Innovative System for 3D Clinical Photography

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A new system for 3D clinical imaging was recently developed that takes a 2D image and converts it into a 3D image. This is incredibly useful in the medical imaging world as it is cost effective, easy to use, and non-invasive. We seek to improve the algorithm and software coding used to create 3D images so that it is compatible with other cameras and provides a better image. There are three main goals to this project: improve depth resolution, calibrate depth, and create a real time feed of the images from the camera.

I. INTRODUCTION

This project began by investigating Kaposi's Sarcoma, a leading cancer among men in Mozambique and a disease that predominantly affects those with the HIV/AIDS virus. In this region, healthcare is incredibly limited. However, a 3D imaging technique was developed that allowed a 2D image to be taken, sent via cell phone signal, then converted into a 3D image after depth information was extracted [1]. This entire technique is incredibly cost-effective and easy-to-use, which makes it incredibly appealing to regions of the world with poor health-care, and to the medical world as a whole [2]. However, this technique is not without shortcomings.

One problem with this technique is that it requires a sufficient amount of time to pass before a change in depth can be detected by the camera. While the Lytro camera allows us to successfully diagnose a tumor, tracking its growth is more difficult [3]. Therefore, we seek to improve the depth resolution to gain sharper images and detect smaller changes in tumor growth.

In addition, with the success of the proof of concept study with Kaposi's Sarcoma, we wish to apply the basic concept of 3D imaging to other cancers, and malignancies, on different parts of the body. This requires us to improve the software code that processes the image in order for it to be compatible with other cameras, and process the information better.

II. GOALS

There are three main goals for this research project: improve depth resolution, calibrate the depth, and create a movie mode for the image collection and processing.

First we seek to improve the depth resolution on the images we are currently gathering. Currently we take an image at different focus settings where objects at different depths appear more in focus than another. We then identify the focus setting that results in the optimal focus for a given imaged object. However, it is possible there is a point between two focus settings that produces the theoretical optimal focus. Therefore, we seek to determine where exactly we can get the best, in focus image for each object in the field of view. This ends up translating into a more accurate depth determination.

The second goal is to calibrate the depth we find. Currently, the depths extracted are relative in the sense that they are unitless. Consequently, we are attempting to come up with a scale that matches standard units.

The third goal is to create a real time feed of the images we take (or a movie-mode). This movie mode will be a continuous version of the all-focused image. However the images will be processed in real time so the final product is a movie that plays as the camera takes snapshots that allows us to see the object, continuously as we film.

III. METHOD

In order to generate our image there are several key steps. First, an image is taken from above the target (see FIG 1). For this example we will use the concept of four different point sources of light. We take four different images at different focus settings so that a different point source is in focus in each image (see FIG. 2).

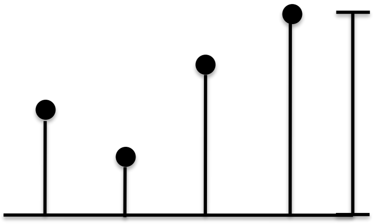

FIG. 1. This is a schematic of four point sources of light. Each point is at a different height (h) so that when the image is taken at bird's eye view, different points will be in focus depending on what focus setting is used.

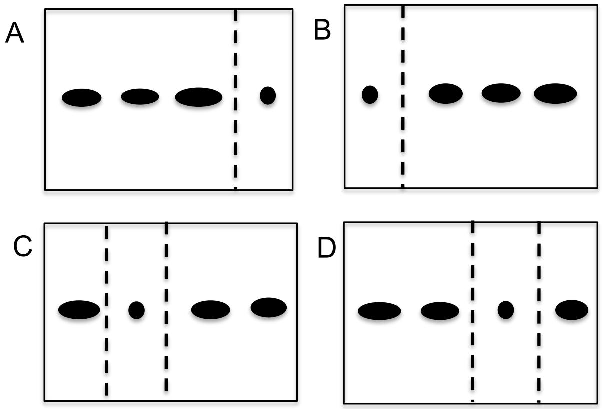

FIG. 2. The figure above shows a schematic of the images taken at different focus settings. Frame A shows when the fourth point is in focus, while the other three are out of focus. Frame B shows the same, but with the first point in focus. Frame C has the second point in focus and the other three out of focus. Frame D has the third point in focus and the remaining points out of focus.

Next we grab the region where a point source is in focus on each snapshot and translate them over to a grid. This new image has all four point sources in focus and is considered an all focused image (see FIG. 3).

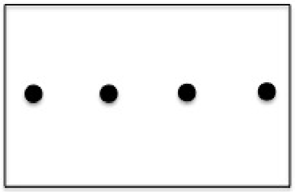

FIG. 3. This is a sketch of the all focused 2D image that comes from combining the different portions of images taken with different Focus Settings.

Our next step is to analyze the depth of each of these points. In order to do this, a computer code takes the gradient in order to measure sharpness. To generate the gradient, the code is measuring the change in pixel value over the change in pixel distance around a given point. This measure of sharpness can reveal the point that is quantitatively most in focus. In FIG 2, Frame A for example, the the gradient of that schematic would show the greatest sharpness near the far right point. Once a gradient is generated for all four images, we can use the information to map out which parts of the images result in the best focus. The end goal is a depth map describing the depth of each point when it is in focus (see FIG 4).

Our all focused image is a 2D image, but combining it with the depth map gives us the desired 3D information. With the Proof of Concept study using the Lytro camera, the Lytro camera automatically gave the depth map. In this case IDL was used to process the data, which was then input into Mathematica to give us a 3D plot of the image.

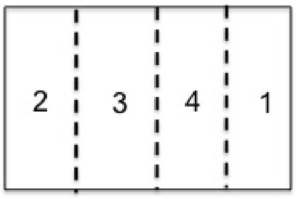

FIG. 4. This is a schematic of the depth map generated from the gradient of each of the points. It shows that at Focus Setting 2, the first point was in focus, at Focus Setting 3 the second point was in focus, and so on. We also learn depth information from this image

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To calibrate the depth, we will take snapshots of objects with well-known the dimensions, and compare our results to the actual, known values. This will allow us to understand what the uncertainty of our measured depth actually is.

Lastly, to create a movie mode of the images captured by the camera. This is simply a sped up version of the snapshot mode, so the process of converting the 2D image the camera captures remains the same as previously described. However, with the movie mode, we may lose some of the image quality in order to process data faster. Ideally, we want to be able to create the real-time feed without largely compromising image quality and depth information.

IV. RESOURCES

To successfully accomplish this project, we will need access, which we currently have, to computers equipped with programming and computational software.

The software aspect of this project requires us to create a code that can transfer the data from a camera into a 3D image that we are able to manipulate. The current code for the method used above was run using MATLAB; however, if this code is understood completely it is possible it can be translated into a different language as well, such as IDL, Mathematica, C, or Python (the code used with the Lytro camera).

Images from partner clinics (such as the clinic in Mozambique), and collaborators in California allow us to actually apply our technology and see it in use. Images from clinics depend on the current situation in the geographic regions, and we are seeking to make contact with other clinics as well. However, if contact cannot be made with these clinics, we can still continue to develop and improve our software so that when contact is eventually made, we can quickly apply the technology.

We also require the use of a 3D printer if we continue to use the Lytro camera to create the adaptor for each different type of cancer.

We currently have all the supplies we need and will not require Departmental Resources.

V. BUDGET

Sources of funding relevant to this project:

- Howard Hughes Memorial Institute Summer Research Grant, $3,500 for student stipend, $1,500 for research advisor to use on needed materials.

VI. TIMELINE

- 05/2015-Begin paid internship with Dr. Carson. Goals: Learn programming language (ex: MATLAB, IDL, etc.). Work on improving depth resolution and the calibration of depth.
- 08/24/2015-present at the Summer Undergraduate Research with Faculty Poster Session on Convocation Day.
- 08/2015-begin Independent Study (PHYS 390) Goals: Finish improving depth resolution and the depth calibration (by 10/2015). Begin developing software for the movie mode.
- 01/2016-enroll in PHYS 420. Goals: continue to develop the software for movie mode (complete by late 02/2016). Begin writing Senior Research Paper.
- 04/2016-Finish Senior Research Paper, present results of research at the Spring Poster Session, and one other outside location TBD.

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[1] Baghdadchi Liu, Knapp, Prager, Graves, Akrami, Manuel, Bastos, Reid, Carson, Esener, Carson, Liu, 2014, Journal of Translational Medicine, 12, 169.

[2] Menchaca, R. "Professor and Student Help Develop Life-Saving Use for Digital Camera." 2014. The College Today.

[3] https://store.lytro.com/collections/the-first-generation-lytro-camera/products/first-generation-lytro-camera-16gb