IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

A Review Of 3D Reconstruction And Its Applications

[1]Trupti Kularkar, [2]Pranav Agwan, [3]Tanvi Jikar

[1]Research Student, [2]Research Student, [3]Research Student

[1]Department of Artificial Intelligence,

[1]G.H. Raisoni College of Engineering, Nagpur, India

[2]Department of Artificial Intelligence,

[2]G.H. Raisoni College of Engineering, Nagpur, India

[3]Department of Artificial Intelligence,

[3]G.H. Raisoni College of Engineering, Nagpur, India

Abstract: Many technologies have caused a huge effect that exceeded the technology itself. But none of the technology has the potential to alter human life that Artificial Intelligence can do. AI has started to create an impact on fields such as education, medical, entertainment, etc. In this review paper, we will be going through a concept known as 3D reconstruction, which has been very useful in this era of AI. The motive of this paper is to highlight the uses of 3D reconstruction in a range of fields. We will moreover be supplying some of the algorithms and software program applications that will be used to feature the 3D reconstruction. The challenge of producing fast and proper 3D snapshots with the aid of 3D reconstruction has determined its utility in fields such as robotics, augmented reality, human-computer interaction, entertainment, reverse engineering, the scientific field, and animation.

Keywords **- 3D Reconstruction, 3D model, Computer Vision, Deep Neural Network.**

INTRODUCTION

3D reconstruction is the process of reconstructing a digital version of real-world objects from pictures or scans of the object. Its techniques have been widely promoted nowadays. 3D reconstruction has finite applications in visual, mechanical, simulation, automation, enhancement, production, and many more. There are many 3D acquiring methods, such as ultrasound, synthetic aperture radar (SAR), LIDAR system, Stereoscopic technique, and Rendering technique [1]. Some other techniques have also been developed that help in developing 3D reconstruction models such as CNN networks, Deep Learning algorithms, and Computer vision. Some software is also introduced till now for 3D reconstruction such as Meshroom, Maverik System, and Hidden Markov Model. In this paper, our main attention is to flash out different types of applications, software, and algorithms that are used to build a 3D reconstruction model. Most of the 3D reconstruction models are built with the help of images but now videos are also used to reconstruct the scenes. As 3D reconstruction is one of the trending technologies these days and it is essential to talk about its applications. The challenge of constructing accurate 3D images can be performed in the fields like robotic mapping, pavement engineering, entertainment, reverse engineering, augmented reality, virtual environment, 3D object recognition, earth observation, and many more. The use of this 3D geometric representation includes the population of virtual worlds and gaming engines.

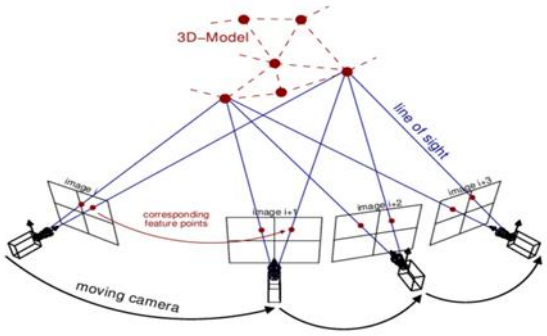

Fig. 1 3D Scene Reconstruction

RECENT TECHNIQUES

Starting with application in medical fields 3D reconstruction provides a real-time tool for pre-surgical evaluation and planning. It is also used in tomographic reconstruction. Computed tomography and neutron tomography are some methods that use 3D reconstruction. It is also widely used in creating virtual tour systems and virtual environments. It helps in recreating archeological sites. The non-reversible nature of excavation can be mollified with the aid of the usage of the methods of 3D reconstruction by using reachable hardware and methods of reconstruction and computer vision. 3D reconstruction helps researchers and scientists to observe the earth and human vegetation. This technique is also used for the mapping purpose used in robots for the purpose of navigation. The reconstruction of a 3D hand model presents a flexible illustration of hand gestures [2].

A. Robotic Mapping

Robotic Mapping in AI and robotics, robots require maps to judge their spatial environment, which helps for the purpose of navigation through different surroundings. 3D reconstruction is used here to create a 3D map. Following are some of the techniques that have been used recently for this purpose.

- **Hector Simultaneous Localization and Mapping (SLAM) Algorithm:**

This method consists of a mobile robot that is divided into vertically mounted LiDAR (Light Detection and Ranging), horizontally mounted LiDAR, and a mobile platform. There are 3 steps: static scan, dynamic scan, and point cloud registration. In static scan, the robot collects high-resolution static scan with color information. In the dynamic process, the SLAM algorithm is used by means of horizontal LiDAR to estimate the location of the robot in the horizontal plane. For every scan taken via horizontal LiDAR, scan matching is carried out many times with the present estimated map of the surroundings to get the translation and rotation parameters of the present scan. With the help of vertical scanners, we can also generate 3D maps of the surroundings [3].

- **Convolutional Neural Network (CNN):**

CNN is used for performing a dense reconstruction, which means we will be able to find the density of objects in a 3D view. This method consists of two metrics: hand-crafted metrics and data-driven metrics to perform the 3D mapping. Hand-crafted metrics consist of a robotic arm that requires an RGBD frame input and a calibrated sensor pose that can be given using the SLAM method. This helps in scene reconstruction and representation. The data-driven metric consists of a CNN architecture. The CNN model consists of 5 convolutional layers and it takes the present image as input and outputs the movement path. After completing the above-given steps, we perform a metric combination. Both the metrics are combined using methods such as Naïve Switching and Temporal Conditioning [4]. More algorithms have been used till now such as binocular disparity, image blur, motion parallax, structure from motion, and silhouette for 3D reconstruction using a single image. Linear perspective, atmospheric scattering, shape from shading for 3D reconstruction using 2 or more images [5]. Iterative Closest Point (ICP) for ranging method and Random Sample Consensus (RANSAC) algorithm for feature matching and detection method, etc [6].

B. Archaeology

The research work of human records via the excavation of archaeological locations and the evaluation of artifacts and other earthly remains is called archaeology. 3D reconstruction is very useful in the archaeology field. It can construct a 3D model for archaeological data such as cultural landscapes, artifacts, etc. Following are some of the techniques that have been used recently in the archaeology field.

- **Object Reconstruction Generative Adversarial Network (ORGAN):**

For repairing archaeological objects, this technique was introduced. It is a data-driven approach. A GAN architecture is used and a deep neural network is operated on it. The first step is data generation. This data consists of incomplete and complete objects. The second step consists of a shape completion network. In this network, the 3D encoder compresses the input voxel grid using convolutional layers. In the consequent step, the compressed values are added with the embedded information about the input class label. After that, a 3D decoder predicts the output using 3D transposed convolutional layers. The third step consists of adversarial network architecture, in which the GAN algorithm is used. Using this whole method, we can create an accurate 3D model of incomplete or fractured objects [7].

- **Parametric Recreation, Perspective matching, Structure wide extrapolation, Texture overlay:**

This technique uses 4 methods for 3D reconstruction. The first method is parametric recreation, which uses a CAD program to re-plot the old hand-drawn sketches. The second method is perspective matching, in which a single photo is used and its 3D features are extrapolated. Features are then traced in 3D space when the image is aligned. To create a texture on the 3D object, the photo is projected over the 3D shape. The third method is structure-wide extrapolation, which allows the extrapolation and estimation of complex compound curvatures. The fourth method is texture overlay, which helps in scaling and alignment of the high-resolution photos and also reprojects the images over the surface. With the use of the above methods, we can generate the 3D model of the tomb of Hairan by just using old hand-drawn sketches and images [8].

More algorithms have been used till now such as Zhang's method for camera calibration, Harris Detector and Correlation Matching, Normalized Cross-Correlation (NCC) method & Scale Invariant Feature Transform (SIFT) for feature point detection and matching, etc [9].

C. Medical Field

There is a vast use of 3d reconstruction in the medical field. We can use this reconstruction on medical images such as MRI, CT scans, X-rays, etc. It can help medical staff to conduct research, diagnosis, and treatment. Following are some of the techniques that have been used recently for medical imaging.

- **Flying Edges (FE) and Multi-Level Partition of Unity (MPU):**

The flying edge algorithm uses a table to determine the triangle configuration of the voxels present in a 3D grid. The first pre-processing stage finds the intersection of the edges in one dimension. Using this, the second stage determines the intersection of the edges in the remaining two dimensions. The third stage allots memory to store the points and triangles. The end stage creates triangles by calculating the intersection points. The Multi-level Partition of Unity (MPU) models produces a 3D mesh by working on contours which are then converted into 3D points in 3 dimensions using the coordinates of the contour pixels. After this, FE and MPU are compared to pull out the regions and are combined to get a final 3D model [10].

- **Deep Organ Net:**

Deep Organ Net is a deep neural network that has been used to generate 3D surface meshes of many organs from single-view medical image projections. The first step is dataset preparation. For this experiment 3D projections of lungs have been taken in the dataset. Many types of projections of lungs have been taken in the dataset. After this, the dataset is passed through our deep neural network, i.e., Deep Organ Net and thus we get our 3D model. In this way, we perform 3D reconstruction on lung images using Deep Organ Net [11]. More algorithms have been used till now such as Stereo and Non-Stereo Corresponding Point-based techniques (They both used DLT

algorithm and they are both point-based methods), Non-Stereo Corresponding Contour (NSCC) algorithm & Kriging algorithm (They are contour-based methods) and Principal Component Analysis (PCA) algorithm (It is a statistical shape model-based method, etc [12].

D. Earth Observation

Gathering data the use of the physical and botanical system of Earth is known as Earth Observation. It can be done with the use of satellites or via direct-contact sensors in ground-based platforms. The use of 3D reconstruction in Earth Observation can simplify the number of obligations for researchers. It has definite applications in reconstructing fashions and city place models. Following are some algorithms that can be used.

- **Image Mapping Algorithm:**

It is suggested for a real-time computer-generated (CG) integral imaging system. This algorithm generates images from an intricate 3D structure. It is much less affected by system factors and object image resolution than the preceding technique. Using this technique, it is feasible to comprehend an interactive CG critical imaging system that can be utilized in virtual reality. The existing data is filtered via 'clustering technology' in this algorithm to obtain comparable data to the target data. It can bolster up all display modes of the integral imaging system [13].

- **Digital Elevation Models (DEMs), Digital Surface Models (DSMs), and Digital Terrain Models (DTMs):**

Digital Elevation models or DEM is a raster grid of Earth's surface reference to the surface of face of zero elevation to which heights are referred by way of scientists, insurers, and geodesists. A Digital Surface Model or DSM captures a surface—including herbal and man-made structures such as vegetation and buildings. They illustrate reflective surfaces of all factors accelerated above the 'bare earth'. A DSM is beneficial in 3D modeling for telecommunications, city planning, and aviation. DTM indicates the enhancement of the geodesic surface. Bare-earth refers to the fact that vegetation and human-made aspects such as trees and energy traces are filtered out with DEMs. 3D reconstruction can be executed using these three models. These models are combined with several techniques to reconstruct the 3D scene [14].

E. Augmented Reality

The technological know-how that superimposes a computer-generated image on a user's view of the actual world is known as augmented reality. It is a built-in technique of image processing and shows a system of complex information, which includes real-time computing, motion tracking, pattern recognition, image projection, database linking, feature extraction, and coordinate transformation. It can relate with the physical world in real time. The most frequent way to do that is via 3D reconstruction and mapping. Following are the methods which are used in Augmented Reality with the assistance of 3D reconstruction.

- **Bayesian classifier and GrabCut Algorithm (BCGC):**

The Bayesian classifier (BC), one of the primary statistical classification methods, has an image segmentation extraction function. The BC algorithm can segment the foreground and background where the consultant case is located. They contain the determination of the prior probability function, as well as the probability density function, for distinguishing whether or not the pixel belongs to the foreground or background pixel. GrabCut considers the global color distribution of background and foreground pixels for segmentation, so it can get rid of internal pixels that do not belong to the precise object. With the assistance of this algorithm, a virtual home environment was once created [15].

- **Structure from motion:**

Structure from motion (SfM) is a photogrammetric range imaging method for making an estimate of 3D images from a collection of 2D images that may additionally be occupied with local motion signals. Using SfM and Multi-View Stereo (MVS), it is hoped to protect cultural heritage. The way to address a problem relies on different factors, such as the number and kind of cameras used. If the picture is taken with a single calibrated camera, the 3D structure and camera movement can solely be rescaled to an existing scale and can nevertheless keep observation. The SfM algorithm takes one set of images as input and produces two things:- digicam parameters of each image and a set of 3D factors seen in images [16].

F. Tomographic Research

Tomographic reconstruction in 3D has been created using several methods which include minimal surfaces, level sets, graph cuts, multi-scale approach, patchwork, etc. Tomographic reconstruction helps to yield an estimate of a unique system from a limited number of projections. Tomography dispenses 3D images of engineering components, and offers an unprecedented insight into their internal structure. 3D reconstruction is used in all kinds of tomography to get clear images of X- rays of patients.

- **Algebraic Reconstruction Technique (ART):**

It is a recursive reconstruction method used in computed tomography. It takes a collection of angular projections and reconstructs images. It is effortless to combine prior knowledge into the reconstruction process. It is a large benefit of ART over other reconstruction methods such as filtered back projection. Three algorithms are combined with the ART algorithm to execute direct 3D reconstruction, Simultaneous Iterative Reconstruction Technique (SIRT), and Iterative Least Square Technique (ILST) [17].

- **Optical Coherence Tomography (OCT):**

Optical coherence tomography (OCT) is a widely used noninvasive imaging modality that can rapidly provide volumetric images of samples like it can create photos of the back of your eye. It has five sorts that can be used in look-up for 3D imaging. They are, frequency-domain OCT (FD-OCT), Spatially encoded frequency-domain OCT (SEFD-OCT, spectral-domain or Fourier domain OCT), Time encoded frequency-domain OCT (TEFD-OCT, or swept-source OCT), full-field OCT (FF-OCT), Line-field confocal optical coherence tomography (LC-OCT). OCT makes the use of low coherence light to seize micrometer resolution, 2D and 3D images from within optical scattering media. It is used in cardiology, dermatology, and many different clinical fields [18].

G. Virtual Environment and Virtual Tourism:

The interaction between the computing environment and the work of different users is called a virtual environment. Simulation of an existing location through videos or still images that may or may not contain sound effects, music, narration, and text is called a virtual tour. Virtual tourism provides users a 360-degree view of any kind of structure or destination and we get a real experience of that place. These applications are used in recreating crime scenes, agricultural environments, heritage tours, and many more. Following some of the algorithms were explained how to use these applications.

- **Deep Belief Neural Network:**

A DBNN is a generative graphical model, or a kind of deep neural network, composed of a couple of layers of the latent variable, with connections between the layers alternatively now no longer between devices inner each layer. It is used to understand the aim of the center of attention and reconstruction in digital reality. It shows 3D scenes of digital certainty such as traveler factors of pastime in accordance with its superb performance [19].

- **Stereoscopic Technology:**

The 3D reconstruction of the object is realized by means of the potential of the use of stereo ingenious and prescient technology. By inspecting and processing two-dimensional images, the 3D facts of each and every object in the processed photograph is extracted through the utilization of the mature stereovision theory. The use of the two-view nature of stereo pictures to find out the 3D form and for this reason, beautify the reconstruction performance [20].

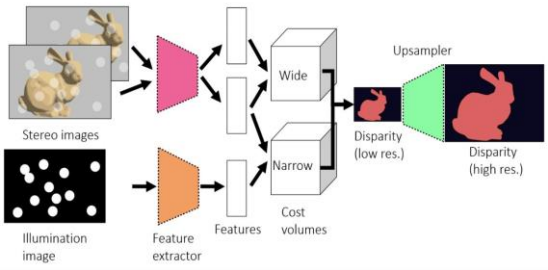

Fig.2 Stereoscopic Technology

- **Kinect Device:**

Kinect is a movement seizure gadget for Microsoft Xbox360. It can seize the depth of the picture via a binocular-like depth sensor primarily based on IR. Currently, many researchers tried to use Kinect as a deep digital camera to get a real-time 3D reconstruction gadget of indoor surroundings [21]. These are some algorithms and devices which are used to reconstruct virtual environments. There are some more algorithms and techniques that are used such as MAVERIK System, and the Rendering technique [22].

H. 3D Object Recognition

3D reconstruction is used top proper right here to convert the 2D image into a 3D model. 3D Object Recognition is the local of artificial Genius concerned with the knowledge of robots and precise AI implementations to apprehend numerous things and entities [23]. Object attention lets robots and AI aspects pick out and stop being aware of devices from inputs like video and then as soon as extra digital digicam images [24]. Different strategies and algorithms have been enormously utilized in 3D object center of attention popularly which can be pooling, clustering, ensemble learning, 3D-Den model, and a lot more. Some of the techniques are described underneath [25].

- **MV-CNN (Multi-View Convolutional Neural Network):**

MV-CNN is a community topology that mixes statistics from extraordinary views into totally linked layers to categorize the voxel whereby the planes cross. In MV-CNN, 3D geometry is rendered into 2D and then the 2D skills are calculated and determined with the useful resource of max pooling [26].

- **Mem3D:**

The concept of Mem3D is to reconstruct the 3D structure of an object from a single entered photograph. The memory neighborhood learns to retrieve 3D volumes which can be notably related to the entered photograph. Humans robotically use incomplete or noisy seen cues from an image to retrieve related 3D shapes from their memory and reconstruct the 3D structure of an item. Inspired with the aid of this, we advise a singular method, named Mem3D, that explicitly constructs structure priors to complement the missing documents inside the photograph [27].

I. Gesture Recognition

Gesture recognition comes below CV resourceful and prescient and helps in recognizing human gestures by way of unique algorithms. Sometimes when we show off gestures from one of the types of angles, then the computer is no longer able to apprehend them. To maintain away from this bother we use 3D reconstruction. Gesture consciousness is the fastest-growing self-discipline in photo processing and artificial technology. Gesture focus is a method in which the gestures or postures of human physique aspects are diagnosed and are used to manipulate pc structures and one-of-a-kind digital items. These functions are considerably used in hand monitoring systems, hand gesture recognition, and moreover in sign language recognition. To supply clarification for it greater in reality some strategies are described below [28].

- **HMM (Hidden Markov Model):**

An HMM is a mathematical model that is additionally used in machine learning. It can be used to describe the assessment of observable activities that rely on inner factors, which are now not immediately observable. HMM, fashions are a category of probabilistic graphical fashions that permit us to predict a sequence of unknown variables from a set of located variables. From the HMM model, we can assemble a 3D constructing model from satellite tv for pc pictures [29].

- **3D-CNN (3D-Convolution Neural Network):**

3D-CNN is an effective and fine model using spatial-temporal features. It can analyze the function of objects, it is regularly used in shifting 3D images, mainly in clinical images. It takes an entry of 3D extent information or a sequence of 2D frames. The 3D-CNN approach is used in hand gesture recognition. It additionally makes use of the depth and depth channels with the neural community to function in 3D convolutions. Some more methods and algorithms are also used in gesture recognition such as HCI(human-computer interface), 2D and 3D Kalman Filter, CNN Gesture Classification, Image segmentation, and many more methods are used in these applications.

OPINION

Augmented reality and Virtual reality have gained a lot of interest these days and 3D reconstruction is one of the main concepts required to build these technologies, like making a 3D model of any scenario, etc. In our opinion, AR and VR have an increasing market and they are very useful in the field such as gaming, entertainment, virtual tourism, etc. Thus, applying 3D reconstruction for these technologies will have a great scope ahead.

CONCLUSION

In this paper, we have enclosed the topic of 3D reconstruction, some of its applications, and algorithms by taking references from different research papers and review papers. We can also gain an understanding of different types of applications in which 3D reconstruction is performed with the help of images or videos. To perform 3D reconstruction, we have to familiarize ourselves with different types of algorithms, some of which are introduced in this paper. Different types of software are also mentioned that are used to reconstruct 3D scenes, sketches, shapes of objects, and much more. Our main aim is to explore 3D reconstruction techniques and learn more about different kinds of algorithms.

REFERENCES

[1] Ham, Hanry & Wesley, Julian & Hendra, Hendra. (2019). Computer Vision-Based 3D Reconstruction: A Review. International Journal of Electrical and Computer Engineering (IJECE). 9. 2394. 10.11591/ijece.v9i4.pp2394-2402.

[2] Wei, H., Tang, L., Wang, W. and Zhang, J., 2022. Home Environment Augmented Reality System Based on 3D Reconstruction of a Single Furniture Picture. Sensors, 22(11), p.4020.

[3] Kim, P., Chen, J. and Cho, Y.K., 2018. SLAM-driven robotic mapping and registration of 3D point clouds. Automation in Construction, 89, pp.38-48.

[4] Wang, Y., James, S., Stathopoulou, E.K., Beltrán-González, C., Konishi, Y. and Del Bue, A., 2019. Autonomous 3-D reconstruction, mapping, and exploration of indoor environments with a robotic arm. IEEE Robotics and Automation Letters, 4(4), pp.3340-3347.

[5] Aharchi, M. and Ait Kbir, M., 2019, October. A review on 3D reconstruction techniques from 2D images. In The Proceedings of the Third International Conference on Smart City Applications (pp.510-522). Springer, Cham.

[6] Nuchter, A., Surmann, H. and Hertzberg, J., 2003, October. Automatic model refinement for 3D reconstruction with mobile robots. In Fourth International Conference on 3-D Digital Imaging and Modeling, 2003. 3DIM 2003. Proceedings. (pp. 394-401). IEEE.

[7] Hermoza, R. and Sipiran, I., 2018. 3D reconstruction of incomplete archaeological objects using a generative adversarial network. In Proceedings of Computer Graphics International 2018 (pp. 5-11).

[8] Bobou, O., Kristensen, N.B., McAvoy, S. and Raja, R., 2020. Archive Archaeology in palmyra, Syria a new 3D reconstruction of the tomb of Ḥairan. Digital Applications in Archaeology and Cultural Heritage, 19, p.e00164.

[9] Meline, A., Triboulet, J. and Jouvencel, B., 2012, October.Comparative study of two 3D reconstruction methods for underwater archaeology. In 2012 IEEE/RSJ International Conference on Intelligent Robots and Systems (pp. 740-745). IEEE.

[10] Lechelek, L., Horna, S., Zrour, R., Naudin, M. and Guillevin, C., 2022. A Hybrid Method for 3D Reconstruction of MR Images. Journal of Imaging, 8(4), p.103.

[11] Wang, Y., Zhong, Z. and Hua, J., 2019. DeepOrganNet: on-the-fly reconstruction and visualization of 3D/4D lung models from single-view projections by a deep deformation network. IEEE Transactions on Visualization and Computer Graphics, 26(1), pp.960-970.

[12] Hosseinian, S. and Arefi, H., 2015. 3D RECONSTRUCTION FROM MULTI-VIEW MEDICAL X-RAY IMAGES–REVIEW AND EVALUATION OF EXISTING METHODS. International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences, 40.

[13] Min, S.W., Park, K.S., Lee, B., Cho, Y. and Hahn, M., 2006. Enhanced image mapping algorithm for the computer-generated integral imaging system. Japanese Journal of Applied Physics, 45(7L), p.L744.

[14] Guth, P.L., Van Niekerk, A., Grohmann, C.H., Muller, J.P., Hawker, L., Florinsky, I.V., Gesch, D., Reuter, H.I., Herrera-Cruz, V., Riazanoff, S. and López-Vázquez, C., 2021. Digital elevation models: terminology and definitions. Remote Sensing, 13(18), p.3581.

[15] Ren, D., Jia, Z., Yang, J. and Kasabov, N.K., 2017. A practical grabcut color image segmentation based on bayes classification and simple linear iterative clustering. IEEE Access, 5, pp.18480-18487.

[16] Kholil, M., Ismanto, I. and Fu'ad, M.N., 2021, February. 3D reconstruction using Structure From Motion (SFM) algorithm and Multi View Stereo (MVS) based on computer vision. In IOP Conference Series: Materials Science and Engineering (Vol. 1073, No. 1, p. 012066). IOP Publishing.

[17] Andersen, A.H., 1989. Algebraic reconstruction in CT from limited views. IEEE transactions on medical imaging, 8(1), pp.50-55.

[18] Podoleanu, A.G., 2012. Optical coherence tomography. Journal of microscopy, 247(3), pp.209-219.

[19] Song, Fuli. (2021). 3D Virtual Reality Implementation of Tourist Attractions Based on the Deep Belief Neural Network. Computational Intelligence and Neuroscience. 2021. 1-11. 10.1155/2021/9004797.

[20] Bastanlar, Y., Grammalidis, N., Zabulis, X., Yilmaz, E., Yardimci, Y. and Triantafyllidis, G., 2008. 3D reconstruction for a cultural heritage virtual tour system. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 37-B5, pp.1023-1036.

[21] Chen, Y., Zhang, B., Zhou, J. and Wang, K., 2020. Real-time 3D unstructured environment reconstruction utilizing VR and Kinect-based immersive teleoperation for agricultural field robots. Computers and Electronics in Agriculture, 175, p.105579.

[22] Howard, T.L., Murta, A.D. and Gibson, S., 2000, February. Virtual environments for scene of crime reconstruction and analysis. In Visual Data Exploration and Analysis VII (Vol. 3960, pp. 41-48). SPIE

[23] Wang, C., Pelillo, M. and Siddiqi, K., 2019. Dominant set clustering and pooling for multi-view 3d object recognition. arXiv preprint arXiv:1906.01592.

[24] Koguciuk, D., Chechliński, Ł. and El-Gaaly, T., 2019, October. 3d object recognition with ensemble learning—a study of point cloud-based deep learning models. In the International Symposium on Visual Computing (pp. 100-114). Springer, Cham. [25] Jain, S. and Kasaei, H., 2021. 3D_DEN: Open-ended 3D object recognition using dynamically expandable networks. IEEE Transactions on Cognitive and Developmental Systems.

[25] Su, H., Maji, S., Kalogerakis, E. and Learned-Miller, E., 2015. Multi-view convolutional neural networks for 3d shape recognition. In Proceedings of the IEEE international conference on computer vision (pp. 945-953).

[26] Yang, S., Xu, M., Xie, H., Perry, S. and Xia, J., 2021. Single-view 3D object reconstruction from shape priors in memory. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (pp. 3152-3161).

[27] Malassiotis, S., Aifanti, N. and Strintzis, M.G., 2002, June. A gesture recognition system using 3D data. In Proceedings. First International Symposium on 3D Data Processing Visualization and Transmission (pp. 190-193). IEEE

[28] Keskin, C., Erkan, A. and Akarun, L., 2003. Real time hand tracking and 3d gesture recognition for interactive interfaces using hmm. Icann/Iconipp, 2003, pp.26-29.

[29] Vrskova, R., Hudec, R., Kamencay, P. and Sykora, P., 2022. Human Activity Classification Using the 3DCNN Architecture. Applied Sciences, 12(2), p.931.]

[30] Molchanov, P., Gupta, S., Kim, K. and Kautz, J., 2015. Hand gesture recognition with 3D convolutional neural networks. In Proceedings of the IEEE conference on computer vision and pattern recognition workshops (pp. 1-7)