) To this effect, there is this need to afresh point out this problem by studying and bringing newfound technologies to notice and establish a foundation for cultural heritage experts' understanding. This can help heritage experts and managers to communicate with surveyors and information specialists using a 'technical language' (Letellier et al., 2007: xiv), which will lead them to better prioritize the project needs and ameliorate the output of their conservation measures. To this purpose, this paper aims at studying different techniques of documentation and reviewing their pros and cons.

2. CATEGORIZATION OF DOCUMENTATION TECHNIQUES

Each object has its own unique characteristics and it is according to the its physical condition, time, and the amount of accuracy needed and other requirements of the project that the conservation team decides what specific documentation approach or tool is more applicable. To this end, a classification of these techniques can aid to better understand and deal with their characteristics. The variety of documentation techniques in the process of recording cultural heritage has caused different classifications to be offered by the survey experts. In this paper, the categorization is based on the metric data and acquisition of points' coordinates of the targeted object with or without taking images. In this regard, based on the following diagram, three categories will be studied in the following chapters: Image-based, non-image-based, and combinative methods.

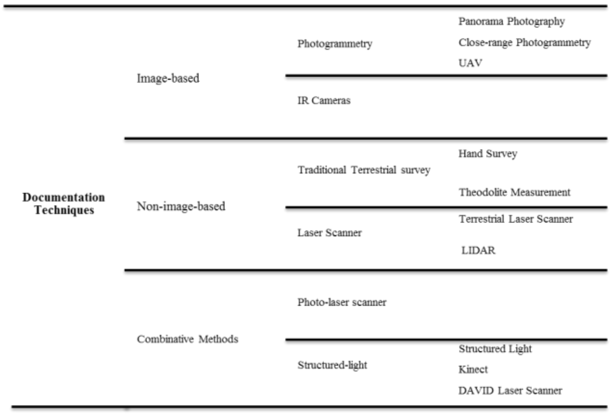

Figure 1. The categorization of documentation techniques

2.1 Image-based Techniques

Photography is a basic tool for documentation of cultural heritage in a certain point of time. Production and archiving of these data are crucial for the future needs in the preservation and conservation process. In this category, image is the base for data acquisition of the targeted object and the coordinates can be accessible after the processing phase. Here, photogrammetry and IR camera are reviewed as the most important examples of the image-based techniques.

2.1.1 Photogrammetry: Photogrammetry consists of techniques for interpreting, measuring, and modeling the objects based on their acquired images.

2.1.1.1 Panorama: Panorama photography multi-image photogrammetric methods. This method is a an excellent example of rendering based on image in contrast to rendering based on model, which overcomes the problems of 3d modeling. Panorama images are useful for measuring. Moreover, these images can be used for analyzing the dimensions if adjustment and camera calibration is operated properly. Nowadays, panoramic cameras have increased the reliability of this method, and removed the problems relating to the stitching and overlapping process of images. Panoramic photography can be used in documentation, education, tourism, and presenting the historic buildings and sites. The most important advantage of this method is its capability in storing the data of a large object with the help of low number of pictures. Low cost, less time, ease of use in geographical information systems, the ability of presentation in web pages, high attraction for users are among the other advantages of this method. On the contrary, large image size which needs large memory, the need for viewer softwares, the limitation for movement in the interior spaces, limitation in the camera angle are some the disadvantages of this technique.

2.1.1.2 Close-range Photogrammetry: Photogrammetry is an independent method in the documentation process. This method is based on at least two images with overlapped data, which guarantee the triangulation process. The aim of digital close-range photogrammetry is making the process of recording and processing data simpler and faster. This method is an accurate technique for documenting color and texture, and providing metric data of objects with different size and complexity in a relatively short time. This technique can be used when the access to the object is limited, or when the direct measuring on the object would threaten it.

Today, using of-the-shelf cameras with high accuracy has made the close-range photogrammetric process much easier and more cost-effective to apply. Close-range photogrammetry has also a high applicability in generating 3D models of the targeted objects. These models can be useful in creating a 3D archive and answering to different aims of documentation. In short, Productions of photogrammetry can be rectified photos, ortho-photos, and 3D models. Although the usability of photogrammetry can be classified according to the required accuracy and detail, generally, its application in archeology and heritage conservation can be enumerated as follows:

- Documentation of historic buildings and small artifacts, measuring the facades
- Providing color and texture data
- Measuring the deformation of buildings, analyzing the changes, and predicting the future changes, for example cracks and fissures. for this purpose, a cloud point model of the object should be generated in different periods of time in order to be able to perform a continuous comparison between models and analyse the changes.
- Surveying the excavation sites
- 3D modeling of historic cities
- Reconstruction of destroyed objects
- Creating an accurate metric archive for analysis and future needs

In photogrammetry, the results can be quickly presented, before other operational measures in the preservation process. In comparison with hand survey, this method is more secure due to its nonintrusive and non-contact nature, and provides a large amount of data. The advantages of photogrammetry can be summarized as follows:

- Ease in creating an archive for future needs
- Large amount of data (Patias, 2006)
- High accuracy depending on the needs of the project
- Providing 3D models from small objects to large complex objects such as archaeological sites
- Providing metric and vector data of the texture of the object due to its image-based nature, which increases the understanding of the user.
- Geographical data, which can be indirectly extracted from the images at any time and according to the needs of project
- Low-cost and portable equipment

In contrast, the disadvantages of this technique are:

- Sophisticated to be applied by non-expert users
- influenced by and dependent on the accuracy and resolution of the camera
- Its applicability is limited by lack of proper points for photography or hindrance. In this case, it should be combined with or replaced by other techniques.

2.1.1.3 UAV: UAV or Unmanned Aerial Vehicle as it can be understood form its name operates without an on-board pilot. (Remondino et. al., 2011) Other terms such as Remotely Piloted Vehicle (RPV), Remotely Operated Aircraft (ROA) Remote Controlled Helicopter (RC-Helicopter), Unmanned Vehicle

Systems (UVS) and model helicopter (Eisenbeiß, 2004) are also used for this system. Different types of UAV are categorized according to their weight, size, endurance, flying attitude. (Remondino et al. 2011) This system is composed of a light low-cost aerial vehicle such as a small helicopter, a digital camera, and GNSS/INS systems for identifying the position and navigating the system.

The initial motivation for developing UAV systems was for military purposes. However, in the recent years, the application of UAV has expanded considerably so that it is used for documentation and surveying purposes. This low-cost system can be an appropereiate alternative to the classical manned aerial photogrammetry (Colomina et al., 2008; Remondino et al., 2011).

This method has indeed proved its efficacy in the documentation of cultural heritage and archaeological sites. Documentation and 3D modeling and surveying of historic sites and structures can be performed using low-altitude flight. Using UAVs, we are able to produce panoramic images, Digital Surface Model (DSM), ortho-photo, and three-dimensional models with high accuracy of the surveyed objects. Some advantages of this non-intrusive system are:

- Real-time capability (Eisenbeiß, 2009), fast image acquisition, and short interruption times which make it suitable for archaeological field-work (Sauerbier & Eisenbeiß, 2010)
- Small areas can easily be covered by this system so that images from different sides of the targeted object can be provided. (Eisenbeiss, 2004)
- UAVs provide the opportunity to survey inaccessible and/or dangerous areas which cannot be accessed directly using other systems or piloted aerial systems. (Everaerts, 2008; Eisenbeiß, 2009)

In contrast, vibration due to their relatively low weight and the impact of wind, the maximum load they can carry and the integration of different sensors are some of the problems we are dealing with in UAVs.

2.1.2. IR Camera: IR is the part of the electromagnetic spectrum that we perceive as heat. Thermal or infrared energy is not visible to the naked eyes because its wavelength is too long to be detected by the human eye. In the spectrum of electromagnetic waves, we generally work with visible light. Standard CCD/ CMOS cameras for example, are sensitive to visible light spectrum. However, nowadays with the help of advanced technologies, we are able to acquire data in ultraviolet (UV), and infrared (IR) portion of the electromagnetic spectrum.

Everything with a temperature above absolute zero emits heat. In thermography or infrared light, an infrared imaging and measurement camera is used to observe and measure the emitted thermal energy from a target. This capability can be highly useful in the documentation of cultural heritage and studying the art work (Pelagotti et al., 2007) for deeper analysis (Voltolini et al., 2007) particularly for monitoring and conservation of historic monuments (Moropoulo et al., 2001).
These cameras are able to show thermal distribution of the surface in an image. Some physical conditions such as relative humidity, atmospheric temperature, reflected apparent temperature and material properties of an object like the degree of emissivity affect this distribution. (Kordatos et. al., 2012) Modern IR imagers are highly sensitive temperature differences of 0.1ºC or less, which enables them to evaluate and present subtle thermal phenomena, in the form of slight temperature gradients. (Rizzi et al., 2007) IR camera provides the capability of observing and documenting back structure of frescoes and paintings, padding, older layers, hidden structures, pentimento and preparatory drawing. It also helps analyse the composition of objects and buildings, and the state of conservation of façades, vaults and architectural structures (Moropoulo et al., 2001; Pelagotti et al, 2007; Voltolini et al., 2007) This non-destructive tool (Rizzi et al, 2007; Voltolini et al., 2007; Mercuri et al., 2011; Kordatos et al., 2012) can be used in detection of moisture and rising damp in buildings and masonry structures (Kordatos et. al., 2012), identification of cracks (Rizzi et al., 2007). IR images can also be integrated with and mapped on digital images and 3D models. With this capability a quantitative analysis of damages is possible as we access to the metric data. (Voltolini et al., 2007)

2.2 Non-image-based Techniques

Here, images are not the base of the surveying process and the coordinates of the different points can be accessible directly using range-based tools.

2.2.1 Traditional Terrestrial Survey: In this category, and survey and theodolite measurement will be reviewed in

2.2.1.1 Hand Survey: In this technique hand measurements are performed using a simple tape or a laser distance measurer, 'spirit level or plumb line'(MacDonald, 2006). The measures are recorded onto a sketch which is drawn prior to survey. The results of the measurements can be drawn in CAD software. This method can be used for producing the detailed drawings of buildings when modern techniques are not accessible or expensive to apply. The unavoidable physical interaction with the targeted object during the survey process helps achieve an accurate result which is limited only by the visual acuity of the surveyor. (MacDonald ,2006) In comparison to other methods, hand measurement, is particularly helpful where visibility is limited. (Haddad, 2011) Its low-cost and non-complex nature, which can be performed by non-expert operators with basic knowledge of surveying, is the major reason for its frequent application in cultural heritage documentation. In contrast, some disadvantages of this technique, which limit its application, are as follows:

- It is time- consuming and needs hard field-work
- Curved and high detailed surface cannot be measured with the help of this method
- High accuracy cannot be guaranteed in this method even though the final production is similar to the real object
- Inaccessible features cannot be surveyed
- If data are not recorded on field, the survey is incomplete and cannot be complemented in office (Daneshpour, 2009)

2.2.1.2 Theodolite Measurement: Theodolites can be used in topographic survey, determining the coordinates of points, and providing the outline of the targeted objects –even with curved surface- (Harrison, 2002) since they can generate both angle and distance measurements simultaneously (MacDonald ,2006). A wireframe model can also be generated, which with further process and using modelling software such as CAD Software, can be the base for production of a solid 3D model. Accordingly, these instruments are applicable and multi-purpose means for cultural heritage documentation. This low-cost method provides accurate measurement of the target. However, this method needs skilled operators, is time-consuming, and in dealing with complex forms with a large number of points is not quite efficient. (Haddad, 2011) Similar to hand survey technique, if data are not recorded on field, the survey is incomplete and cannot be complemented in office. (Daneshpour, 2009)

2.2.2 Laser Scanner

2.2.2.1 Terrestrial Laser Scanner: 3D scanning technique has been available since the 1980s. (MacDonald, 2006) Laser scanner is in fact a robotic total station, which can acquire data from the target at a high speed and in a short time. Distance measuring is performed in regular networks without the need for reflector. The fundamental basic in the operation of this instrument is based on the two elements of distance and angle.
Laser scanners have a field of view similar to human eyes. They can be controlled by computer and integrated with a GPS.

Laser scanners can have a wide range of applications in cultural heritage documentation from small objects to large complex buildings. The application and capabilities of this modern technique is continuously developing. Real-time data acquiring in a real scale, high accuracy, high speed and producing large amount of points are among the major capabilities of laser scanners. The acquired point cloud can be used for different purposes. Generally, three steps in the documentation process with laser scanner:

- Field survey and data acquisition
- Editing and data processing including eliminating redundant data and noises, transferring the information into a coordination system, integration of the point clouds, integration of the scanned data with images
- Production of final output including measurements, sections, texture and 2D drawings, Solid 3D model

The most important advantage of this technique compared to theodolites is its high speed in data acquisition which decreases the field work considerably. In contrast to image-based techniques, the surface form can cause no limitation in laser scanning. In fact, laser scanners can provide better results in regards to detailed irregular objects. This technique can be used independently or in combination with other techniques (Rüther et al., 2003) according to the needs of the project.

Despite the multitude advantages of laser scanner, its limitation in documenting surfaces with sharp edges (Rüther et al., 2003; Lerma et al., 2008) and color and texture data of is unanimously approved. Though laser scanners are recently integrated with digital cameras, the integration of scanning result with the image data complicates the process. The areas with obstacles or hidden points are another problem, which limits the capability of laser scanner as it impedes a thorough survey. In this case, more stations are needed to fill the gaps. Nevertheless, in some cases, even more stations cannot solve the problem and it is required to use other surveying methods. Objects with reflective surface are another example from which laser scanner fails to provide accurate data. Since water absorbs the rays near IR spectrum, while there is moisture on the surface, the reflection of laser beam cannot perform properly. Accordingly, rainy condition and moist surface affect the quality of the data acquisition and degrade the accuracy of the result. Due to its large size and the minimum range of laser beam, the application of laser scanner is limited in small interior spaces. High cost, the need for skilled operators, time-consuming post processing are another limitations of laser scanners.

2.2.2.2 LIDAR: Light detection and ranging (LIDAR) system which was first introduced by NASA in 1970. (Haala & Brenner, 1999) is a developing technology for producing digital surface model (DSM) at a high speed (Flood & Gutelius, 1997). LIDAR can scan a region in a stripe pattern so that the integration of the scanned stripes provides a point cloud model of the region. This data acquisition system functions based on measuring the distance with laser beam.

The components of LIDAR are Differential Global Positioning System (DGPS) for identifying the coordinates of the laser pulse transmission location; Inertial Measurement Unit for measuring the laser transmission angle; and Laser scanning system for measuring the distance between laser pulse transmission point and earth surface. These components are installed on a plane or helicopter. The time for returning a transmitted laser pulse from the features located on the earth is calculated to determine distance between transmission point and earth surface and finally the coordinates of the targeted point. However, when a laser pulse is transmitted to earth, it might hit various obstacles. This will affect the accuracy of the survey. Modern systems have the capability of recording at least two signals, first pulse and second pulse. This characteristic differentiates LIDAR from normal photogrammetry systems since in regions covered by vegetation, in addition to the digital model of the earth surface, vegetation can be surveyed as well. High speed of data acquisition is a major advantage of LIDAR. However, laser pulse transmitted from LIDAR might change considerably due to the fact that laser can be spread by air molecules and dust particles. This problem will cause a shift in the wavelength and affects the accuracy.

LIDAR sensors have the capability of surveying hundreds of points in a second, which makes it an ideal tool for surveying archaeological sites and systematic research on historic buildings and excavation areas. The integration of data from LIDAR with photogrammetry using GIS would create a reference base for archaeologists in conducting their research.

2.3 Combinative Methods

Tools that are introduced in this section have the structure and characteristics of both previous categories, which means they take advantage of image-based methods with photogrammetry base, and non-image-based techniques, which survey the target by transmitting beam to the surface. To this effect, these tools try to overcome the weaknesses and problems of two other categories.

2.3.1. Photo-laser scanner: Photo-laser scanners combine close-range photogrammetry with the point cloud produced by laser scanning. The reflectors used in this technique have more reflective nature than other objects. Thus, automatically they can be recognized in the software process. Since all reflectors have distinct coordinates, transformation of laser points to the standard coordinate system can be performed automatically.

After scanning the whole target using the laser scanner part, the digital camera mounted on the scanner starts taking image. Afterwards, images will be integrated with the point cloud and points find their actual color and texture.

This tool is highly applicable in documentation of cultural heritage and is particularly useful in surveying inscriptions and reliefs. Ortho-photo can easily be produced with the help of photo-laser scanner and 3D model can be processed with a single image. High speed of this instrument is a great advantage, which decreases the fieldwork load considerably. Since laser scanner operates weakly in surveying the edges, images taken with the camera obviate this problem so that edges and cracks are easily recognizable and the accuracy of the final product would be more reliable.

2.3.1 Structured Light: Structured light, Kinect and David laser scanner are placed in this category since all of these methods use the same logic in documenting the target.

2.3.1.1 Structured Light: In the coded structured light or topometric technique (Akca et al., 2006) projection of a single pattern or a set of patterns onto targeted object shapes the fundamental basic of coded structured light. A single camera or a set of cameras should also image the target. This coded pattern helps correspond between image points and projected pattern points and perform the triangulation process. (Salvi et al., 2004) Using this process a 3D model of the surveyed object can be generated. The aim of structured light technique is increasing the corresponding points in each image, which in turn expedites and eases the modeling process. In fact, this technique operate with a similar method to photogrammetry while finding and matching points from different images forms the foundation for producing a 3D model. However, colored light pattern sent out to the surface of target so that the matching operation can be performed automatically with a high accuracy and in a relatively high speed.

With the help of the generated 3D model of the target, measures and coordinates of points can be extracted easily. Accordingly, this technique is an ideal tool for documenting cultural heritage objects in particular inscriptions, reliefs, statues and decorations. Nevertheless, this method cannot be operated easily and requires skilled operator and complex software system.

2.3.2.2 Kinect: With the help of this developed depth/range sensors, direct generation a rough 3D geometry of surfaces is possible. (Comb`es et al., 2011) RGB-D cameras are examples of this category of sensors, which are mostly designed for computer gaming and entertainment applications. (Henry et al., 2012) Kinect is in fact a game-oriented RGB-D camera which is known as the first general consumer-grade structured-light camera. (orrego, 2012) This structured-light-based sensor is composed of RGB and IR sensors with an IR pattern projector. (Comb`es et al., 2011) and provides 'real-time colour and depth data' (Joubert & Brink, 2011) Kinect field of view is 60° and its capability in providing depth data is limited to a distance of about 3.5 meters. (Bonnal P.E., 2011: 4)

Low cost, small size, low weight, and portability of this system in addition to possibility of its utilization while moving from one point to another are the properties, which make Kinect a proper tool for documenting indoor spaces of cultural heritage. In fact, in small spaces where the application of other tools such as laser scanner and total station is not possible can be scanned and documented with the help of Kinect. For example, in the documentation of historic buildings while we are facing with narrow staircase and corridors, this tool can be moved in the space to survey the space and acquire the coordinates of the points. Kinect can also be applied in the documentation of small objects and statues for generating point cloud and subsequently a 3D model. The major disadvantage of the Kinect is its limitation in scanning outdoor spaces. (Bajpai & Perelman, 2012) Moreover, the application of this tool is relatively easy and can be performed by a non-expert user, the post processing phase needs a high skilled user for achieving the desired result.

2.3.1.2 David Laser Scanner: DAVID laser scanner is a low-cost three-dimensional documentation method, which is composed of a computer, video camera, a background containing control points and a line laser source. (Aydar et al., 2011) This technology is in fact a software package based on triangulation method. The components of David laser scanner are: Plain board in the background; hand-held line laser; Camera; and DAVID-laser scanner software. Its self-calibration capability is major advantage preventing further expenses. (Bajpai & Perelman, 2012)

In the scanning process, the user manually moves the laser source around the object. (Aydar et al., 2011) The accompanied software of this tool provides the possibility of mapping the texture and color data on the generated 3D model. Low cost and the user friendly characteristics of DAVID laser scanner give it a popular tool for documenting small objects.

3. CONCLUSION

The application of a wide spectrum of technologies for metric documentation of cultural heritage confirms the multiplicity of appropriate choices for documentation of an object. However, a single method cannot guarantee the desired accuracy and there are always obstacles and problems, which limit the capabilities of a technique. Cost, time, complexity and size of the object itself, accessibility, the skill of the survey team etc. play an important role in selecting a survey method. Each single method has its own particular characteristics. Nevertheless, in most cases, a single method cannot be responsive to the requirement of a project and it is needed to exploit a combination of different techniques to achieve the desired result. This hybrid approach –if the allocated budget allows- is the best possible method for documenting cultural heritage.

Thereupon, in the documentation process of valuable objects and sites, studying and planning the needs of the project and other influential factors have to be done to guarantee the usefulness of the project. To this purpose, a knowledgeable cultural heritage expert can manage to grasp the needs and the requirements of the project and be a reliable and trustworthy counselor for surveyor and IT specialist. The result of this cooperation is of a great importance inasmuch it decreases the risk of wasting time and budget and assures the usability of the output. The following table is designed based on the previous chapters to provide a summary of the discussion and help cultural heritage experts to gain a better insight on the recent technologies used in the documentation Process of Cultural Heritage.

Technique			Pros	Cons
Image-based Techniques	Photogrammetry	Panorama Photography	Quick data capture, simple, low-cost, free accessible software, effective presentation of objects, color and texture data, ease of use in GIS, the ability of presentation in web pages, high attraction for users	Requires pre-planning for photography, needs processing and viewer software, limitation of movement in the interior spaces
		Close-range Photogrammetry	Short field-work period, cost-effective, accurate, non-intrusive, texture and colour data, cheap portable equipment, output can be processed in common CAD software, ease in generating an archive	requires network design and pre-planning for ideal photography, influenced by the accuracy and resolution of the camera, obstacles limit the integrity and accuracy, requires high skilled operator for data processing
		UAV	Real-time capability, fast image acquisition, cost-effective, short interruption times, texture and colour data, proper coverage of target, proper for inaccessible and dangerous areas	requires skilled experts for processing data, dependant on the wind condition due to its low weight, obstacles limit the integrity and accuracy
	IR Camera		Non-destructive, appropriate for damage evaluation such as moisture and rising damp, identification of hidden structure and older layers, high accuracy, capability of combining with RGB images and 3D models	Requires high skilled expert to integrate data with other sensors and techniques
Non-image-based Techniques	Traditional Terrestrial Survey	Hand Survey	Low cost, simple to apply by non-experts, requires low cost and accessible equipment, helpful where visibility is limited	Low accuracy, time-consuming, hard and long field-work period, problem in documenting curved and high-detailed objects, difficulty in documenting inaccessible features, influenced by human errors
		Theodolite Measurement	Cost-effective when number of surveyed points are limited, ease of use, appropriate accuracy	long field-work period, color and texture data cannot be documented, dependant on the climate condition, need for skilled operator
		GPS	Provides location coordinates in global geographical system, highly useful in combination with other techniques, appropriate in documenting mass targets and structural deformation	Expensive in data acquisition with high accuracy (The cost is dependent on the accuracy of the GPS type), not applicable in indoor spaces
	Laser Scanner	Terrestrial Laser Scanner	High accuracy, high speed, non-intrusive, large amount of data, documenting complex surfaces and objects, can be applied in dark spaces and at nights	Expensive, requires high-skilled operator and special software, difficulty in processing and storing data due to high density and low memory, time-consuming data processing, influenced by obstacles, dust reflective features of the object, sunlight and rainy weather, difficulty in recording small spaces, weak in documenting edges and cracks
		LIDAR	High accuracy, high speed, non-intrusive, appropriate in documenting mass targets and large-scale sites, data acquisition in vegetated areas, large amount of data	Expensive, requires high-skilled operators, weak in documenting edges, noise and gaps, difficulty in processing and storing data due to high density and low memory
Combinative Techniques	Photo Laser Scanner		High accuracy, short fieldwork period, cost-effective, large amount of data, texture and color, appropriate for complex surfaces	Expensive, requires high-skilled operator and special software, time-consuming data processing,
	Structured-light	Structured Light	High accuracy data, automatic process, high accuracy in matching process	Requires high skilled operator and special software
		Kinect	Low-cost, low field-work period, applicable in documenting small objects and interior spaces, texture and color data	Time consuming processing, high skilled operator for programming (if needed) and data processing
		DAVID Laser Scanner	Low-cost, quick, ease of use, accessible equipment, appropriate in documenting small objects, texture and color data	high skilled operator for programming (if needed) and data processing

Table 1. Documentation Techniques; Pros and Cons

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