3-D Scanning and 3-D Printing in Archeology

Akshat Gupta[1] Dr. Jagjit Singh Randhawa[2] Manarshhjot Singh[3] Sepaldeep Singh Dhaliwal[4]
[1]M.Tech student [2]Assistant Professor
[1,2,3,4]Department of Production and Industrial Engineering
[1,2,3,4]PEC University of Technology, Chandigarh, India

Abstract— The 3-D scanning and 3-D printing is an emerging field. Reverse engineering has made it possible to construct the parts which were difficult to reconstruct or their source of construction was unknown. 3-D scanning has made it possible to rebuilt the parts without the need of actually knowing its dimensions, steps of construction. This paper highlights the types of 3-D scanning techniques and 3-D printing techniques. The restoration of a damaged statue from the museum is also discussed using the cheap and convenient technology as per the conditions. It has a multiple advantage in the field of Archeology. Our nation has verity of cultures and their statues are degrading, so there is a need to reconstruct/ restore by the use of technology.

Key words: 3-D Scanning, Archeology, 3-D printing, Restoration

I. INTRODUCTION

There are many technologies which can be used to develop 3-D scanning devices. The devices have their advantages, disadvantages and cost. There are many technologies which can obtain digital 3-D model. These can be classified mainly into two types: contact and non-contact. They can be further classified as:

1) Contact Scanners.
2) Non-contact Passive Scanners.
3) Non-contact Active Scanners.

A. Contact Scanners:

In Contact scanners physical contact with object in required. Supported, fixture or dedicated surface is required for these kind of the scanners. The contact measurement system is used by the Coordinate measuring machine (CMM). Geometrical coordinates of the subject are measured using CMM. Operator controls the machine manually. The scanners are very precise and are used in manufacturing.

The disadvantage of CMMs is they are slow to operate and more over require contact with the subject. It is difficult to scan the valuable subjects as it might damage or modify the originality of the subject (archeology).

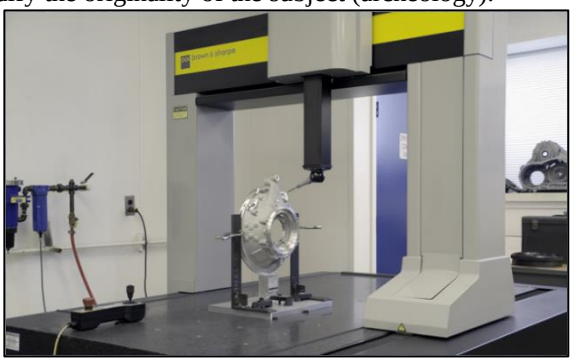

Fig. 1: Co-ordinate Measuring Machine (CMM)

B. Non-contact Passive Scanners:

In these type of scanners there is no physical contact between the product and the scanner. Passive scanners do not emit any kind of radiation. They depend on ambient radiations which are reflected. These type of scanners detect visible light as it is found in the ambient radiations and all type of infrared radiations are also used. Passive methods are economical because they do not require any particular apparatus except for digital cameras.

The disadvantages of this type is that they provide low accuracy of the scanned object.

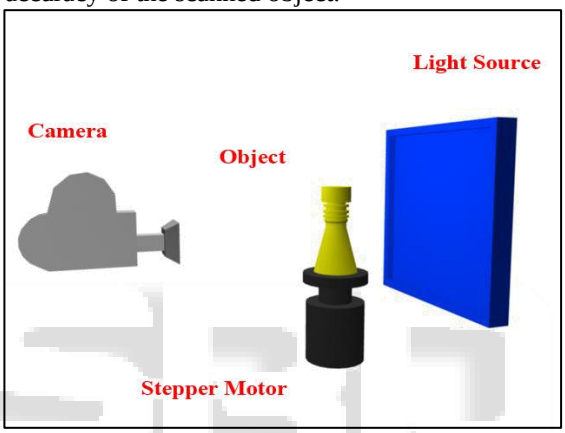

Fig. 2: Non-contact passive Stereoscopic Photogrammetry

C. Non-contact Active Scanners:

These type of scanners discharge radiations (X-ray, ultrasound) or light and detect the reflection or radiation passing through the target. The radiation discharged by the scanner is reflected by the target scanned and the surface distance information is sent back to the scanner.

The disadvantage of this type of scanners is, they can't scan translucent, transparent, refractive and reflective objects.

Different technologies are used in Non-Contact Active scanners. Technology used are follows:

D. Time of Flight:

This type uses laser light equipped with a time-of-flight laser range finder which finds the distance of a surface by timing the round-trip time of a pulse of light. The laser transmits a pulse of light and the amount of time is measured before the detector sees the reflected light. Since the speed of light c is known, the round-trip time determines distance travelled by the light, which is twice the distance between the scanner and the surface. If *t* is the round-trip time, then distance is equal to (c*t)/2. The accuracy of a time-of-flight 3D laser scanner depends on how precisely the *t* time can be measured: 3.3 picoseconds are approximately the time taken for light to travel 1 mm.

E. Triangulation:

The triangulation laser shines a laser on the subject and uses a camera to look for the location of the laser dot which appears at different places in the camera field of view, depending on how far away the laser strikes a surface. In this technique the laser dot, the camera and the laser emitter form a triangle. Three pieces of information determine the triangle shape and size. First, the length of one of the triangle sides the distance between the camera and the laser emitter is known. Second, the angle of the laser emitter corner is also known. Third, the angle of the camera corner is determined by looking at the laser dot position in the camera's field of view. In most cases a laser stripe, instead of a single laser dot, is swept across the object to speed up the acquisition process.

F. Structured light:

Light pattern is projected on the target by these type of scanners. The deformed pattern is projected on the target using light source/ LCD projector. Moving targets can be scanned by existing techniques in the real-time. The camera, slightly offset from the projector pattern, looks at the shape and calculates every point's distance in the field of view. They scan field of view or the various points at once. The exponentially more precise profiles are developed than laser triangulation in just second. These eliminates the motion distortion.

G. Modulated light:

These projects a continual changing of light on the target. Linear pattern (sinusoidal pattern) on the target is produced. Reflected light calculates the distance traveled by the light and is detected by the camera. This allows the scanner to disregard the light from sources other than laser, so there is no interference.

H. Handheld laser scanner:

In these type of scanners 3D model is created using the triangulation mechanism. The handheld device (sensor) projects a laser dot/line on the target. Data is collected by the internal coordinated system. Therefore, the scanning device position is obtained by collecting data while the object is moving. The scanner obtains the targets position by using the reference features of the scanned surface. These scanners use the actual shape (color/texture) using external monitoring. Three or more cameras are used to provide six degrees of freedom to the scanner while single integrated camera determines the orientation of the photogrammetric solution or the scanner. Both techniques use infrared light-emitting diodes attached to the scanner. Infrared light-emitting diodes are seen by the camera(s) through filters providing resilience to ambient lighting. The data (collected points) is collected by the computer and recorded within a three-dimensional space. That is transformed into a triangulated mesh and then to the CAD model.

Fig. 3: Non-contact Active Handheld laser scanner

Most commercially available rapid prototype machines (3-D printing) that are currently available in the industry are:

1) Stereo Lithography (SLA)
2) Selective Laser Sintering (SLS)
3) Laminated Object Manufacturing (LOM)
4) Fused Deposition Modeling (FDM)
5) Polyjet 3D Printing.

I. Stereo-Lithography (SLA):

Ultraviolet light is used in this method for the selective polymerization of a photosensitive resin. In this system, an ultraviolet laser beam is focused on the top layer of photo sensitive resin contained in a vat. The horizontal X and Y direction beams are positioned to polymerize the resin at a particular cross-section boundary. The platform attached to the cured layer of polymer is lowered and the new layer of liquid resin is fetched.

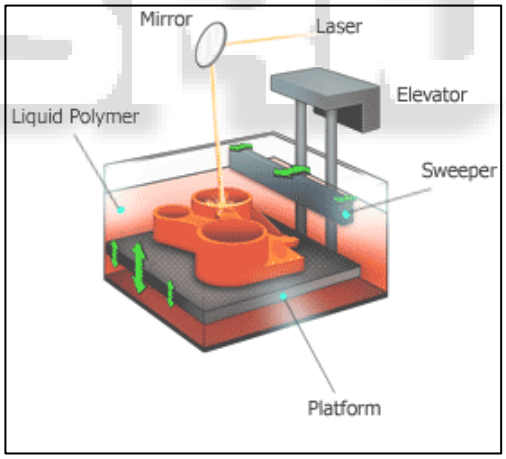

Fig. 4: Stereo-Lithography (SLA) technique

This system provides the accuracy, high details and good surface finish in industries.

The disadvantage of this system is, it requires post-curing. Support is necessary and removal of this support is quite difficult.

J. Selective Laser Sintering (SLS):

High power laser beam is used to fuse and melt the powdered material. The powder is spread by a counter rotating roller in a precise amount. The powder is fused with in the section boundary through a cross-hatching motion using a laser beam. Lowering the table depends upon the corresponding distance of the layer thickness (0.01 mm) before the roller spreads the next layer of powder on the built layer. The support for overhanging portions is served by the unfiltered powder layer if any.

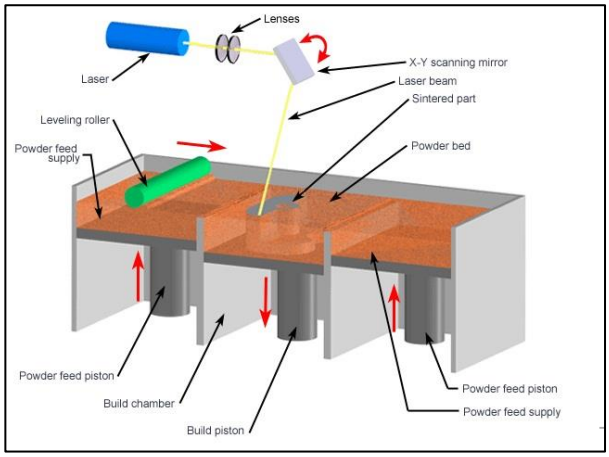

Fig. 5: Selective Laser Sintering (SLS) Technique

This system has fast building time and no curing is required.

The disadvantage of this system is that, it has rough surface finish and material change over is difficult.

K. *Laminated object manufacturing (LOM):*

Cross-section profiles of the object are taken up from the web material or from paper using a laser. The paper is unwound from a feed roll onto the stack and first bonded to the previous layer using a heated roller which melts a plastic coating on the bottom side of the paper. Optics system is used to detect the profiles on the X-Y stage. Excess paper is removed when the cutting of layer is finished from the web. Take-up roll takes up the waste paper. Undercuts and overhangs are self-supporting. Heavily cross-hatched cross-section areas are deleted from the end object with the help of laser.

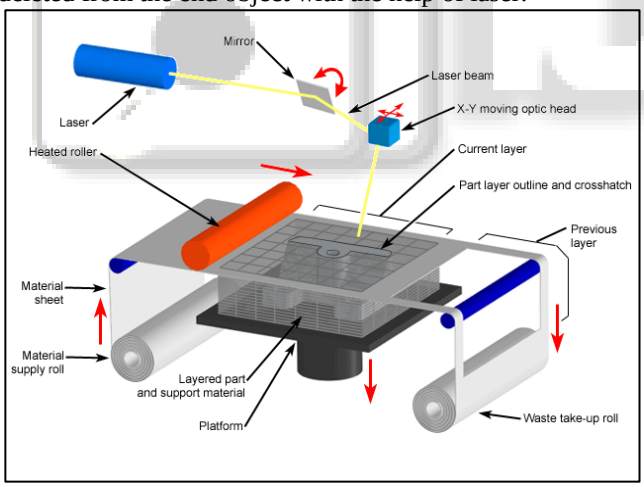

Fig. 6: Laminated Object Manufacturing (LOM)

This system can use various type of inorganic and organic materials like composite, paper, ceramic and plastic. Non required deformations and internal stress are not obtained.

The disadvantage of this system is that, the firmness of the object depends upon the strength of the glued layer. Hollow parts can't be constructed.

L. *Fused Deposition Modelling (FDM):*

This is an additive process in which material is deposited on a working platform in layers. As with the SLA technology, the layers of 3D data file are deposited consecutively on a work platform. The melting point for the material is around 280ºc, if supplied with an extruder and cures directly onto the underlying layer. The whole chamber is headed and maintained at a temperature to ensure the individual layers bond to one another. Too early curing could prevent a new layer bonding with the previous one. Models are constructed on the building platform and requires supporting fixture.

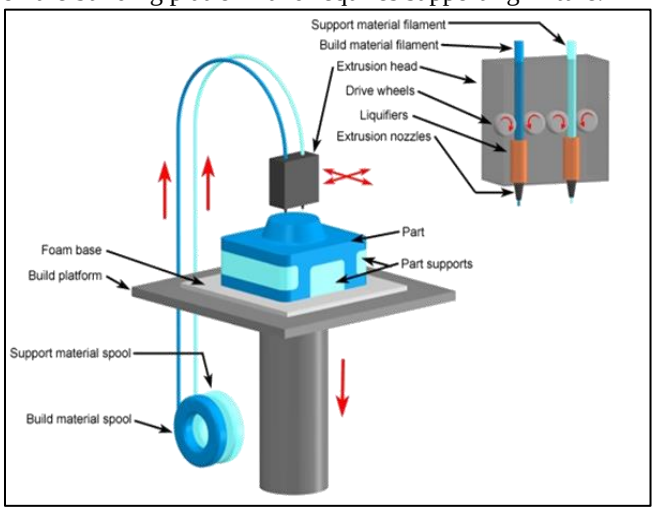

Fig. 7: Fused Deposition Modelling (FDM)

This system possess ability to build thin parts, less maintenance cost, ease of material change, compact size and non-toxic materials.

The disadvantage of this system is that, it requires supports, less part strength and requires long build time due to increase area in slices.

M. *Polyjet 3D Printing:*

The working of this method is identical to the working of an Inkjet printer. Instead of dropping ink on the paper, polyjet drops the layer of curable liquid photopolymer into a built tray. photopolymers and support material installation is automatically done by the software. This jets the tinny droplets of liquid photopolymer. Support material is a detachable gel like material. The support material is removed effortlessly by the hand or the water.

The products aesthetics are explained properly and provides the smooth surface finish. It produces short-run manufacturing tools, jigs and assembly fixtures.

The disadvantage of this process is, it a very costly process, time consuming and does not produce a strong product.

II. METHODOLOGY

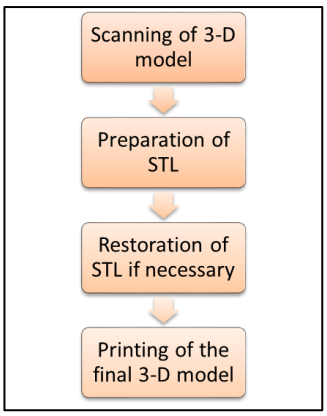

Fig. 8:

A. Step I: Scanning of model:

The scanner is used to scan the model. The handheld scanner does not require any physical contact, is best for the conditions where model cannot be transported from one place to another as in the case of statues in the museum.

Fig. 9: Statue of Buddha in Museum.

B. Step II: Preparation of STL:

The scanner software is used to convert the scan file into the STL (Standard Triangle/Tessellation language) format. This format is read by all the restoration software's (CAD/CAM software's) and by the 3-D printing technologies too.

Fig. 10: STL file of the Buddha Statue

C. Step III: Restoration of STL:

The CAD/CAM software's are used for the reconstruction of the broken parts or the missing parts. The back of this statue is broken and is restored using the CAD tools. Construct a plane on an offset from the back of a statue. Use of projection will construct the curves on the plane. Now use the circle command to construct the back and coincide the circle with the projected curves. Draw the rest of the area by using line and spline commands of the CAD software's. Use the Boolean command atlast to make the final 3-D model.

Fig. 11: Reconstructed back of Buddha statue

D. Step IV: Printing of 3-D model:

The FDM technology is cheap to use and is less time consuming. The STL is fetched into the predefined software of the 3-D printer. The software allows the printing on the prescribed ratio and notifies the usage of material and time.

Fig. 12: 3-D Printing Buddha

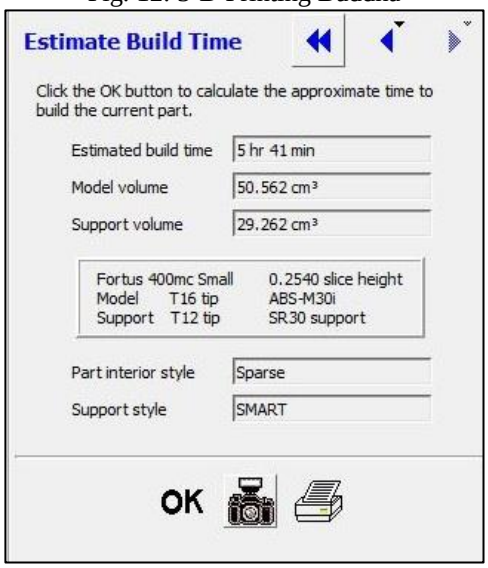

Fig. 13: Buddha statue Built timing

III. CONCLUSION

The technologies which provides best results in minimum time with better built quality is Handheld scanner with FDM printing technology. The handheld scanner is better if the statues are to be scanned, as this is the only scanner which is a portable device which can be carried to any place. And more over this scanner does not require any reference points to be marked on the surface. The FDM uses the ABS material for printing. This material doesn't cost much and more over this process time efficient, cost efficient as compared to others. This technology is best suited for the printing of the statue.

REFERENCES

[1] Garsthagen, R. "The Pi 3D Scanner Project". Available online: http://www.pi3dscan.com/ (accessed on 10 August 2013).
[2] Ahn S., Lee C., Jeong W., "Development of translucent FDM parts by post processing". Rapid prototyping Journal (2004) Vol. 10 (4), pp.218-224.
[3] Banga, H.K., Kalra, P., Belokar, R.M. & kumar, r. "3D scanning and rapid prototyping of foot drop patient's leg." International Conference, Humanizing Work and Work Environment (HWWE-2016), 2016, 1(2), 202-206.
[4] Ancau M., Caizar C., "Optimization of surface quality in rapid prototyping." Romanian academy, (2014), series a, vol. 15. pp 362-370.
[5] Fantini M., Crescenzio F.D., Persiani F., Benazzi S., Gruppioni G., "3D restitution, restoration and prototyping of a medieval damaged skull", Rapid prototyping Journal, (2008) vol. 14 Iss 5 pp.318-324
[6] Banga, H.K., Kalra, P., Belokar, R.M. & kumar, r. "Enhancing walking stability of patients with foot drop deformities using ankle foot orthosis fabricated by additive manufacturing: A review. 3rd International Conference on Industrial Engineering (ICIE-2015), 2015, 1(2), 1046-1052.
[7] Przybilla H. J., Peipe J., "3D modelling of heritage objects by fringe projection and laser scanning systems. (2011).
[8] Namir Ahmed, Michael Carter & Neal Ferris "Sustainable archaeology through progressive assembly 3D digitization" (2014), World Archaeology, 46:1, 137-154,
[9] Banga, H.K., Kalra, P., Belokar, R.M. & kumar, r. "Rapid prototyping applications in medical sciences", Int. J. Emer. Technol. Comput. Appl. Sci., (2014), 5(8), 416-420.
[10] Types of 3D scanners and 3D scanning Technologies. (ems-usa 3D printing, scanning and product design)
[11] Banga, H.K., Kalra, P., Belokar, R.M. & kumar, r., "Three Dimensional Gait Assessment during walking of healthy people and drop foot patients" Defence life Science Journal, Vol.2, No.1, (2017) pp. 14-20.
[12] Wai H.w., "RP in art and conceptual design", Rapid Prototyping Journal, (2001) Vol. 7 Iss 4 pp. 217-219.
[13] Pandey, Pulak M. "Rapid prototyping technologys, Applications and part Deposition Planning." (2010).
[14] Yagnik D., "Fused Deposition Modeling A Rapid Prototyping technique for product cycle time reduction cost effectively in Aerospace Applications." IOSR Journal of Mechanical and Civil Eng. (IOSR-JMCE), p-ISSN: 2320-334X, pp 62-68.

