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Implementation of Digital Holograms to Diagnose Cancer Cells

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ABSTRACT: Early and accurate diagnosis of cancer may significantly increase the survival rate of patients. In this study aim is to introduce Deep Transfer Learning (DTL) model to classify cells with tumour. The lens-free digital in-line holography (LDIH) is promising microscopic tool that overcome several drawbacks of traditional lens-based microscopy like limited field of view. The object images are recorded using diffraction pattern produced by LDIH and reconstruction of images are done using Direct Binary Search algorithm (DBS) to maintain the image information in 3D form. Using DTL approach with pre-trained model VGG19 the features are extracted and sent to the classifier to classify the cells. The DTL-based approach including a VGG19 pretrained network showed robust performance. Combined with the developed DTL approach, LDIH could be realized as a low-cost, portable tool for point-of-care diagnostics.

KEYWORDS: Digital Holograms, Deep Transfer Learning (DTL), Lens-free Digital in-line Holograms (LDIH), Direct Binary Search (DBS), VGG19

I.INTRODUCTION

The term holography was introduced by Greek words “Holo” - whole and “Graphy” - writing. The Holographic projection is the new way of technology of viewing things in the 3-d form and also provides facility to manipulate, zoom-in, zoom-out, slicing of the object for better understanding of the image. Holography is the method used to record patterns of light. These patterns are reproduced as three-dimensional image called holograms. In medical, many systems generate complex data using advanced imaging technology, such as Magnetic Resonance Imaging (MRI) and ultrasounds scans. These images are in 2-d form which is difficult to understand for surgeons. So, this technology helps in forming the image in 3-d form and providing facilities to manipulate, zoom-in, zoom-out and slicing of the image.

In predicting the human cells has cancer or not the standard method followed is tissue biopsy but the test is relatively expensive and complex, and it requires the use of sophisticated facilities that becomes serious challenge in regions with limited resources. This technique produces around one-tenth of the thickness of a human hair that can be difficult to view complete information at a time. Hence the holographic technology is used such that it produces holographic lens-free microscope that's capable of producing 3-D pictures with one-tenth the image data that conventional scanning optical microscopes need to do the same thing. Thus, forming digital holograms allowing doctors to view different cross-sections, or digital slices of the tissue sample

The object to be captured is placed in free space and the light emitted from each object point is collected by a beam splitting system, in which the input wave is split into two or more waves and each wave is modulated differently. The waves are originating from the same object point thus, they are mutually coherent, and hence they can produce an interference pattern on the image sensor plane. The sensor can accumulate the entire interference patterns of all the object points into an incoherent hologram. Here a single hologram or several acquired holograms are formed, they are fed into a digital computer. In the case of several holograms, they are combined into a single digital hologram. Finally, the image of the object is reconstructed from the processed hologram using DBS algorithm. The reconstructed hologram contains details of both amplitude and phase thus helps in recording every information of the object.

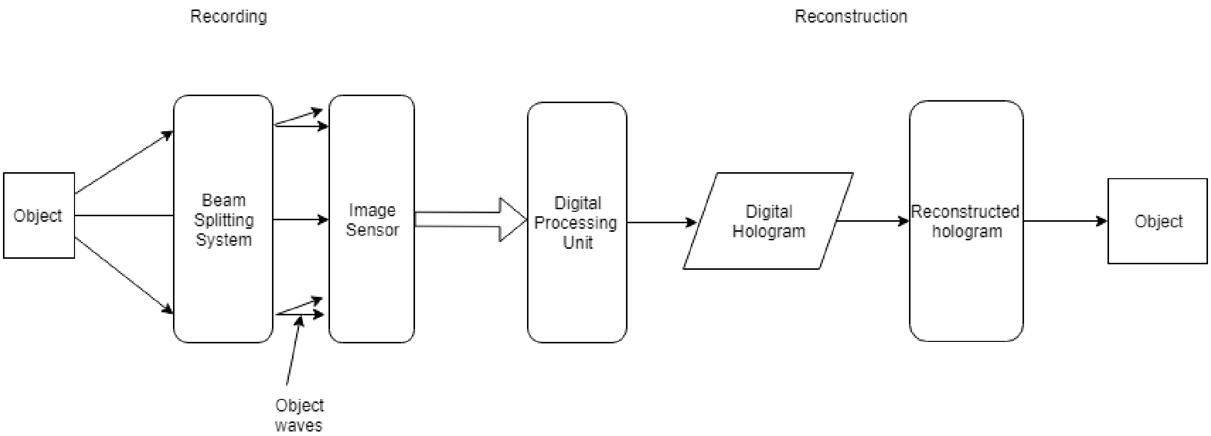

Fig 1: Architecture diagram for recording and reconstructing holograms

II.LITERATURE SURVEY

The author [1] have discussed the issues that affect the acceptability and adoption of the true 3D radiology are like-resolution of the image, clarity of the image, usefulness of three-dimension, incremental cost in terms of time and reimbursement and means to evaluate the clinical effectiveness of the volumetric image in medical practise. Applying holographic and mixed reality technology to provide interface for manipulating the image and creating high-definition virtual image [2]. It is attracting students during their training period as it provides real like image of human organ with better understanding of human anatomy [3]. Full parallax hologram can also be used for three-dimensional biomedical images for medical analysis [4]. Introducing HoloLens devices to deliver healthcare to remote and under-served areas [5]. Using peak detection algorithm to detect pulse's speak using smartphone [6]. The development of Holographic microwave imaging array (HMIA) technique for detecting early breast cancer detection and brain stroke detection [7]. Comprehensive sensing is introduced to capture essential aspects of high-dimensional object using a few measurements possible [8]. Bulk photorefractive crystals and photoreactive multiple quantum-well (MQW) devices have been investigated as the hologram recording element this could be important for vivo imaging through biological tissue [9].

III. SUMMARY OF LITERATURE SURVEY

Holographic techniques are applied to medical imaging with greater focus and increasing benefit than ever before. In recent the appreciation of three-dimensional(3-D) rendering of medical radiological data has increased and provides the opportunity to employ holographic rendering as an additional means of displaying the radiological volume. As medical imaging plays important role in diagnostic process it is necessary to observe and analyse hidden details of the human anatomy, which is critical to the success of surgeries or clinical treatments. The holography and mixed reality technologies allow for the creation of high-definition virtual computing models of human organs and direct manipulation of interacting surfaces through such 3D models within holographic environment.

Three dimensionalities are a consequence of the recording of phase information in the hologram. The presence of phase information in holographic images makes them extremely versatile and amenable to such a posterior technique as interferometry and dark-field imagery. Holography can also be used to analyse images, that is, to enhance image contrast and resolution, or to perform such functions as correlation analyses and pattern recognition. Moreover, the versatility of holography extends beyond the visible portion of the electromagnetic spectrum; holograms made with infrared, ultraviolet, microwave, or ultrasonic illumination, or synthetic holograms made using a computer can be used to produce visible images or to analyse nonvisible images.

IV.PROPOSED METHODOLOGY

Medical images such as CT, MRI, ultrasound images are in 2-d form surgeons has to imagine these images in 3-d form in their mind for better understanding So to make it easy for doctors, holographic technology has evolved that helps not in displaying medical image in 3-d form also helps in rotating, zoom in, slicing and manipulating the image This technology also helps surgeon to take better decisions before operating on the real patients. The proposed system consists following modules that are required to develop reliable system to provide point of care devices.

- Recording Holograms: In holography, the light interference between the unscattered waves and scattered object waves is first recorded on photosensitive film. When this recording film is illuminated by the same

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coherent reference wav used in recording, an image is formed. In LDIH, the photosensitive film used in holography is replaced with modern digital image sensors such as charge coupled device (CCD) and Complementary metal-oxide semiconductor (CMOS) chips to directly record the lens-free holograms. After the holograms is acquired by an image sensor, it is digitized and then processed to reconstruct.

- Converting to binary image and Reconstruction: The direct binary search (DBS) algorithm enables holographic data to be converted into a binary hologram The DBS algorithm is an iterative method that starts from a random binary pattern On each iteration, the propagation of a wave front diffracted by the binary Fourier hologram to the space domain is calculated by an inverse discrete Fourier transformation.To check that the algorithm converges to a binary hologram that can reconstruct the recorded object numerical reconstructions are performed for the binary hologram computed with the DBS algorithm. The reconstruction is examined in a different plane to verify that the depth of the object is not lost after the conversion to binary data

$$H_{space}^{i}(n,m)=\frac{1}{\sqrt{M\cdot N}}\sum_{u=\frac{-M}{2}}^{\frac{M}{2}-1}\sum_{v=\frac{-N}{2}}^{\frac{N}{2}-1}H_{Fourier}^{i}(u,v)\exp\left[j2\pi\left(\frac{u\cdot n}{M}+\frac{v\cdot n}{N}\right)\right]$$

Eq (1)

In the above equation M and N represent the size of the Fourier hologram, and $H_{Fourier}$ (u,v) is the value of pixel in the binary Fourier Hologram on the i_{th}iteration.

The reference hologram is obtained by convoluting the raw complex hologram from Eq (1) with the FZP z = $-z_o$this is given by:

$$H_{ref}(n,m)=H_{com}(n,m)\otimes\frac{j}{-\lambda z_o}\exp\left\{j\frac{\pi\Delta l^2}{-\lambda z_o}\left(n^2+m^2\right)\right\}$$

Eq (2)

The two complex holograms from Eq (1) and Eq (2) are compared by computing mean square error (MSE)

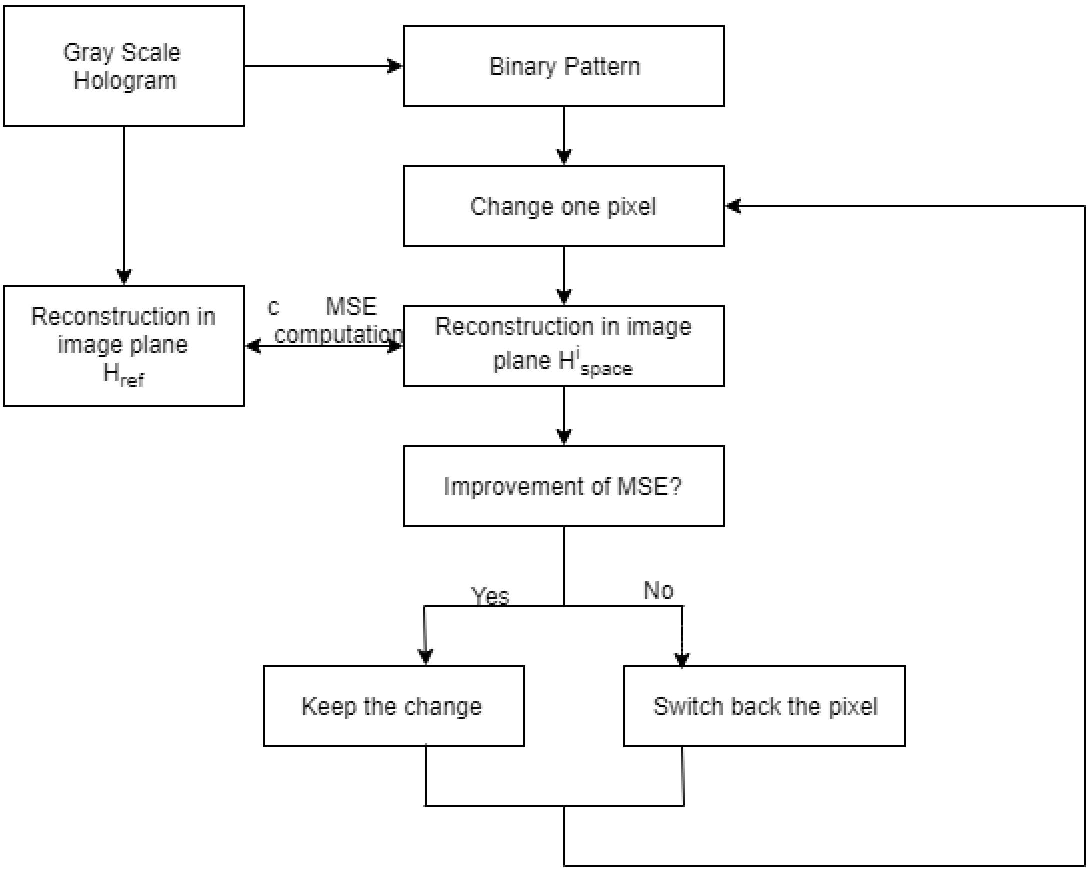

Fig 2: Block diagram of the iterative DBS Algorithm

- Converting image to DICOM: The reconstructed images are converted to dicom format using HoloDicom software with three-dimensional content in a holographic image of mixed reality. Once these images are located in the space, it is possible to transfer, rotate, segment and scale on images, to adjust their location and size according to the demand and need of the user.
- Segmentation, Feature extraction and Classification: Using VGG19 pre-trained model to extract features from the training set of holograms. Since the VGG19 was trained using colour images and the considered data images are in grayscale, copy the same image in each channel in VGG19 pre-trained model. Then, using PCA (Principal component Analysis) the feature dimensions are reduced. Using the features from VGG19-PCA or PCA alone, multilayer perceptron is trained for hologram images consisting of three fully-connected neural network blocks for the classification. The first two blocks have a fully-connected (FC) layer, Batch Normalization layer, ReLU activation and Dropout layer (parameter: 0.5). The FC layers in the first two blocks have the sizes of 128 and 64, and the L2 norm regularize (parameter: 0.05). The third block has an FC layer with SoftMax activation. The considered dataset can be randomly split into training, validation, testing dataset with a 64:14:20 ratio. By using binary classification, the images are classified into as cells with tumor or not with percentage of accuracy of result and percentage of affect. The model is selected based on validation loss and the model performance is evaluated based on testing data. The accuracy of VGG19-PCA-MLP is up to 90.12% for holograms whereas accuracies of PCA-MLP is only 79.5%.

  The performance of algorithm can be compared with Support Vector Machine (SVM) and Random Forest (RF) algorithm by training both the algorithms with VGG19-PCA features. In classifications MLP outperforms SVM and RF significantly.

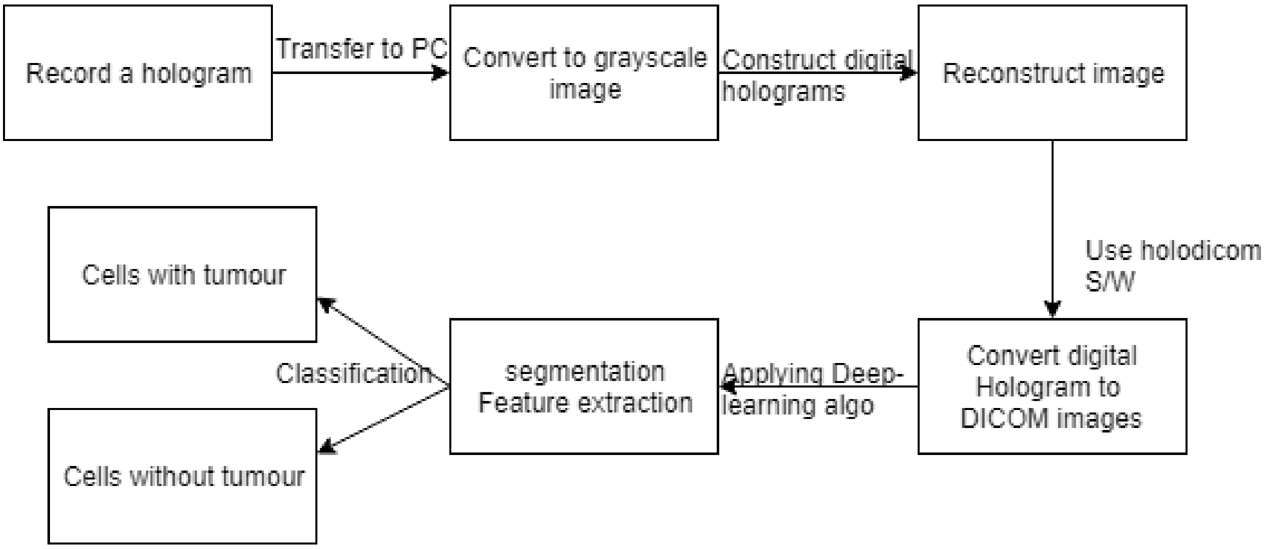

Figure 3: Block diagram of Digital Holograms to diagnose cancer cells

V.CONCLUSION

The DTL approach requires much less computational power, which could allow for Point-of-care devices to train and predict holograms. The neural networks reliably handle overlapping of interference pattern among cells or between cells. The DTL approach offer deep learning-based training/classification to be executed at the local device without computational power and not relying on high-resolution reconstructed images. The network is elastic and can be continuously updated for high accuracy in POC devices. With these metrics, that the developed ML networks will significantly empower LDIH, realizing truly POC diagnostic platform.

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