ABSTRACT

Holograms can record and reproduce all the three dimensional information like motion parallax, accommodation, occlusion, convergence and so on. Hence it is possible to perceive a three dimensional object very close to reality, when looking into a hologram, from any direction. But the potential of the holography is restricted by the geometrical shape of the hologram. Usually holograms were made on flat surfaces, which has a limited viewing angle. It is not possible to view or record any information about the other (back) side of the object. This constraint has been overcome by making holograms on cylindrical surfaces (Jeong 1967). A cylindrical hologram has a “look around property” and hence can be observed from any direction. Hence it was planned to do some research to improve the techniques and procedures that exist for cylindrical computer generated holography or cylindrical digital holography. Accordingly, the main aim of this work is to develop a new numerical procedure and programming scheme inorder to achieve faster and efficient generation and reconstruction of the cylindrical hologram on the computer.

For computer generated holography in plane surfaces, Fourier transforms, Fresnel transforms, convolution method and Angular spectrum method are the most used scalar diffraction formulae to simulate wave propagation (Goodman 2004). These formulae consider propagation as diverging or converging or parallel plane waves. Of these the angular spectrum method alone deals with propagation in spectral domain. Whereas,
for holography in cylindrical surfaces, either the direct integration method is
used (which is very slow) or the above mentioned plane surface methods, such
as Fresnel transforms and Angular spectrum methods are used (Sakamoto and
Tobise 2005, Yamaguchi et al 2008) (by approximating and segmenting the
cylindrical surface to be multiple plane surfaces). These methods also
consider propagation as diverging or converging or parallel plane waves and
hence are slow due to the large samples required to compensate for the
approximations. Propagation from cylindrical surface as cylindrical waves
was first demonstrated using the convolution method (Sando et al 2005),
which was a fast computation formula in real domain. It was faster than the
earlier mentioned ones and used three FFT operations. So far no one has used
a propagation formula for cylindrical waves in spectral domain (similar to the
angular spectrum method for the plane waves). This could be still fast because
it uses only two FFT operations. This work reports such an attempt with
results.

A hologram was made for cylindrical object using the numerical
method proposed in this work. The cylindrical hologram was able to
successfully reconstruct the object back using the same numerical method.
Inorder to test the correctness of the hologram, the reconstructions were also
performed on plane surfaces using direct integration. The cylindrical object
when reconstructed on plane surface gave the correct results as expected. The
cylindrical hologram was also tested for simulated reconstructions from
various view angles. These simulation results were also good in agreement
with the object chosen. Thus the proposed numerical method could generate
the hologram correctly.

The hologram of a 3D object was also generated using the same procedure. The proposed numerical method can only calculate wave propagation from one cylindrical surface to another concentric cylindrical surface. So the 3D object was dissected into cylindrical segments and wave propagation from each cylindrical surface was calculated on the hologram surface. Then from this cylindrical hologram each object surface is reconstructed back. But during reconstruction each reconstructed surface also has the defocused image which greatly spoils the reconstruction and the 3D object becomes unrecognizable. A segmentation algorithm was executed on the reconstruction inorder to get rid of the defocused reconstructions. This procedure resulted in a good reconstruction of the 3D object. Thus it was verified that this numerical method can successfully reconstruct 3D objects which has potential applications in 360° microscopy.

The calculation procedure proposed in this work can be highly parallelized. This property of the calculation method has been put to full use by implementing the entire calculation on a General Purpose Graphics Processing Unit (GP-GPU). Execution on the GP-GPU was three times faster than that on the CPU even when using a very low end GP-GPU device.

To realize the numerical method the generated hologram was printed on a photographic film using a fringe printer. The printed hologram was optically reconstructed using He-Ne laser. The reconstructed images could be recognized but quality was very poor. This was due to the problems
with the optical setup used for reconstruction.

No commercial software or computing packages have been used in this work. All the calculation modules have been programmed from the ground up by using C++ and python. The freely available VTK libraries have been used for the 3D processing and rendering. Hence any one could reproduce all this work at no additional cost. Since every thing has been developed from the ground up and no black boxes were used, it was easily possible to parallise the whole process to improve speed. Hence it was demonstrated that, Digital holography can be done entirely using open source software alone.