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Object Height Measurement Using Non-Contact Fourier Transform Profilometry Algorithm

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Abstract: Fourier Transform Profilometry FTP concept is first produced in 1983.This is basically used for terrain measurement of earth. This is very simple technique for surface profiling. This is basically a computer based technique in that algorithm and the image is processed in computer. For our experimentation we use DSLR camera, DLP projector, computer and actual 3D objects. Only one frame of deformed pattern is required for this algorithm. FTP method uses phase unwrapping concept. In this paper the procedure and experimental results are discussed.

Keywords: *FTP- Fourier Transform Profilometry, QGPU Quality Guided Phase Unwrapping, FFT-Fast Fourier Transform.*

I. INTRODUCTION

FTP is automatic non-contact optical shape measurement of a 3D object using phase un-wrapping of projected fringes. A number of methods and techniques for 3D shape measurement were studied like Laser Triangulation; Time to flight, Stereo Vision, Moiré method, Interferometry, Coded pattern projection, but we have chosen digital fringe projection technique with FTP for our application as it needs only single fringe pattern. For our application sinusoidal fringe pattern were projected using Digital Micro-Mirror Devices (light commander Kit). The frequency of the projected fringe is changed by programming using Matlab. The components used for our experimentation are 3D object, a high resolution Sony DSLR camera, DLP Light Projector Kit and computer.

II. SYSTEM SETUP

In experiment setup we have put the object in front of the camera 1.73m apart. Camera and projector is separated with 1m distance and with 30-degree angular separation. Projector projects fringe pattern on the object the fringe pattern controlled by a computer interface through USB. Camera captures that image. Camera will send that image to computer. Captured image is processed and we get reconstructed image by algorithm applied on the image.

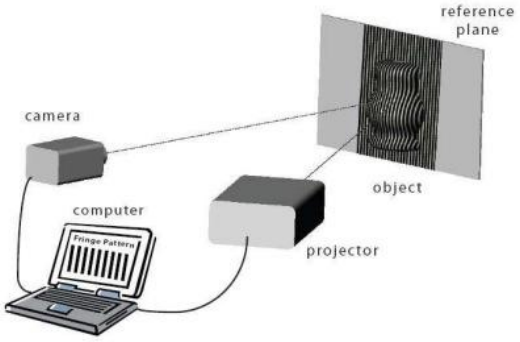


Figure 1: Fringe Projection Profilometry system [1]

III. PROCEDURE

In Fourier Transform Profilometry the object is put in front of the camera at certain distance. Camera and projector are kept at an angular separation of 30deg. Fringe pattern on the object is projected using DLP Light commander Kit simulated by Matlab program through a computer. The Camera captures the image and stores it in to computer. Here when the image goes for processing first fourier transform is applied on it to convert it into a spatial domain. After doing FFT the phase information is separated from the whole image information, as we are going to find the height of the image by using phase information. As the retrieved phase through algorithm is in wrapped form and is bounded in ($-\pi$ to π). So we have to recover that phase by increasing its boundary by (-2π to 2π). It is called phase unwrapping process and it is very important part in FTP. After that finally the height calculation is done.

IV. QGPU ALGORITHM FOR PHASE UNWRAPPING

There are many algorithms used for phase unwrapping like Goldstein's method, QGPU method, Mask cut method, Flynn method, Multigrid method, weighted multigrid method, Preconditioned conjugate gradient method, Minimum L_p- normal method. The comparison of all the algorithms is done as shown below.

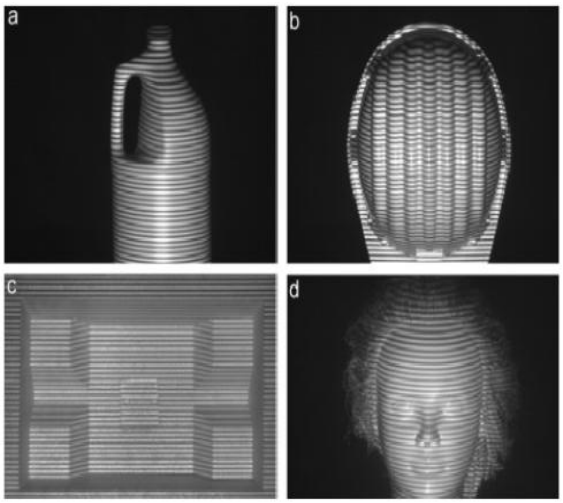


Figure2: Complex objects used in FTP experiments: (a) plastic bottle, (b) helmet, (c) polystyrene box, (d) manikin face.[2]

Algorithm	B	H	P	M	Total
Goldstein	0	3	2	5	10
Quality guided	0	0	2	2	5
Mask cut	0	22	2	3	27
Flynn	0	2	1	2	5
Multi-grid	0	3	3	4	10
Weight multi-grid	2	7	3	3	15
PCG	0	4	2	2	8
L_p-norm	2	2	0	3	7

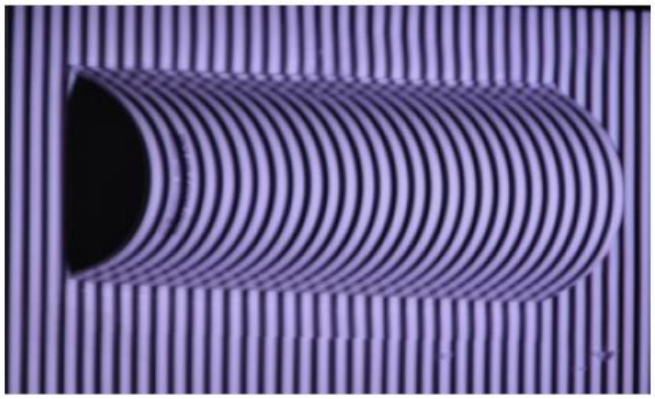
Algorithm	B	H	P	M	Average time
Goldstein	1T	1T	1T	1T	1T
Quality guided	4.5T	4.5T	6T	7.9T	5.7T
Mask cut	12.3T	7.3T	2T	14.1T	8.9T
Flynn	21.3T	31T	15T	76.9T	36.1T
Multi-grid	1T	0.9T	1T	1.5T	1.1T
Weighted multi-grid	1.7T	1.7T	2T	2.5T	2T
PCG	13.3T	12T	18T	24.4T	16.9T
L_p-norm	13T	13T	19T	25T	17.5T

Figure3: (a) Jump errors in phase unwrapping of complex object, (b) Time indexes in phase unwrapping algorithm execution[2]

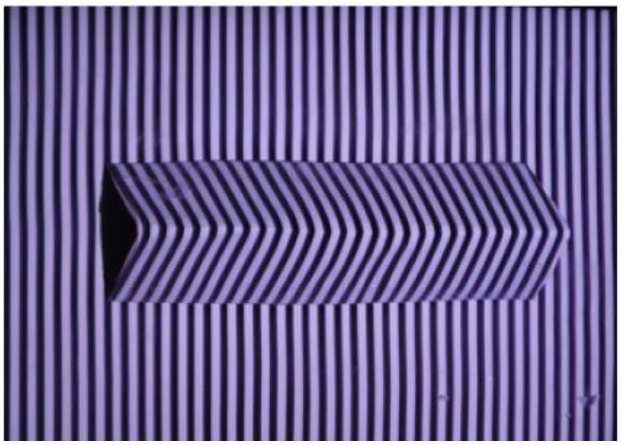
From the above two tables we can say that Quality Guided algorithm has less error than other algorithms and also less execution time than others. Based on the comparison QGPU best suited for our application. So we have chosen the QGPU algorithm. We have used MATLAB for simulation and processing of fringe projected image.

V. EXPERIMENT AND RESULTS

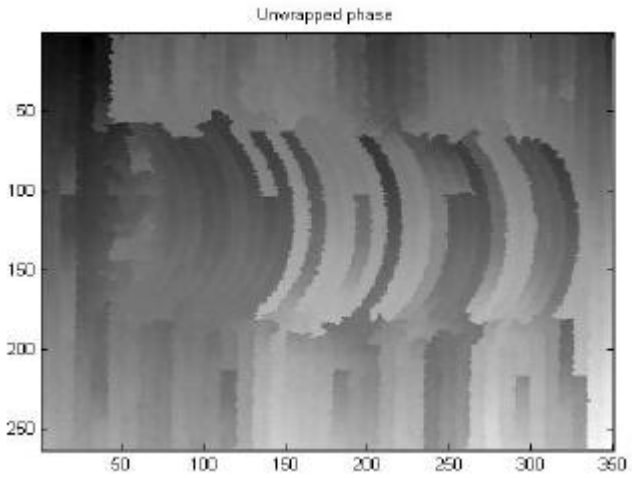
We have used DLP light projector for fringe projection on image that is faster than another simple projector. This projector is having Digital Micro-Mirror Devices in it which supports up to 5000 Hz binary or 500 Hz grayscale pattern rates. We have taken available commercial the Sony DSLR camera. We have done the experiment with two objects triangular shape and cylindrical shape with 20,40,60, 80 and 100Hz frequencies of sinusoidal fringe patterns. Good Matching of actual object height vs retrieved Height using algorithm were observed up to 60Hz. At higher frequencies fringe projection captured image through camera was not sharp enough and software show some noise in the retrieved pattern. By choosing appropriate exposure and synchronization between camera and projector these errors are also correctable. So for this paper we discussed the retrieved results up to 60 Hz only.



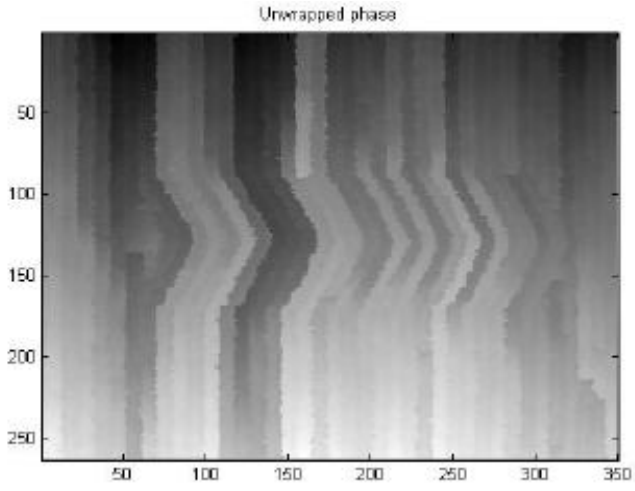
(a)



(b)



(c)



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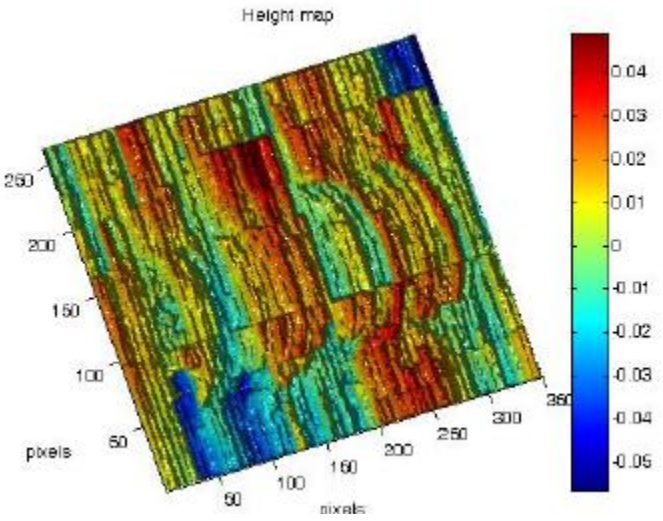

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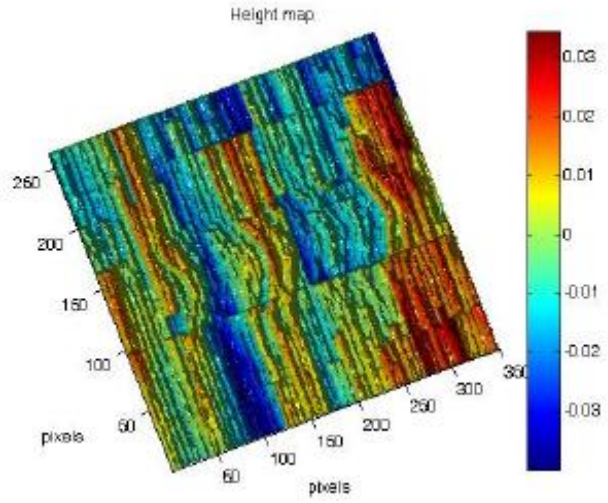

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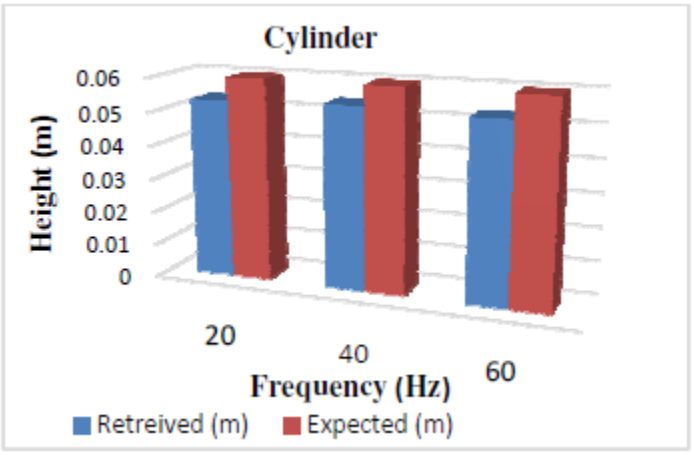
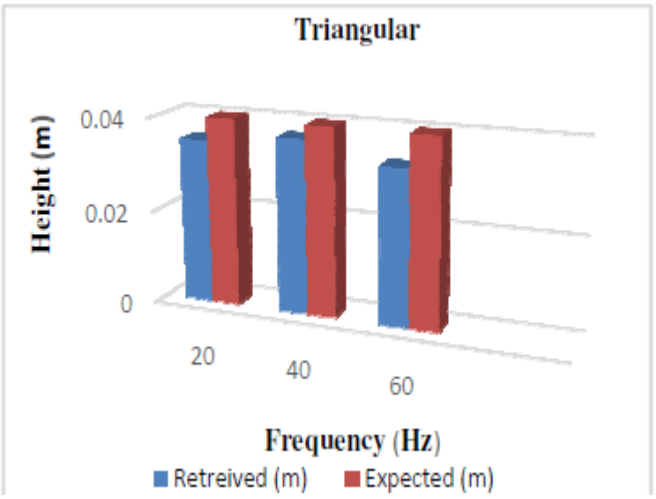


(g)



(h)

Fig 4: (a) Fringe projected cylindrical shape(b) Fringe projected triangular shape(c) unwrapped cylindrical shape(d) unwrapped triangular shape(e) Height map of cylindrical shape(f) Height map of triangular shape(g) Bar graph of cylindrical shape(h) Bar graph of triangular Shape

CONCLUSION

As a non-contract measurement method, FTP method will play an important role in 3-D sensing field in the future because of only one or two images of the deformed fringe needed. A high resolution camera is used to capture the fringe projected image. The camera we can use analog or digital and DLP projector is used to project fringe pattern. We have validated this algorithm successfully up to 45deg angular separation between camera and projector. We can conclude from the above bar graph that we got height for 20,40,60Hz frequencies little bit less than the expected height.

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