NON CONTACT 3D SURFACE RECONSTRUCTION USINGPHOTOGRAMMETRY BASED WORKBENCH

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ABSTRACT: - *In this project we used the technique of Close-Range photogrammetry. This technique has got multiple applications in industries, biomechanical, architecture and in many other areas. The Utility of affordable digital cameras and electronic vision combined with photogrammetry methods made i.e. photogrammetry much workable and reasonable for the above applications. This is a contact-free, nondestructive and powerful technique. It also covers an extensive field of different practical difficulties in terms of accuracy, automation and sensor incorporation. We designed and manufactured a physical model on the basis of photogrammetry technique with the help of Arduino, sensor incorporations and used a photogrammetry software for the better analysis. We designed and manufactured the workbench which has been automated. We obtained the spatial facts about the physical object through the processes of interpretation of image data. Also here we used an Aero-Triangulation process for determining the coordinates of3-D objects. We optimize the number of images and reduce (or) constrained linear and angular positioning of digital camera. We also focussed on the analysis of images*

INTRODUCTION: -

Photogrammetry:

Photogrammetry is nothing but making measurements from photographs. It is a technology which is considered as one of the best technologies for obtaining information of physical objectsand is used to get three-dimensional geometry mainly location size and shape. The process mainly consists of recording , interpreting images and patterns and simulate .The classical definition of Photogrammetry is the process of deriving metric information about an object through measurement made on the photograph of the object. This is concerned aboutmetric or measurement aspect of the process. In addition to this photo interpretation aspect isalso involved while the technology is used for mapping where feature collection is required. The fundamental task of metric information is derived through establishing the geometric relationship between the image and the object as it existed at the time of the imaging. Once thisis established other information of the object are derived.

Non-contact 3D surface scanning techniques are used to extract 3D models of solid objects by computing the 3D coordinates of the object's surface points without physical contact with it.The 3D surface scanning process has two main steps:

(1) generation of 3D geometry; and
(2) the application of colourtextured information over the geometry (

Popular methods of passive and active 3D surface scanning (Figure 3.1) including stereo-photogrammetry, photogrammetry, laser triangulation and structured light scanning are presented in this section.

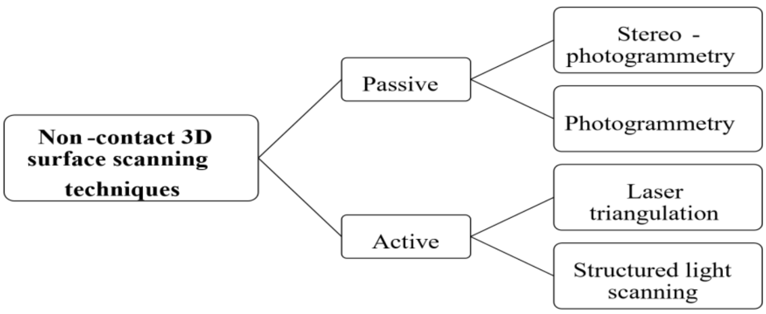


Figure: 3D surface scanning techniques used in forensic medicine

Stereo-photogrammetry:

This is a passive scanning technique based on taking two images of an object using two high- quality calibrated cameras (Figure 3.2). Correspondence between the same points in the two images is obtained by sophisticated stereo triangulation algorithms. The algorithms identify and match unique surface points (features) between the two images, triangulate their 3D position, and generate a point cloud. Once the 3D geometry has been created, the software maps the colour-texture information onto the geometry) as being "concerned with obtaining precise three-dimensional (x, y, z) coordinates of common discrete points appearing on a pair of images".

There are two types of stereo-photogrammetry: passive and active. The passive is based on natural features on the surface of the objects, whereas the active is based on the projection of unstructured light patterns to give the algorithms more information (Lane and Harrell, 2008), and to reduce the correspondence problem

LITERATURE REVIEW:

Ruinian Jiang et al in 2008 led to the evolution of Close Range Photogrammetry in which he had given the light to many applications in the field of industries of civil construction, automobile, mechanics as well as accident remodulation.Also he used digital cameras and photogrammetric software to make the process and study more feasible so because of this the analysis becomes much more easier.He mainly focussed on bridge engineering. He used a Non- Contact, nondestructive technique of Close range photogrammetry in a much better way. He also worked related to the bridge strain and geometric measures. As earlier there was a use of metros cameras(especially constructed for photogrammetry purposes) , diffused targets(non- retro reflective), stereoscopic photogrammetry network layout and analog analytic tools which changed due to the advancement and now the use of non-metric cameras, retro-reflective targets, largely convergently layout and digitized computerized analytic tools.

CH Vasanth Kumar et all in 2018 used the application of photogrammetry to automate the finishing operation.He mainly focuses on the finishing operation named as Buffing which is usually the last and the most vital operation that is being carried out in the manufacturing processes.In an process to automate the process of buffing, robot simulation platforms can develop an offline program for specific geometries. For the unknown geometries it creates the CAD model before processing within simulation platforms which need the specialized costly equipment or the use of photogrammetry. So the process of photogrammetry basically involves compiling the images of the target object and then using a photogrammetric software to generate the 3-Dimensional model of the respective object.This model is then used within the simulationsoftware to generate the final result.

LJ Sánchez-Aparicio, A Villarino, J García-Gago, Diego González-Aguilera

International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences, 2015.Accurate studies of cultural heritage structures usually require the application of combined techniques to understand its structural behaviour. It is in this context, where the article present a set of procedures based on the dual combination of photogrammetric methodologies (image-based modelling and digital image correlation) and the finite element method to understand the structural behaviour of these structures. Through the interpretation of the different obtained products, by the defined approach, it is possible to estimate and evaluate the causes of the structural damage that the analysed infrastructure can suffer and also design subsequent restoration mechanisms, always from a perspective of minimal intrusionto the structure.

Alberto Villarino, Belén Riveiro, Diego Gonzalez-Aguilera, Luis Javier Sánchez-Aparicio Remote Sensing 6 (11), 11107-11126, 2014

This paper presents a multidisciplinary methodology to evaluate an underground wine cellar structure using non-invasive techniques. In particular, a historical subterranean wine cellar that presents a complex structure and whose physical properties are unknown is recorded and analyzed using geomatics and geophysics synergies. To this end, an approach that integrates terrestrial laser scanning and ground penetrating radar is used to properly define a finite element-based structural model, which is then used as a decision tool to plan architectural restoration actions. The combination of both techniques implies the registration of external andinternal information that eases the construction of structural models.

METHODOLOGY

This paper analysed all the things above, so accordingly we then designed our automatic workbench. The main advantage for our workbench is it can be worked manually, semi- automatic or fully automatic So as by testing, We used following components for our workbench with the given dimensions:

OBJECT	SPECIFICATIONS	MATERIAL
1. Circular Base Disc	Diameter: 250mm Thickness: 10mm Material: Glass Nylon	Glass Nylon is used as it have good stiffness and have higher strength
2. LB Bearing	Bearing Inner Diameter:12mm Bearing Outer Diameter:18mm	Stainless Steel
3. Metal Rod	Diameter: 12mm Length: 400mm	Steel
4. Linear Drive	Stroke Length:110mm	-
5.Arduino		-
6.Metal Rods and disc for camera mounting		Steel Disc and rods
7. Tripod ¼ inc.	Screw was used and welded	Steel.

The work done for the above mentioned close range photogrammetry technique using automated operations is described here. Initially, we did the manual testing by capturing the images from all the angles(at particular intervals) but we came across the shortcomings of highrejection level of images and high errors. So to avoid these shortcomings we reduced the numberand complexity of images for reducing the time of aero-triangulation.

Also there were some problems like:

- High number of images comparatively
- Not having a proper focus as distance was varying
- Inclusion of background images during image analysis
- Not a proper edge reconstruction as the edge line was not cleared.

DESIGN

The selected material was cast Nylon on which the following components were fitted:

1) Two stainless steel rods which would act as rails for the camera mount. - The stainless steelrods were fitted vertically with the help of nylon supports at a gap of 105mm, each rod measuring440mm in length from the base

2) Electrical linear drive which would provide vertical movement to the camera mount - The shapeof the base of the linear drive was machined into the nylon base in between the guide rails so that the linear drive can be pressed tightly into place.

The camera mount was fabricated as described:

A flat steel plate of thickness 5mm was fitted with two pairs of linear bearings on opposite edges.These bearings would line up with the steel rods and provide smooth vertical motion to the camera mount .On the other side of the plate, A shaft was welded perpendicularly in the centerwith the other side machined to hold a bearing..

A bolt was welded on the other face of the machined component which would hold the camera through its tripod port. This completed the first two major movements needed, that is vertical and the camera rotation

Design of rotation bed:

1) A circular nylon disc of 240mm dia was selected as the rotation table and it was mixed to the motor's axle using a custom made nylon fixture which would lock the table with the axle using4 bolt

and nut pairs.

Design of linear movement mechanism for rotation bed:The motor and rotation disc assembly was fixed on a wooden slab using screws and the wooden slab was then fixed with a pair of linearsliders.

The following electronic and automation components were used:

1) Jiecang Linear Drive
2) Arduino uno
3) 240V~24A SMPS
4) 24V DC motor Motor driver with PWM frequency=20KHz , peak current=30A

EXPERIMENTAL WORK

Capturing Image:

The foundation step in providing excellent results is proper orientation, number and quality of images. To get the best possible image quality we used a DSLR camera and conducted the experiment with the objective of using least possible images and getting the most efficient rendered result. The pictures were taken from all around the surrounding space; that is 360 degrees.

The camera was moved in the vertical plane with respect to the object to capture the top part of the object in the frame also simultaneously tilting the camera on its own axis to keep the correct orientation with respect to the object.

The rotational motion was provided by the rotation bed wherein a DC motor was fixed with a circular table on which the object would be rotated 360 degrees and would be stopped at decidedangles in between to capture the picture.

1) Automation of vertical movement of camera using an electric linear drive which would slidethe camera mount a certain distance after every 360 degree cycle.

2) Automation of rotational movement of objects with a DC motor controlled using a motor driver to stop it at decided intervals.

Controller Selection:

Arduino was the programming platform selected to control and synchronize all the movements. In case the object is large and doesn't properly fit in the frame the object has to be provided another degree of freedom so that it can move away or close from the camera lens.

These requirements set the prime parameters in deciding the design of the workbench. Deciding the angles between consecutive images was the second most important parameter. With the help of manual testing we concluded that an angle of 30 degrees between images in the horizontal plane and 15 degrees of camera movement on its own axis at every consecutive vertical step would provide the optimum balance between no. of images and required overlap ofat least 50% among images.

Software Requirements:

After studying our requirements we came to a conclusion that we would need two softwares: One for processing the captured images and exporting it into various formats as well as another software to properly view and edit the obtained models or further export it as per requirements. The image processing software used was Bentley context capture to which the captured image set is fed and without any manual inputs the software arranges the photographs in space as they were captured and then finding common stitching points between the images it forms the**3D triangulated mesh.**

The software used for manipulation was chosen as Autodesk fusion 360 as it supports all major file formats ranging from mesh formats to solid model formats. Also it fulfills the prime requirement of mesh simplification which it performs very easily. Also unnecessary background elements can be selected and subtracted with a single click.

Initial Workbench design:

The workbench design started with the selection of base material which would provide sturdy support to the mechanism and also provides easy machinability.

The selected material was cast Nylon on which the following components were fitted:

1. Two stainless steel rods which would act as rails for the camera mount. - The stainless steelrods were fitted vertically with the help of nylon supports at a gap of
2. 105mm, each rod measuring 440mm in length from the base.

RESULT

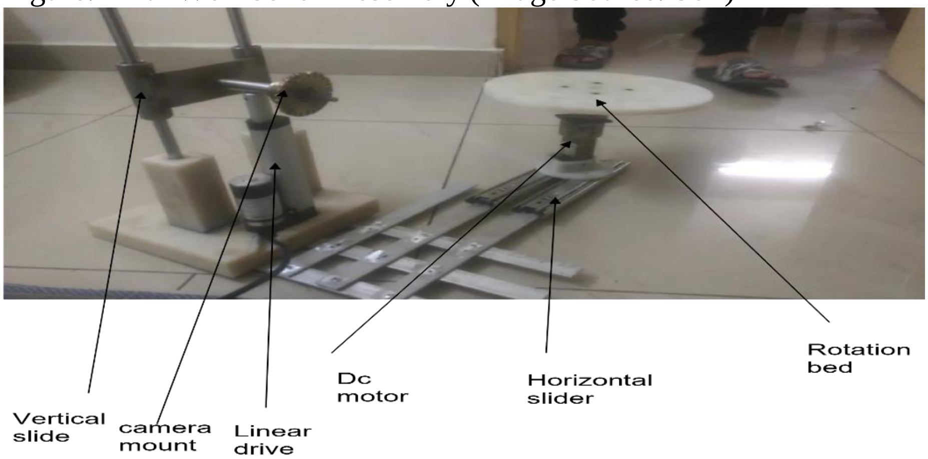
The inbuilt viewer in context capture gave photorealistic renders of the scanned object whereas we primarily exported the object in format which gave a high resolution triangulated mesh as the output , This mesh was imported to Autodesk fusion 360 software where the background clutter was subtracted by easy selection. With desired parts of the object mesh left , the mesh was simplified to reduce no. of triangles as less complex meshes are easier to manipulate and edit .

Further, the meshes can be easily converted to B-rep solids and edited or manipulated in the same software.

This workbench thus gives high utility in scenarios where an old part which does not have CAD support, Its mesh can be easily created and manipulated for modifications and also reverse engineered for mass production.

The Workbench made by us, we tested final reconstruction using it, and we found the result as of reconstruction of images as follows:

Figure: Final Workbench Assembly (Image Source: Self)



CONCLUSION:

The Workbench design after its successful testing provides a blueprint for further automation in the same design but also lays a foundation for further development and enhancement of photogrammetric scanning technique to be utilised in the industries from various disciplines, Itcan be used not only in manufacturing and design sector but already has a vast application inphotorealistic graphics and survey applications.

In case of our work bench we were able to complete the following objectives with desired efficiency:

1. Scanning of objects of various uniform shapes including cuboidal, cubical, cylindrical, spherical and potentially proved to be working perfectly for all uniform shapes.
2. We were able to get a sharp and clear render with as low as 48 images and maximum of 96 images.
3. Sharp and clear edge definition of mesh even after 60% mesh reduction.
4. Conversion to B-rep solid and simple extrude and cut operations performed with ease.

FUTURE SCOPES:

Photogrammetry is the Science of surveying from Photogram, which is a photo with almost no distortion or known distortion. Thus it has wide application in surveying where one can’t go physically.

Support for more airborne & satellite sensor triangulations

- Improve processing tools for elevation data
- Enhancements to GeoMedia Terrain

Provide customers tools (ISAT) to do self calibrations

- Working with USGS to define in-flight calibration process and acceptance criteria”

REFERENCES

1. Dennis J Thevara and CH Vasanth Kumar (2018), Application of photogrammetry to automated finishing operations, IOP Conf. Ser. Mater. Sci. Eng
2. Ruinian Jiang, David.V.Jauregui and Kenneth R. White (January,2008), Closerange photogrammetry applications in bridge measurement, New Mexico State University, Department of Engineering Technology and Surveying.
3. Francesco Mancini and Riccardo Salvini (November 2019), Applications of Photogrammetry for Environmental Research, University of Modena and Reggio Emilia.
4. Chen Jiyang, Huang Xiaoming and Zhu Xenge (July 2019),Real-time identification system of asphalt pavement texture based on the close-range photogrammetry.
5. Hossam-El-Din-Fawzy (October 2019),Head of Civil Engineering Dep., Kafrelsheikh University, Kafr El Sheikh 33511, Egypt,3D laser scanning and close-range photogrammetry for buildings documentation: A hybrid technique towards a better accuracy.
6. Sohail Manzoor, Anna Gustafson and Daniel Johnasson (March 2019),Division of Mining and Geotechnical Engineering, Luleå University of Technology, Luleå,Sweden,Establishing relationships between structural data from close-range terrestrial digital photogrammetry and measurement while drilling data.
7. Armaneh E Kensari and Stanley J Vitton (July 2017),Department of Civil and Environmental Engineering, Michigan Technological University, MI, USA,Creating 3D models of tractor tire footprints using close-range digital photogrammetry.
8. Hossam-El-Din-Fawzy (November 2018),Civil Engineering Department, Kafrelsheikh University, Kafrelsheikh, Egypt,Study the accuracy of digital close range photogrammetry technique software as a measuring tool.
9. Farish Farnood Ahmadi and Nasir Farsad Laygeh (January 2014), Faculty of Civil Engineering, Department of Geomatics Engineering, Tabriz University, Tabriz, Iran,Integration of close range photogrammetry and expert system capabilities in order to design and implement optical image based measurement systems for intelligent diagnosing disease.
10. Thomas Luhmann,Clive Farser and Hans-Gerd Mass (November 2015),Institute of Applied Photogrammetry and Geoinformatics, Jade University, Oldenburg, Germany,Sensor modelling and camera calibration for close-range photogrammetry.
11. AENOR, 2007. Methods of test for masonry units. , Part 11: Determination of flexural and compressive strength of hardened mortar. AENOR, Madrid.
12. AENOR, 2011. Methods of test for masonry units., Part 1:Determination of compressive strength. AENOR, Madrid.

