Building-up Affordable Data Collection System to Provide 3D Scaled Image for Heritage Documentation

Nadia Abood¹. Dr. Imzahim Abdul Kareem², Dr. Hameed Sarhan³

¹,²,³Civil Engineering Dept./University of Technology/ Baghdad/ Iraq

Abstract. To solve the problem of insufficient efficiency of 2D display for damaged and erosional parts of important historical heritage and a high cost of a scanning systems used, affordable data collection system to provide 3D scaled image for Heritage Documentation has been proposed to obtain scaled image with lower cost upon user. The main target of Smart Automated System (SAS) to reconstruct 3D image for various structures and terrain. Mechanically, this system was designed to apply rotation function, that a digital camera will be rotated by using a stepper motor with specific horizontal angles. While the SAS rotates; non-metric digital camera which must be ready to capture automatically a sequence of 2D images. These captured 2D images must be processed and subjected to registration process for obtaining 3D scaled image. MATLAB software has been used to perform automation function between hardware parts (explained bellow) as well as processing of images.

Key words: Computer vision, 3D vision, image processing, MATLAB, cultural heritage documentation, MATLAB package for Arduino and stepper control, Visual Basic.

1. Introduction

The adapted smart automated system (SAS-HD) was as an invention to produce scaled image to preserve important historical heritages that due to eventual model, the antiquated parts of scanned monument can or must be restored to keep abreast of developments around whole archaeologist.

Initially, all these mentioned above, have been preceded by stages which will mentioned in details later. Firstly, electrical and mechanical components had been assembled and would manufacture (SAS-HD). Digital camera (DC) is an essential component of whole system in addition to other parts. It will properly activate data acquisition stage (digital images). Digital images can be considered as a discrete representation of data possessing both spatial (layout) and intensity (color) information (Solomon and Breckon, 2013). Digital Image processing will be a secondary pivotal stage that perform its steps on data (digital images) which obtained on first stage in order to obtain vital, effective, tangible results, which assimilate as a scaled image (3D reconstruction stage). It is possible to create photorealistic 3D models, which permit the exploration and the enjoyment of archaeological heritage, ranging from very small objects to whole buildings. There are also some hybrid techniques, which can guarantee satisfying results. Nowadays, it is also possible to reconstruct large environments, like cities and buildings, while maintaining a high level of graphic definition(Bruno, et al., 2010).

The resulted images are not that good to be used in texturing. Therefore, non-metric digital camera (GOPRO Hero black7) has been mounted on a triple-leg based head and must be used
under best possible light conditions in order to obtain reliable texture. A large number of photos is captured from free-positions then registered with the 3D model using key-points. A challenge in mapping these photos on the geometry is the automation which requires an effective occlusion detection algorithm based on the model geometry (Abdelhafiz, 2012).

2. Methodology and Experimental work

Smart Automated System for Heritage Documentation was invented to convey the mechanism of rotation as same as rotation of terrestrial 3D-laser scanner. The mechanism for (SAS-HD) has been based on assembling a set of electrical and mechanical subsystems that are grouped and controlled to provide regular rotational movement around optical axis of the whole system which settled on a tripod. Digital camera (DC) was the most intentional part to be effective during rotation of the whole system that it must be prepared to capture a series of successive overlapped images (data acquisition) while it controlled to rotate with a specified horizontal angle.

The engine of the whole system was stepper motor (SM). SM had been connected by coils with interface card (IC) or Arduino (UNO). MATLAB package was the used software to steer the motion of (SAS-HD) through a specified code each had destined to control subsystems, kinetically. Additionally, a group of laser pointer sensors were mounted and settled on upper rotational part of system. These four sensors have been controlled by a code made by visual basic application. These sensors had been simulated with DC motion and their functions based on measuring distance (depth) between (SAS-HD) position and scanned building. Finally, (SAS-HD) function will being summarized to conserve heritages by creating 3D-model (scaled image) where cracks can be detected from 3D texture view of them and as a result, they must be subjected to reconstruction process anywhere.

Practically, methodology of work is has been followed in order to obtain scaled image was as following. (Priya, et al., 2017)

| Algorithm 1: 2D to 3D model vision |
|------------------------------------|
| **Input:** 1st and 2nd view of an intended object or sequence of views of an image |
| **Output:** 3D (scaled) image of the overlapped 2D views |
| 1. Input data (2D images) are subjected to Binarization process so it must be converted into grey scale image (`rgb2gray` string) |
| 2. As camera parameters were known, so it should be used for camera calibration. |
| 3. Due to applied in steps 1 & 2 above, the distortion has been removed and the undistorted image had obtained. |
| 4. Identify matched points. |
| 5. The camera pose of the current view should be related to the image space coordinate system. |
| 6. Hereon, triangulation by registration among matched points for obtaining the initial 3D world point should be achieved |
| 7. Display the 3D points, specify the location, and Compute the dense image of the 3D model and display the sample |

3. Exterior design for (SAS-HD)

As a first step of building up affordable system for scaled image production, SKETCH UP program had been used to design the inner structure as well as the outer framework for system. (Figure.1) shown the final design and internal components was devised in Sketchup software.
4. Assembled Components and applied Software
The SAS-HD adapted system comprises of automation among its components; both mechanical and electrical. Automation has been comprised of hardware which were parts to be automated; electrical and mechanical subsystems and software (programs used for automation application). This software as well as hardware had been explained in detail by this diagram below figure No.2:

![Diagram of Adopted system (SAS-HD) parts](image)

**Figure 2.** Adopted system (SAS-HD) parts
5. **Automation of hardware components**

Since the components were assembled, they should be connected by power supplier, battery or PC port with the use of interphase card (IC); Arduino. So, many components will be explained by their automation:

5.1 **Laser rangefinder module sensors**

Sensors were settled ordinarily on rotational part of SAS-HD, they had been rotated as same as non-metric digital camera in horizontal rotation around SAS-HD axis. Their prior function based on measuring distances (depth) between system position and intended scanned object. It had been controlled by a specific code from MATLAB packages. Laser pointer Sensor were characterized by measuring the distance of 50 meters. Its specifications are stated in (Table 1). Additionally, laser sensitivity and control can be used, operated and received through the Serial Port from any controller such as Arduino and others, with very simple instructions. These rangefinders were represented in Figure 3 below:

**Table 1.** Laser rangefinder specifications JRT meter Laser EntfernungsMESSer Sensor Modular for 40m, 50m, 60m, 100 m

| Product Model | M605B          |
|---------------|----------------|
| Accuracy      | ±1 mm (0.04 inch) |
| Measuring Unit| Meter/inch/feet |
| Measuring range (without reflection) | 0.03-150 m |
| Measuring Time | 0.1~3 seconds |
| Laser class   | Class II       |
| Laser Type    | 635nm, <1mW>   |
| Size          | 75 × 40 × 18 mm |
| Weight        | About 21 g     |
| Voltage       | DC2.5~3V       |
| Operating Temperature | 0-40°C(32-104°F) |
| Storage Temperature | -25~60°C(-13~140°F) |

![Laser distance meter](image)

**Figure 3.** Laser distance module sensor
5.1.1 Laser distance module sensor code and operation

Laser distance sensors are transmitter-receiver devices, these four sensors have been settled on DC corners by the way ensures visibility of them toward the target. It will be being rotated as same as DC rotation with specified horizontal angles selected by user need. The motion of sensors were basically made by code with MATLAB workspace.

While code of operation of rangefinder laser sensors has been done by visual basic software and apply following steps as below:

1. Connect USB cable connector to USB 4Port Hub which then plugged into PC adapter.
2. Open visual basic app.
3. Insert activation code into VB workspace
4. Click on start command in toolbar
5. Choose COM no. has been read while connecting USB adapter into PC (point2 in figure No.4)
6. Click on start measure, so distance will be measured and appear in field appoint to COM no.
7. Repeat steps 4-6 with all sensors been used.

Hereon, a figure state basic steps as sensor connected to PC serial port:

![Figure 4](image)

**Figure 4.** Steps followed to measure distance by sensor

As steps has been followed, laser rangefinder should be ready to measure distances as shown in (Figure 4). The measured distance is helpful that it will be known for more than three points (by using four rangefinder) and for each capture. The sequenced overlapped images with known depth of more than three points have been subjected to triangulation equations in computer vision field to reconstruct 3D scaled image for intended site.

5.2 Stepper motor connection with interphase card (SM &IC)

In MATLAB, there was an Arduino package that should been installed in order to control subsystems connected with it by specific codes. Since servo motor was an operator for whole system, it has been connected with IC by coils. IC can be connected with USB or matched by power supplier in order to energize it. After connection, code to operate SM has been inserted in MATLAB interface and just need to run. SM has been prepared to rotate with horizontal angles specified due to deficiency which was based on data acquisition stage. Rotation was applied to move camera and attached laser sensors group in order to obtain data with this specific mechanism. Figure. 5 show this connection.
5.3 Digital camera connection with portable computer (PC)

Practically, digital camera (DC) which is GOPRO Hero black 7 is an essential part of system since data acquisition has been dependent on it. The mechanism of DC activation and rotation should be running properly. As a result, for these connections the adapted system has been manufactured due to required specifications of DC and laser sensors around with motion ability due to matched hardware (Figure.6) show a result for adapted system. (SAS) has been manufactured and second step of testing it come to be ready for experiment.

6. 3D Reconstruction (reverse engineering)

Since most usual works related reconstruction of objects depends on using a model and extract 2D images of it, hereon an opposite case has been followed to reconstruct or obtain 3D scaled image by using a sequence of RGB-colored images with a range (depth) information at four corners for every obtained color image. There are many different reverse engineering techniques that aim to create a 3D reconstruction of real objects for different purposes that the purpose of our study has been related with archaeological study as well as documentation of traditional monuments. Additionally, if the 3D reconstruction focuses on a small archaeological piece, the user must be able to observe it from every point of view and to look at its details without a loss of definition, through an efficient control device (Bruno, et al., 2010). One of the important outcomes of this study is the 3D digitization system for cultural in order to perform 3D reconstruction using multiple images one needs to find correspondences among the set of images being used. This turns out a more basic but key problem in 3D reconstruction: finding matches across an image pair (Galindo, 2015).
7. System Progress Evaluation
Mechanically, the electrical and mechanical system components in (Figure 6) were simulated with each other to operate SAS-HD in appropriate manner. Digital camera (DC) has been settled on a triple-leg tripod. DC has been controlled by a specific code to rotate it with specific horizontal angles, during this rotation a group of laser distance sensors perform which were matched and distributed on DC corners perform their function by lurching a spot laser beam toward intended target, as this beam collides into target surface the distance that had been travelled by laser beam will been monitored and recorded due to a specified code processed in sequenced steps and share in reconstruction of scaled image. (Figure 7) illustrated the methodology work flow chart.

8. Experimental work (Case study)
The field selected to achieve the operation of adapted system is Taq Kasra 33°5’37”N 44°34’51”E height about 37 m (121 feet) which is built in 3rd-6th century AD. It is located near the modern town of Salman Pak, Iraq. It is the only visible remaining structure of the ancient city of Ctesiphon. The archway is considered a landmark in the history of architecture,[1] and is the largest single-span vault of unreinforced brickwork in the world. The first date made the first documentary film about the vault was made by Iranian researcher, Pejman Akbarzadeh in 2017. The monument was in serious danger of ISIS attacks in 2015-2016 and this was the main motivation for the documentary maker to travel to Iraq twice and film the arch before it was potentially destroyed. The film explores the history and architecture of Taq Kasra with prolific scholars and archaeologists in various countries (contributors, 2019).

Figure 7. Methodology Work Flowchart
A tripod has been used as base for adapted system also attached leveling bubble had been settled on it to assure leveling of system with horizon (Figure 8). The system began rotation clockwise and counterclockwise horizontally with, -15, 0, +15, degrees angle. During these sweeps GOPRO Hero black 7 has been connected by mobile and obtains capture at each of these angles in addition to activated four laser sensors which were controlled by code to measure depth at four corners of every capture (image), the RGB-colored depth images with depth information for many points should been processed together to estimate depth for all pixels so to obtain 3D model of intended edifice means Taq Kasra (Figure 9).

![Figure 8. Leveling bubbles](image)

**Figure 9. Taq Kasra (Iwan Kasra) – Data acquisition state**

9. **Discussions and conclusions**

As a sign to above mentioned, automation is an efficacious part that has been contributed in connection among mechanical and electrical subsystems to build the invented system properly with motion steering until data acquisition stage has been passed. Based on the error of adapted system motion with the procedures of acquiring data (images) and how to detect such defects in areas that been imaged, the correctness is proved. As many such procedures use a rangefinder laser there may be errors occurring due to machine precision faults. One of these errors due to that the projection of laser beam on target surface difficult to notice due to solar radiation since the scanning time was at radiation peak. The area of treated skin is taken to a picture by digital camera (GOPRO Hero black 7) and then entered into MATLAB for processing with text file of sensor readings of distance at each image that the result is a RGB-depth image and depth of four to real object that this data will be subject to triangulation procedure to obtain depth-image (scaled image). What is that needed to be found is the area of
overlapping points (used for the procedure). This can be identified by an algorithm. If can, It is necessary to correct these errors while working on image processing steps until obtaining 3D (scaled) image for buildings (Wijesinghe, et al., 2016). Although most of the archaeological sites were excavated decades ago, their value to the scientific community has not decreased. 3D technology is easy to use and produces an excellent, nondestructive choice for conservation and research in biological and forensic anthropology. Working within the field of bio archaeology finally have the ability to employ sophisticated and affordable methods in their work. The digital models help in creation valuable archives for conservation and preservation of cultural heritages. The area study mentioned; Taq Kasra, has been subjected to war effect as well as for slackness for a long time so it needs to reconstruction at high level in addition to be care with all outer surrounding. This re-build can be done with modeling results.

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