# High Speed 3D Shape and Motion Capturing System

Dung A. Nguyen,* Zhaoyang Wang†
The Catholic University of America

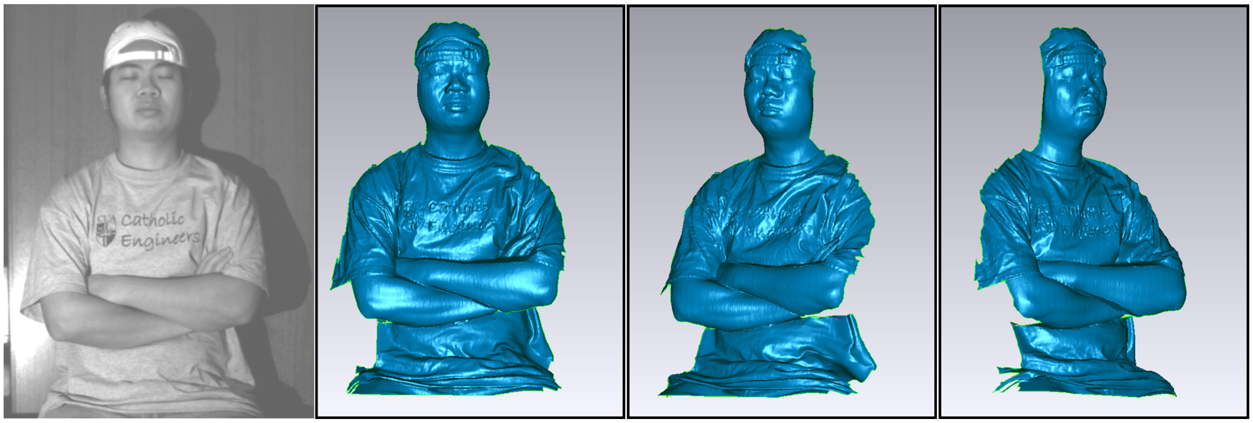


**Figure 1:** *Demonstration of a single 3D view result of a human body from three different angles*

## 1 Abstract

A 3D motion capturing and reconstructing system at high speed is presented. The system utilizes the fringe projection technique with one modified DLP projector, one camera and a computing unit to provide real-time reconstruction of forty-two 3D frames per second with the relative accuracy of 1/5000.

## 2 Introduction

Fringe projection profilometry (FPP) is one of the leading techniques for 3D shape measurement and 3D imaging in a variety of fields. Despite the tremendous development of the FPP technique in the last two decades, there are a few practical challenges restricting the broader applications of the technique, [Gorthi and Rastogi 2010]. For instance, the capability to measure multiple objects with complex shapes in a real-time manner is one of those challenges, and it is highly demanded by numerous applications. In this paper, a novel and robust 3D imaging system is presented, and the system is capable of providing high speed, high accuracy, and full-field 3D imaging of multiple objects. A basic FPP-based 3D imaging and shape measurement system usually contains a digital projector, a digital camera, and a computer. During the 3D imaging, a set of fringe patterns are projected onto the surfaces of the objects of interest. The surface height/depth information is naturally encoded into the distorted fringe patterns, which are captured by the camera for further processing to get back the height of 3D objects.

## 3 High Speed 3D Imaging

A single-chip Digital Light Processing (DLP) projector is utilized with the colorwheel removed; this leads to gray scale image projection for any color image. Meanwhile, a fast speed CMOS camera is employed to capture each RGB channel of the image. An external triggering circuit is developed as a microcontroller to control and synchronize the capturing process of the fast speed camera with the projecting process of the DLP projector. Therefore, three images can be obtained in each projection cycle which will significantly increases the speed of 3D measurement.

In 3D imaging, both the in-plane and out-of plane dimensions must be determined. Due to the fact the 2D in-plane dimension can be directly calculated from the corresponding digital image through a simple transformation with acknowledgment of the camera-object distance, the primary task of the 3D imaging is to rigorously determine the out-of-plane height and depth information. It has been shown that the governing equation of the out-of-plane shape determination can be expressed as:

$$z = \frac{1 + c_1\phi + (c_2 + c_3\phi)i + (c_4 + c_5\phi)j}{d_0 + d_1\phi + (d_2 + d_3\phi)i + (d_4 + d_5\phi)j} \tag{1}$$

where $z$ is the out-of-reference-plane height or depth at pixel $(i, j)$, $\phi$ is the projection fringe phase at the same point, and the coefficients $c1 - c5$ and $d0 - d5$ are constants determined by the geometrical and other system parameters. The above approach based on arbitrary and generalized setup of system components is very easy to implement; more importantly, it can cope with the numerous uncertainties in practice of FPP.

## 4 Results

To demonstrate the validity and applicability of the system, a few experiments have been carried out and the highest speed obtain is 42fps at the relative accuracy of 1/5000. We have also confirmed that if higher accuracy is required for other application, relative accuracy of 1/15,000 is achievable at the speed of 8fps. The above figure demonstrates a result from three different angles of 3D contructed model of a student. A visual inspection shows that the 3D images have a very good match with the actual objects. The experiments thus demonstrate the practicability of the presented FPP approach or 3D imaging of object(s) complex shapes.

## References

S. Gorthi and P. Rastogi, "Fringe projection techniques: Whither we are?", Optics and Lasers in Engineering **48,** 133–140 (2010).

*e-mail: 65nguyen@cardinalmail.cua.edu
†e-mail:wangz@cua.edu


SIGGRAPH 2010, Los Angeles, California, July 25 – 29, 2010.
ISBN 978-1-4503-0210-4/10/0007