IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

REVOLUTIONARY REAL-TIME HOLOGRAM DEVELOPMENT USING DEEP LEARNING: A SURVEY

[1] Swathi Edem

[1]Assistant Professor

[1] Computer Science and Engineering Department,

[1] Chaitanya Bharathi Institute of Technology, Hyderabad, India

Abstract: Holograms are as same as photographic images or videos which also stores phase of the light which gets reflected from the object beam. These holograms are initially used to store the 3D photographs as a trademark such as a hologram at the back of a Debit/Credit card etc. The initial development of holograms involved basic optical physics which later expanded to computational imaging as occlusion is quite low which imbalances background or edge parts of images. Hence, different approaches are being made in recent studies to improve the computational power of developing a hologram.

The initial techniques which were used are point-based, which captures the high resolution images and calculates the RGB-D values at each pixel, render those values and project through Spatial light modulators (SLM) or Digital Micro-mirror Devices. If the data is more or images are more, the frames per pixel increase which make the rendering harder. So different deep learning techniques are used which initially train the RGB-D images to create a holographic image of an object. The development of this technique has started in 2020 and researchers are continuing to optimize the approach. This work aims to present the different approaches used to create a holographic images using deep learning techniques.

Index Terms **- Hologram, Reflection, Convolutional Neural Network(CNN), Computer-generated holograph (CGH)**

I. INTRODUCTION

1.1 Introduction

Holograms are the photographic recording of objects which store the image as a recording of the light form reflected from the object rather than the lens. Holograms are generated using basic reflections of light and optical physics. This technique enables a wave to be recorded and reconstructed later. The Holograms are also called as Ghost technology as it projects the recorded data using light beams in 3D view. The First Hologram was generated by Dennis Gabor in 1948. The Holograms are the three-dimensional image formed by the reflection of light from an object that can store both the intensity of light bounded back and phase of those light waves.

The main difference between a camera-captured image and a holographic image is the phase. While capturing a normal image using a camera, the lens captures the intensity of light bounded back by the object and stores the light pattern on the film or screen which can be viewed later whereas, a holographic image also captures the phase of light bounded back by the object which stores depth of objects present in the image.

1.2 Types of Holograms

Holograms can also be used as an alternative to screens. There are different kinds of holograms that are used for different purposes. Unlike photographic images, holograms are images that result from the diffraction and interference of light rays. The different kinds of Holograms are[3]:

1. Reflection Hologram
2. Transmission Hologram
3. Hybrid Hologram

1) Reflection Hologram: Reflection Holograms are the kind of holograms that are visible using white light. The structure of the captured holograms allows them to also be viewed without a laser, using more ordinary light sources. The object and the reference beam are on the opposite side of the Holographic plate. This type produces high-quality images, thus very expensive. With a reflection hologram, the image is stored in a thick emulsion and can be viewed in white light.

2) Transmission Hologram: In Transmission Holograms, Both object and the reference beams are on the same side produced a good quality of holograms inexpensively compared to Reflection Hologram. Diverging lenses are used to spread the coherent light from the main beam. Beam splitters can also be used instead of the diverging lens. Transmission Holograms are generally used for Security Holograms such as trademark images, originality checkers for Textbooks, ATM cards, etc. When a coherent light beam is

forced on a beam splitter it splits the beam in half. A part of the beam is reflected on the object and the other beam is considered as a reference beam. Now, these laser beams fall on a holographic plate with which an interference pattern is formed on the plate thus creating the hologram.

3) Hybrid Real-Time Hologram: In this Hologram, the real-world object is not necessary to generate a hologram. The interference pattern is generally developed using Computer Generated Algorithms (CGA). Essentially there are three basic elements in Holography. Those are the light source, the hologram, and the image. If any of the two are predetermined, the other can be calculated. From the light source, we can get the diffraction pattern by using experiments such as the double-slit experiment, with which interference and diffraction patterns are generated helping in calculating the wavelength of the light source. Hence by changing the phase of the light source, we can get any kind of pattern and a hologram can be designed by the algorithms.

In other words, the tasks are divided into three subparts namely, Computation(scattering of light to get the wavelength), Encoding (Changing the wavefront to get the required pattern), and Reconstructing (Modulating the interference pattern onto a coherent light beam using hologram projectors).

Few Computation Algorithms are:

1. Point Source Algorithm: Here object is broken down into self-luminous points anelementary hologram is calculated for each chunk of points and the final hologram is synthesized by superimposing all the elementary holograms. This kind of approach is also used in the concept of ray tracing.

2. Fourier Transform Method: In the Fourier Transform method, Fourier transformation is used to simulate the propagation of each plane of depth of the object in the image. Here the image plane is broken into depth images and depth for each image is calculated.

Spatial Light Modulator: Spatial light modulators are the devices that impose spatially varying modulation on the coherent beam of light. These were placed on overhead projectors to project the beam of light which prints the hologram. Usually, an SLM modulates the intensity of the light beam. However, it is also possible to produce devices that modulate the phase of the beam or both the intensity and the phase simultaneously. These devices are used in holographic projection. Computer-generated holograph(CGH)'s can be projected using SLM devices. These devices use different techniques in projecting the holograms. The main challenge of SLM devices is forward propagation[5].

II. LITERATURE SURVEY

Using physics simulations for generating holograms involves calculating the chunks of elementary holograms and then superimposing them together to get the Computer-Generated Holograms[4]. To store the frequently used chunks, a data structure named look-up tables is used which helps in computationally improving the problem but accuracy is depicted. For a 3D object or image, making this work using a computer uses a lot of GPU, and also it's computationally slow.

The main problem behind the approach of physics simulations is bad light occlusions generated which causes leakage of foreground 3D scenes and bad rendering of background scenes thus reducing the realistic approach. Hence two algorithms are used to accelerate the CGH computations. Those are:

1. Light Field Approximation: In this approximation technique, coherent light beams are passed from a single point in a 3D plane, and the depth of each object in the image plane is calculated. Thus a good RGB-D image can be produced for accelerating 3D CGH.

2. Multilayer Approximation: In this approximation technique, a light beam is passed as a layer in a3D plane which enables the calculation of the depth of objects. Here, occlusions are good but rendering is not fast compared to the Light Field Approximation technique.

These approaches are used to reduce the lack of occlusion models but the computation cost and the phase-only method remain the same. Hence deep learning approaches are used to develop the CGH.

Computational speed can be improved by using deep learning techniques where different RGBD images are trained. Deep Convolutional Neural Networks using accurate image data are trained using multiple spatially varying large kernels or filters, non-linear activation functions which can improve the computational speed by generating the elementary holograms faster than physics simulations[2].

The trained network can be subsequently used to perform a predefined image reconstruction which typically takes only a fraction of seconds using standard G.P.U. without any iterations or manual training using simulations.

Organizations working on Holograms

- WayRay: Holographic Navigation System.
- LEIA 3D: Interactive Hologram development.
- HYPERVSN: 3D Holographic displays in industries.
- Microsoft: Devices that enable Holographic projection.
- Facebook: Spectacles that can display holograms and act as VR spectacles.

Adeep-learning-based CGH pipeline capable of synthesizing aphotorealistic colour 3D hologram from a single RGB-depth image in real time.Our convolutional neural network (CNN) is extremely memory efficient (below620 kilobytes) and runs at 60 hertz for a resolution of 1,920 × 1,080 pixels on a singleconsumer-grade graphics processing unit. A CNN is trained with differentiable wave-based loss functions5 and physically approximates Fresnel diffraction. With an anti-aliasing phase-only encoding method the speckle-free, natural-looking, high-resolution 3Dholograms are demonstrated [6].

A deep neural network based on generative adversarial network (GAN) to perform image transformation from a defocused bright-feld (BF) image acquired from a general white light source to a holographic image is proposed [7]. Training image pairs of 11,050 for image conversion were gathered by using a hybrid BF and hologram imaging technique. The performance of the trained network was evaluated by comparing generated and ground truth holograms of microspheres and erythrocytes distributed in 3D. Holograms generated from BF images through the trained GAN showed enhanced image contrast with 3–5 times increased signal-to-noise ratio compared to ground truth holograms and provided 3D positional information and light scattering patterns of the samples. The developed GAN-based method is a promising mean for dynamic analysis of microscale objects with providing detailed 3D positional information and monitoring biological samples precisely even though conventional BF microscopic setting is utilized.

A sectional holographic reconstruction method with a complex deconvolution approach is proposed [8]. Both the amplitude and phase of the complex wavefront were taken into account in each step of the inverse problem modeling and solving. The experimental results show that the proposed method works for both simple and relatively complicated 3D objects, even for partially occluded objects. The sectional capacity of the proposed method was indicated as approximately six times of the resolution of the diffraction limit for a two-point-like object. Because of the perfect 3D imaging quality, the proposed method has the potential for true volumetric holographic imaging. The limitations of the method is the method is time consuming, however, it can be accelerated with parallel computing or graphics processing unit. It should be mentioned that even though the proposed method can achieve a perfect hologram reconstruction, the overall quality of the reconstruction is still limited by the recording approaches.

III. METHODOLOGIES

3.1 Implementation of CNN for holograms

For developing a real-time revolutionary hologram, the parameters to be considered are computational speed, the accuracy of generated CGH, and the type of SLM used for holographic projection.

In the initial stage, to improve occlusion, the light waves are propagated in the forward and backward direction which is used in generating the phase of the image. So while rendering any object, the foreground pixels are calculated first and then the background pixels are calculated. Instead of physical simulations, CNN is used. The role of CNN is to reduce the images into a form that is easier to process, without losing features that are critical for getting a good prediction.

The Developed CNN algorithm learns a series of small and spatially invariant convolution kernels that progressively build sub holograms, which is faster than explicitly constructing holograms from chunks.

3.2 RGB-D Object Recognition

At first, we need to recognize the objects present in RGB-D images to train the model for developing a CGH. Due to their strong abilities in image characterization, CNNs have researched their points to solve RGB-D object recognition problems and proven to perform excellently. Discriminative features can be extracted independently from the RGB and depth modalities by taking advantage of CNNs, and the features of the two modalities are fused and fed to a classifier for recognition. A general framework of MMCNNs based RGB-D object recognition is shown in Fig. 1[1].

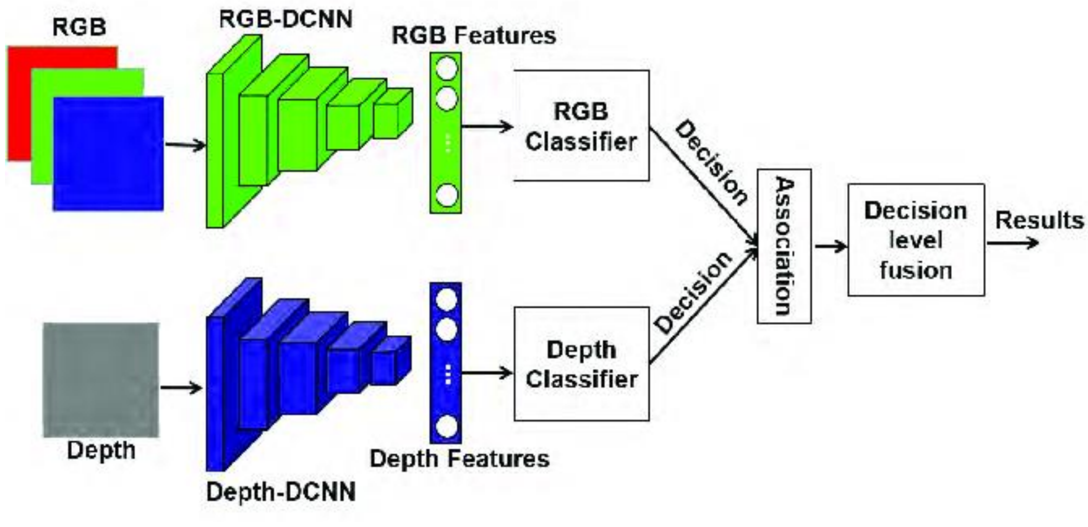

Figure 1 A general framework of MMCNNs based RGB-D object recognition

The number of RGB-D datasets, especially labeled data, is much more scarce compared to the RGB images, and it makes the training of data-hungry algorithms such as CNNs unfeasible. To generate the CGH, the dataset consists of approximately 4000 CGH, which includes RGB-D Images with the same depth effect and uniform pixel distribution, and corresponding Holograms.

Figure 2 The RGB- image(Left-side image) and depth image for a given sample(Right-side image)

From the given Fig. 2, we can observe the RGB- image and depth image for a given sample, which perfectly describes the dataset required to train the CNN model.

In the given MMCNNs, the given RGB-D image consists of both RGB image in a given plane and depth image which records the phase or distance of the object in the given surface plane. The images are then split into RGB images and depth images which were separately forwarded to three staged deep learning CNN model which applies spatially invariant kernels on those images and converts the given images to feature vector of N x 1. The generated feature vectors are later classified according to the color at each pixel and the depth effect of objects in the depth image.

After the classifiers, a feature fusion occurs where integration of prominent features in eachfeature vector occurs to obtain more prominent feature information. Now the images are attached with each object recognized individually and can be used in Hologram generation.

3.3 Block Diagram of CNN model for CGH generation

In the given approach, the RGB-D images are trained in CNN along with non-linear activation units. VGG-net, Google-Net, etc. are used as CNN models.

In the given approach, a deep-learning-based CGH pipeline capable of synthesizing a photorealistic color 3D hologram from a single RGB-depth image in real-time is trained. At first, Our CNN is trained with differentiable wave-based loss functions and physically approximates Fresnel diffraction. With an anti-aliasing phase-only encoding method, the model generates high-resolution 3D holograms. In each layer, there are spatially invariant kernels that filter the data or feature vector. This reduces the data size without lowering the pixels or image.

The main advantage of using CNN is it processes the images also covering sparse data in each image. In between the layers, Rectified Linear unit (ReLu) Activation function is used which is used to naturally stopping the forward propagation of occluded wave fronts.

Here, the numbers of layers are directly proportional to the extent of sub-holograms generated. So to reduce the number of layers of CNN, the target hologram is propagated to the center of the 3D plane or volume of the CGH generator which minimizes the extent of maximum layers. As the layers increase, the computational cost also increases.

After the CNN projection, the predicted hologram will be back propagated to the target location and displayed using the SLM or DMD. The size of the dataset needed to train the model is less than 0.7MB and the CNN runs at 60 hertz for a resolution of 1,920 × 1,080 pixels on a single consumer-grade graphics processing unit.

CNN enables the computation of holograms in a fraction of seconds. Using optical physics, the generated CGH are of 30 -40 frames per second, while projecting a live holographic video. This depicts the slow computational speed of physics simulations meanwhile CNN generates 60 fps-based holograms which are revolutionary in changing the live holographic projections. The main advantages of using CNN for Real-time Holograms are its computational speed and accuracy of generating live holograms.

IV. APPLICATIONS

Holography is not only used to make three-dimensional pictures and it does not confine itself to the visible spectrum. Microwaves are used to detect objects through otherwise impenetrable barriers. X-rays and ultraviolet light are used to detect particles smaller than visible light.

Holography is also used to detect stress in materials. A stressed material will deform, sometimes so minutely that it is not visible. A hologram can amplify this change since the light reflected off of the material will now be at a different angle than it was initially. A Comparison between the before and after holograms can determine where the greatest stress is.

Holography is used in a new kind of computer, an optical computer. Simple reflection holograms are used on polymer matrix which helps in biochemical sensing. 3D Visualization of objects such as graphs or models can be tuned easily using holograms. Transmission Holograms are used in providing security of materials that needed individual access or having trademarks. True 3D projections can be generated using holograms which are helpful in model designing or constructions etc.

Holograms are often used in Contour Generation which designs a topographic map showing valleys, hills regarding any kind of data. Holograms are also used in Interferometry, a measurement method using the phenomenon of interference of light.

V. CONCLUSION AND FUTURE SCOPE

In the Future the holograms are about to change computing devices. Revolutionary Real-time Holograms can replace live concerts or meetings which can be so realistic. The traditional development of holograms using physics simulations is replaced with advanced deep learning techniques that generate CGH with more frames per second compared to naïve methods. Revolutionary Real-time Holograms are made possible with the advancement of computational imaging technologies. In recent days, computational speed has taken the place and most of the problems are needed to solve with low computational cost. Hence Convolutional Neural Networks are used in computing the holograms. Advancements in spatial computing devices such as VR headsets, AR Glasses also include holograms which project the data displaying on a screen.

MIT Researchers are working on adding eye-tracking technology to speed up the system by creating holograms that are high-resolution only where the eyes are looking. Real-time live projection of 3D holograms using deep learning can replace the video calling system or conference calls with virtual 3D projections. Revolutionary Real-time live projections are possible and are made faster using internet protocols and various deep learning techniques in generating CGHs. Smartphones can be computed using Holograms using spatial computing. Spatial computing can be evolved in the future as Deep Learning is now being used in generating real-time holograms.

REFERENCES

[1] M. Gao, J. Jiang, G. Zou, V. John and Z. Liu, "RGB-D-Based Object Recognition Using Multimodal Convolutional Neural Networks: A Survey," in IEEE Access, vol. 7, pp. 43110-43136, 2019, doi: 10.1109/ACCESS.2019.2907071.

[2] Mingliang Gao, Jun Jiang, Guofeng Zou, Vijay John, Zheng Liu, "RGB-D-Based Object Recognition Using Multimodal Convolutional Neural Networks: A Survey" in IEEE Access (Volume: 7), published on 09 April 2019, DOI: 10.1109/ACCESS.2019.2907071.

[3] Avon ampo,"Hologram Types", source https://www.eeweb.com/hologram-types/

[4] Rajesh Uppal, "3D Hologram Technology Advancing to Real-time 3D Holograms on a smartphone" https://idstch.com/technology/ict/3-d-hologram-technology-advancing-to-real-time-3d-holograms-on-a-smartphone/, published on September 2021.

[5] https://en.wikipedia.org/wiki/Spatial_light_modulator

[6] Liang Shi, Beichen Li, Changil Kim, Petr Kellnhofer & Wojciech Matusik, "Towards real-time photorealistic 3D holography with deep neural networks",
https://www.nature.com/articles/s41586-020-03152-0, in Nature Researches, published on 10th March 2021.

[7] Taesik Go, Sangseung Lee, Donghyun You & Sang Joon Lee, "Deep Learning-based hologram generation using a white light source", https://www.nature.com/articles/s41598-020-65716-4, in Nature Researches, published on 02nd June 2020.

[8] N. Chen, E. Y. Lam, T.-C. Poon and B. Lee, "Sectional hologram reconstruction through complex deconvolution", Opt. Lasers Eng., vol. 127, Apr. 2020.