Diagnosis and Surveillance of Covid-19 Pandemic Based on 3D Integral Images Technique

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Abstract—3D integral imaging is a true 3D imaging technology. It offers the simplest form that is capable of recording and replaying the true light field 3D scene in the form of a planar intensity distribution, by employing microlens array. There is a new world health crisis threatening the humanity with the spread of Covid-19 (Coronavirus Disease-2019). The Covid-19 belongs to a family of viruses that may cause various symptoms such as pneumonia, fever, breathing difficulty, and lung infection. Real images of Covid-19 patients confirmed by computed tomography CT were used to segment areas of increased attenuation in the lungs, all compatible with ground glass opacities and consolidations. This paper describes a new method to generate an indicative Covid-19 3D integral image models. The method is based on a Multiprocessor Ray Tracing System including Philips viewer, 3D slicer software and unidirectional camera. Experimental results are extremely satisfactory and for the first time it is proved that 3D integral images Covid-19 models are generated through Multiprocessor ray tracing system in order to deep monitoring and visualization to could be aid diagnosis in the absence of RT-PCR kits as demonstrated. A new file format content is created as well.

Keywords—computer graphics, 3D integral images, multiprocessor ray tracing, Covid-19 pandemic, medical images processing & visualization

I. Introduction

The main idea behind this novel algorithm is to utilize the previous work [1-5] to handle the generation of a covid-19 3D integral image a sequence of frames , and the exploit the new file format to prevent the distortion of the images.

Medical applications 3D endoscopy and tomography for direct observation and diagnosis of Covid-19 is now certain and available application. Creation of real-time 3D covid-19 imaging system has been now achieved to open application.

Existing Radiologic Representation of pathology is limited by its three-dimensional representation on a two-dimensional screen. [2][6].

In this new developed method, Philips Dicom viewer, 3D slicer packages and Multiprocessor ray tracing system are used in order to generate a Covid-19 3D integral images model. As a result, the new method is accomplished by adding a new programming functions in C, C++, Java and Mathlap to adapted Multiprocessor ray tracing system *"Tachyon"* software package, in order to easily diagnoses and observation of the Covid-19.

The new technique for confirmed case, reconstruction in motion and maximal intensity perspective projection do create Covid-19 3D integral images model. 3D reconstruction provides multiple projections with a preview of the surgical field and study of lesion characteristics, which can help achieve faster and safer surgery.

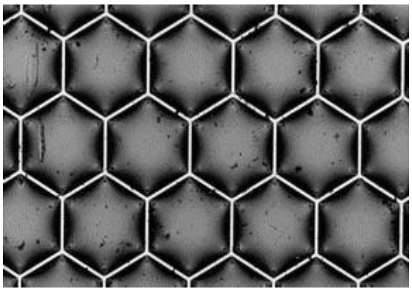
II. Advanced Integral Images Systemes

It is possible to capture 3D integral images electronically using a commercially available CCD array [22-38]. This form of capture requires a high resolution CCD together with specialised optical components to record the micro-images fields produced by precision micro-optics. The object/scene is recorded by a CCD placed behind the recording microlens array through a rectangular aperture. The aperture greatly affects the characteristics of the micro-images recorded. Since each micro-image is an image of the object seen through the aperture independently, its shape and size is determined by the aperture. If the field of a sub-image is fully covered by the image, it is said to be *fully-filled*, otherwise it is said to be *under-filled* or *over-filled.*

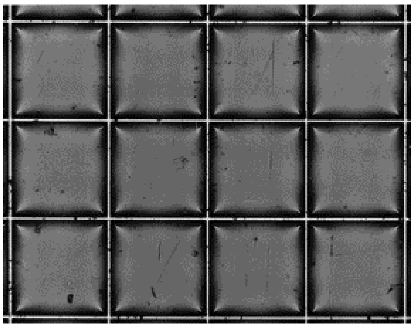
The system will record live images in a regular block pixel pattern. The planar intensity distribution representing an integral image is comprised of 2D array of $M \times M$ sub-images due to the structure of the microlens array used in the capture and replay. Sections of such typical lens array are illustrated in Figure 1. Different configuration patterns can be used in the design and manufacturing of microlens arrays as shown in figure 1. The *packing density* or *fill factor* is an important design criterion. The hexagonal arrangement of element microlenses has a higher capacity of the lens grid, and the hexagonal element shape can lead to 100% packing density without dead space [7]. These properties of the hexagonal microlens array make it a good choice for OII.

The resulting 3D images are termed Omnidirection Integral Images (OII) and have parallax in all directions. The rectangular aperture at the front of the camera and the regular structure of the hexagonal microlenses array used in the hexagonal grid (recording microlens array) gives rise to a regular ‘brick structure’ in the intensity distribution as illustrated in Figure 2. Unidirectional integral images (UII) are obtained by using a special case of the integral 3D imaging system where 1D cylindrical microlens array is used for capture and replay instead of a 2D array of microlenses. A section of a cylindrical lens array is shown in Figure 3. The resulting images contain parallax in the horizontal direction only. Figure 4(a) shows an electronically captured unidirectional integral 3D image and Figure 4(b) shows a magnified section of the image. The *M* vertically running bands present in the planar intensity distribution captured by the integral 3D camera are due to the regular structure of the 1D cylindrical microlens array used in the capture process.

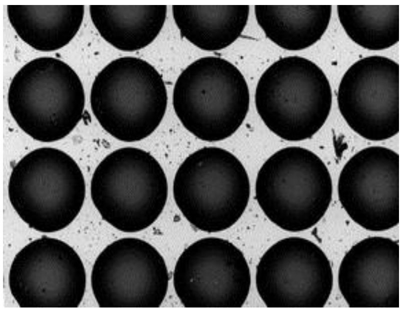
The replay of the 3D Integral images is achieved by placing a microlens array on the top of the recoded planar intensity distributions. The microlens array has to match exactly the structure of the planar intensity distribution.



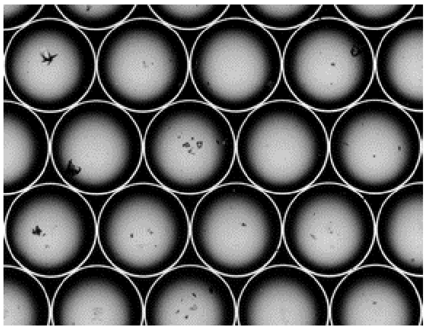
(a) hexagonal microlens array.



(b) Square microlens array.

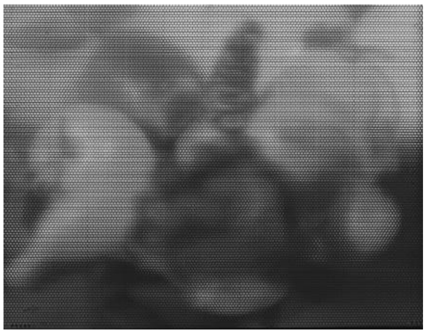


(a) Circular microlens array.
Orthogonal grid arrangement.

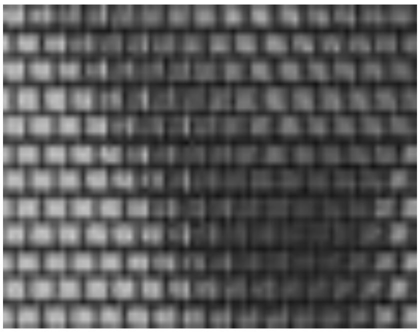


(b) Circular microlens array.
Hexagonal grid arrangement.

Figure 1: Enlarged part of microlens arrays using different configuration [8].



(a)



(b)

Figure 2: (a) Example of the nature of sub-image field. (b) magnified section [8].

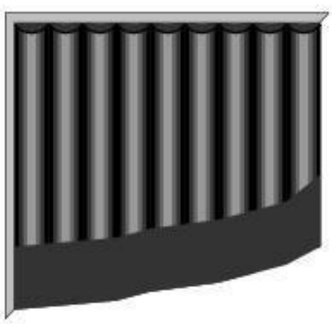
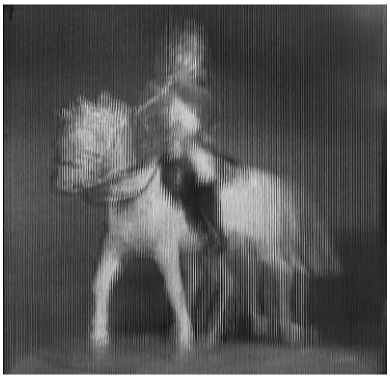


Figure 3: Diagrammatic representation of the lens array [9].



(a)

(b)

Figure 4. An electronically captured unidirectional integral image (a) Full (b) Magnification [8].

III. CAMERA MODEL IMPLICATIONS

Due to the nature of the recording process of integral imaging, many changes the camera model used in standard ray tracing. For lenticular sheets, each lens acts like a cylindrical camera. A strip of pixels is associated with each lens forming a sub-image. Each lens records a sub-image of the scene from a different angle as shown in the Figures 5 and 6. For micro-lenses arrays each lens acts like a square or a hexagonal camera depending on the structure of the lenses, as shown in Figure 7. In the lateral cross section of the lenticular or the micro- lenses, a pinhole model is used. In the case of lenticular sheets, the pinhole forms a straight line parallel to the axis of the cylindrical lens in the vertical direction. For each pixel, a primary ray is spawned. The recording path of the primary ray draws a straight line going forward towards the image plane and backward away from the image plane. Similar primary rays of neighbouring lenses are spawned to similar directions parallel to each other. Therefore highly correlated sub-images are produced which is a property of integral imaging.

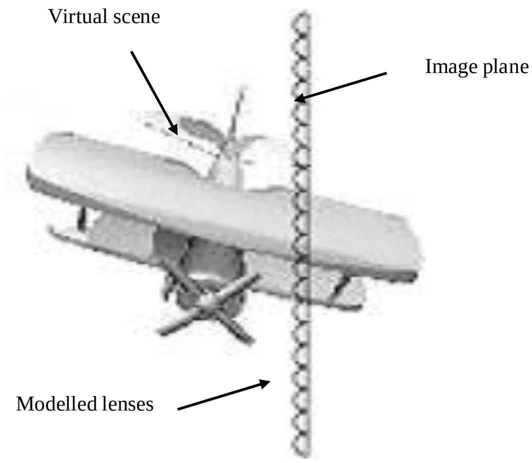


Figure 5: Top view of the modelled optical system of integral imaging [8].

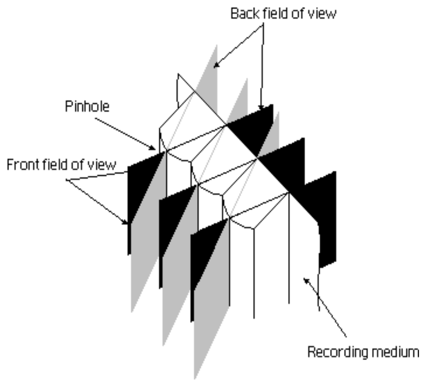


Figure 6: Lenticular sheet model in integral ray tracer [8].

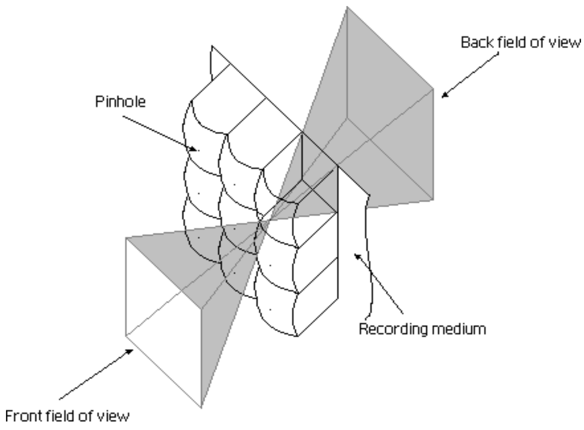


Figure 7: Micro-lens array in integral ray tracing [8].

The structure of the lenses and the camera model in the integral ray tracing affects the way primary rays are spawned as well as the spatial coherence among them.

IV. Computer Generation of Integral Imaging Using Ray Tracing

All the described properties of ray tracing can be migrated to three-dimensional integral imaging and opens the door to computer graphics applications that facilitate integral imaging displays. Integral imaging increases the perception of the photo-realism in ray tracing for the observer. Computer generation of integral imaging has been reported in several literatures [10-14]. Computer generation of integral imaging is very useful where an integral image can be replayed using a LCD monitor by overlaying it with a lenticular sheet.[19] modelled the optical system of integral imaging and applied it inside a ray tracing renderer. This new renderer is represented in the work by the term integral ray tracing (IRT) [32][37]. For both lenticular sheets and microlens arrays, each cylindrical lens or microlens acts like a separate camera. The virtual scene is straddling the modelled lenticular sheet as well as the image plane as shown in Figure 3.3. In recent years several research groups have proposed similar techniques for generating synthetic integral images [10] [12] [14-18][32-38]. However, most of the work concentrated on reproducing the various physical setups to using computer generation software packages such as *TACHYON* [19] and *POVRAY* [20].

V. Analysis Of Covid-19 3D Integral Images Models

The following described method leads to use 3D integral images for direct observation of Covid-19. Philips viewer software is used to read real CT scan sequence of images *113* frames or CT images for confirmed Covid-19 case as shown in figures 10 and 11.

This phase of the method is to load the images to a 3D Slicer software, then use the segmentation and volume rendering. Ultimately, the Covid-19 model is exported as **.obj* file. see Figure 8. There is a problem that has been encountered with importing the **.obj* file to an adapted multiprocessor ray tracing system is how to except the proper format of the new file.

The answer is to add unidirectional camera parameters to the new scene description file see Figure 9 and [5]. Eventually, The Covid-19, 3D integral images are generated see Figures 13, 14 and 17.

```
# 3D Slicer output. SPACE=LPS
mtllib right lung.mtl
v -30.9241 67.18 -938.605
v -30.2498 67.1033 -938.385
v -32.5224 67.9554 -938.655
 v -31.7196 67.6447 -938.791
vn 0.626329 -0.77382 0.0944195
vn -0.401724 0.914948 0.0385832
vn -0.496852 0.866905 0.0401653
f 3361//3361 4949//4949 4950//4950
f 4950//4950 4949//4949 6704//6704
f 4950//4950 6704//6704 6705//6705
……………………
……………………
```

Figure 8: *. *Obj* file format.

```
3D-Model
begin_scene
resolution 1024 768
camera
FOCALLENGTH 6.8
LENSPITCH 2.116667
LENSPIXELS 9
APERTUREDISTANCE 10.0
SIZE 38.0
ZOOM 1.0
aspectratio 1.0
antialiasing 0
raydepth 2
CENTER 4.86 7.2 5.4
VIEWDIR -0.475149 -0.703924 -0.527943
UPDIR -0.29537 -0.437585 0.84928
END_CAMERA
```

Figure 9: unidirectional camera 3D integral images parameters.

VI. Philips DICOM Viewer Software

The Philips DICOM Viewer is an application that is used to open DICOM data The application consists of a series selector and a series viewer and supports basic image viewing operations like playing movies and adjusting image settings. The Philips DICOM Viewer is a read-only application [39] as shown in Figure 10.

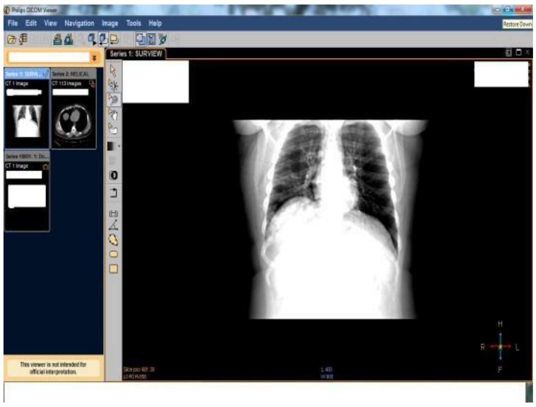
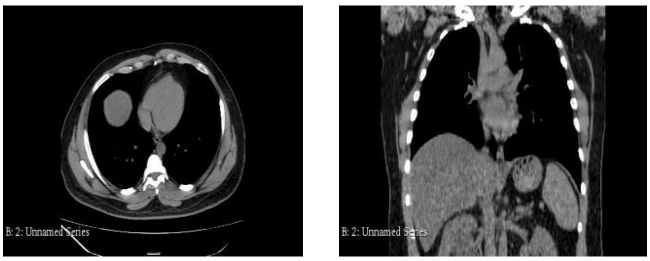
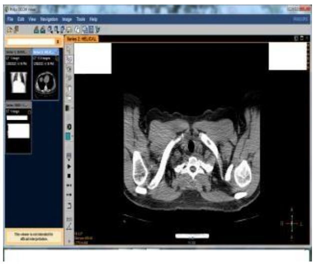


Figure 10: Screenshot of Philips multimodality DICOM viewer.



a) b)


c)


d)


e)

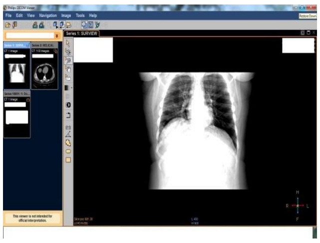
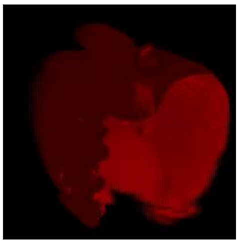
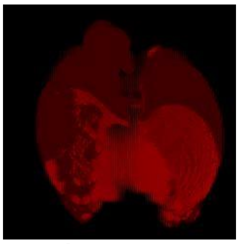
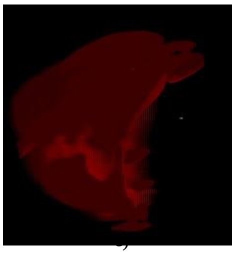
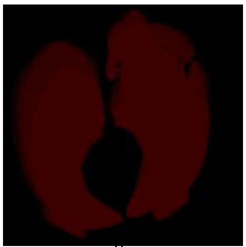

f)

Figure 11 (a-f) : CT images of Covid-19 obtained from a clinics and hospitals are displayed by Philips viewer software.


a)

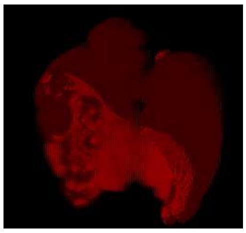

b)

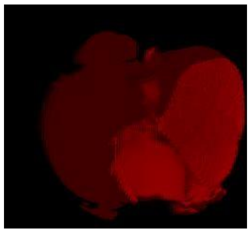

c)

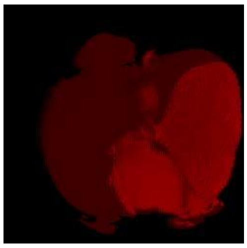

d)

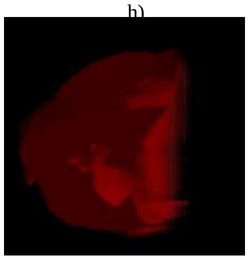

e)

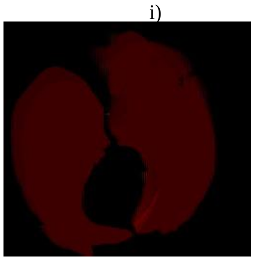

f)


g)


h)


i)


j)


k)

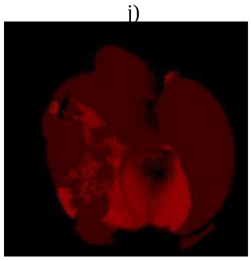

l)

Figure 12 (a-l): Covid-19 3D integral image frames of lung.


a)

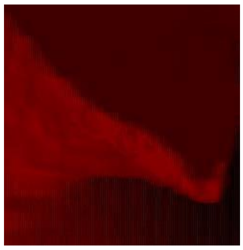
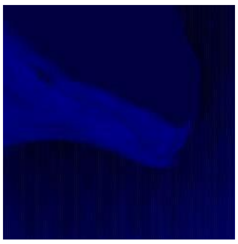

b)

Figure 13 (a,b): Zoom in view of Covid-19 3D integral images, camera *SIZE* 30.0.


a)

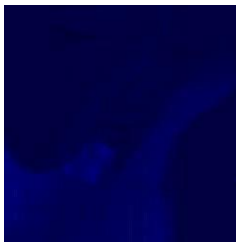
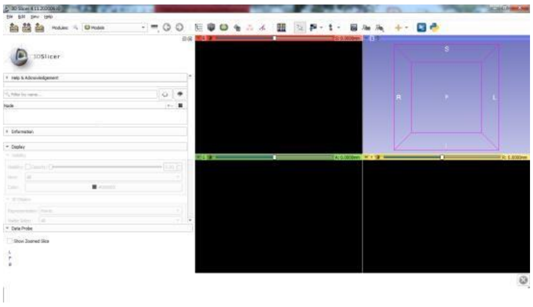

b)

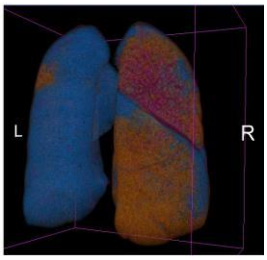
Figure 14 (a,b): Zoom in view of Covid-19 3D integral images camera *SIZE* 38.0. Different positions of camera

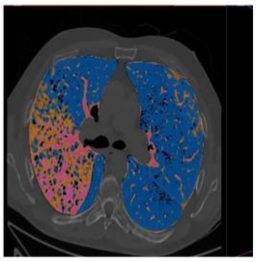
VII. 3D SLICER DICOM SOFTWARE

A software application for visualization and analysis of medical image computing data sets. All commonly used data sets are supported, such as images, segmentations, surfaces, annotations, transformations, etc., in 2D, 3D, and 4D. Visualization is available on desktop and in virtual reality. Analysis includes segmentation, registration, and various quantifications [40], as shown in Figures 15 and 16.



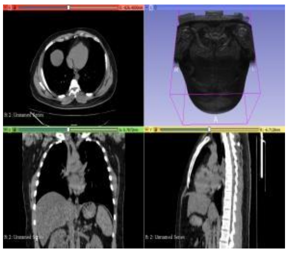
a)



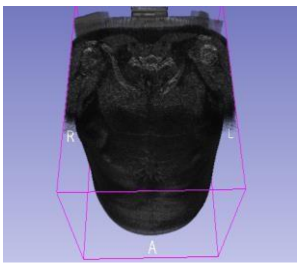


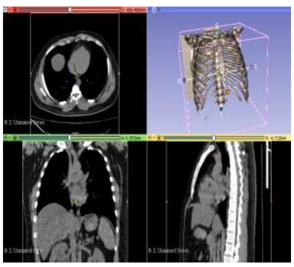
b) c)

Figure 15 (a-c): Cross-platform open-resource medical image processing and visualization system of 3D slicer [40].

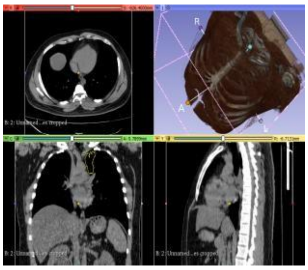


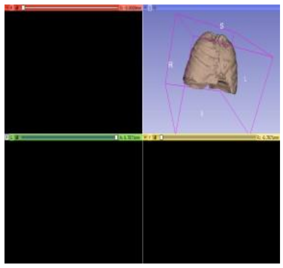
a) b)



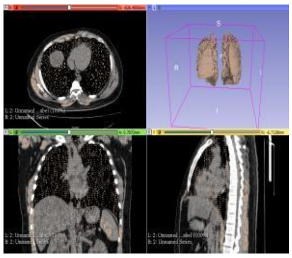


c) d)



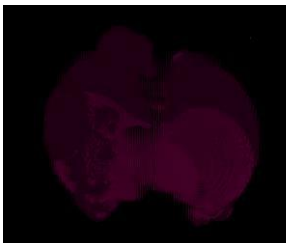


e) f)

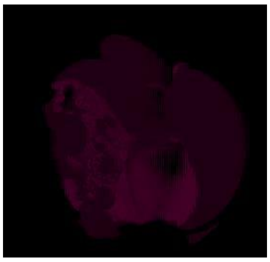


g) h)

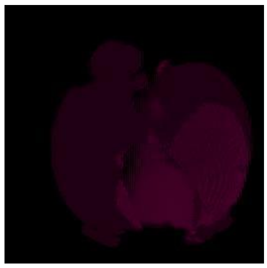
Figure 16 (a-h) : CT images of Covid-19 are displayed by 3D slicer software.



a) b)



c) d)



e) f)

Figure 17 (a-f):different sequence of Covid-19 3D integral image frames of lung.

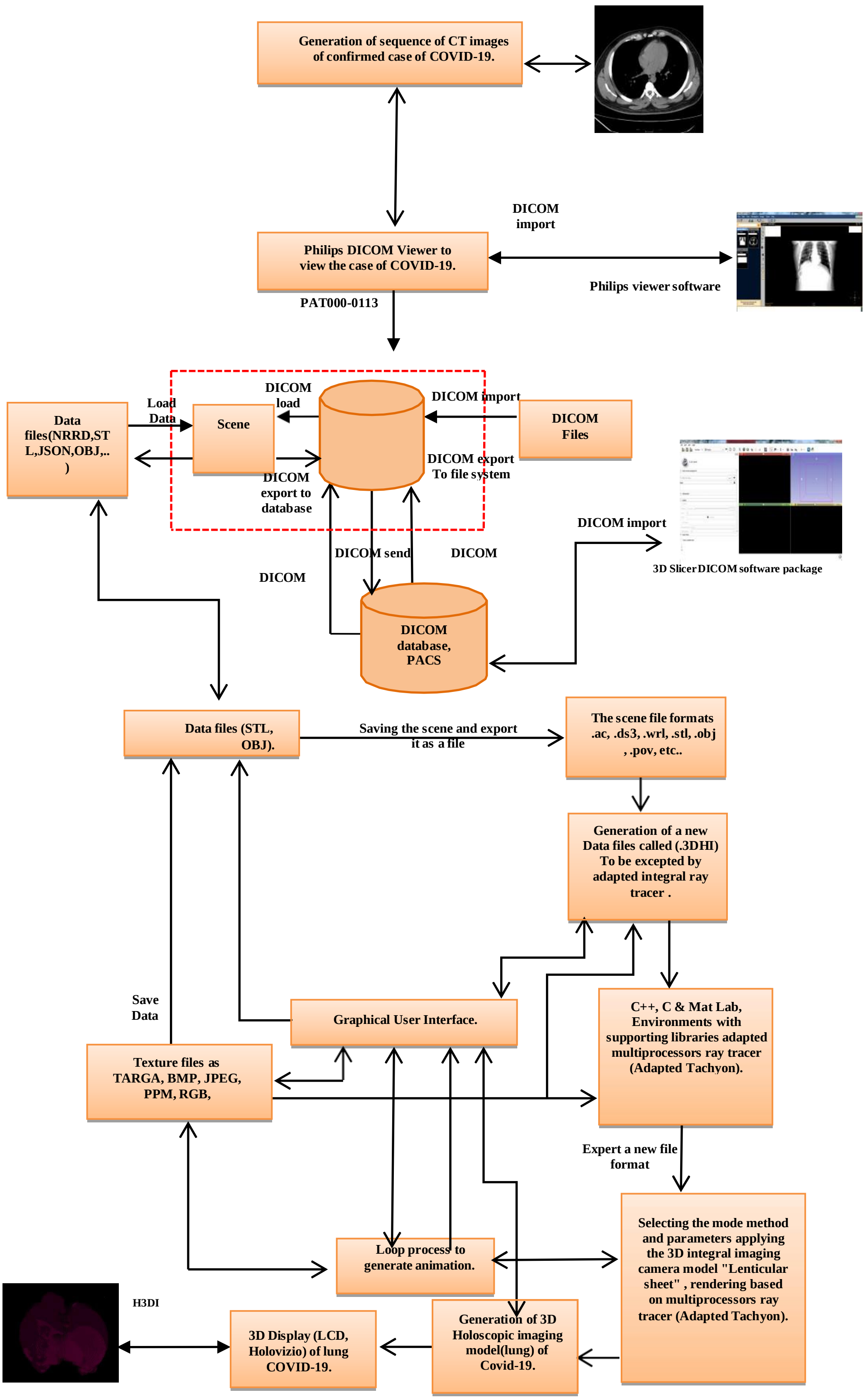


Figure 18:Flowchart Of Novel Generation Covid-19 3D integral images.

VIII. Experimental And Result

The results are extremely satisfactory and for the first time it is proved that Covid-19 images can be modeled to 3D integral images based on adapted parallel ray tracing system. In this paper a unidirectional integral images camera model is adopted. A new file format is created. An example of rendered scenes such a lung confirmed case of Covid-19 using the multiprocessor integral imaging ray tracer is shown in Figures 13, 14, 17 and 18.

IX. Conclusion

This paper presents new method to allow a computer generation of Covid-19 3D integral images modeling that would lead to easily diagnose and surveillance this virus. In this report, the CT images are loaded and then viewed by commercially available software tools such as Philips viewer and 3D slicer. The experiment was conducted on real CT scan data of Covid-19 case provided by clinics and hospitals achieving promising results. To my knowledge the first time this has been achieved. For this study the Adapted Multiprocessor ray tracing system Tachyon has been used as render. A new Covid-19 3D integral images description scene file format is generated.

X. References

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