Final Project Proposal: Structured Light

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1 Abstract

Structured light 3D imaging is a method of obtaining a 3-dimensional rendering of an environment without relying on a standard time-of-flight distance sensor. Time-of-flight distance sensing is a method of calculating distance to an object by projecting a particle or wave of known speed and timing how long that particle or wave takes to return. Time-of-flight sensing can only detect distances at one point in space before having to reposition the sensor. In structured light 3D imaging, this time-of-flight distance sensor is replaced by a projector and a camera, which are able to scan large environments without repositioning. This is accomplished by projecting a known image onto the surface of the environment, capturing the environment with the overlaid projection in 2D, and then calculating a 3D render of the environment. The 3D render of the environment's characteristics, such as accuracy, reliability, time of calculation, and ease of implementation, depend almost entirely on the chosen projected light structure [3]. For my project, I will create my own structured light rig, implement the leading structured light projections, compare them across characteristics of accuracy, reliability, time of calculation, and ease of implementation, and then attempt to refine one of the compared structured light projections based on what I learn.

2 Background

2.1 Key Terms

Environment: Typically an object or scene of importance that is being 3-dimensionally inspected.

3D Imaging/3D Rendering: The process of obtaining 3-dimensional information about an environment.

Structured Light Projection Pattern/Projected Light Structure: The image chosen to be projected onto the environment, typically chosen for its properties of 3D imaging, such as accuracy, reliability, time of calculation, and ease of implementation.

2.2 Context

Many research institutions and companies in industry are working towards more effective and efficient methods of 3D imaging, including structured light. Currently, the applications of structured light are mainly limited to imaging stationary environments since the most accurate light projections require tens of frames to be captured in a single state before the environment changes [1]. As projected light structures become more intelligently designed, 3D imaging of dynamic environments using structured light becomes more feasible [5]. Two such intelligent design improvements of structured light projections include implementing functions with visual features more easily detected by a projector-camera system such as sinusoidals, which have no sharp hard-to-interpret edges [3], and allowing for projected light pattern adaptation based on environmental factors such as color and variability [4].

3 Significance

Many professionals have devoted a significant amount of time and resources to researching effective methods of structured light 3D imaging. I do not claim to be staking an entirely novel claim in this field of research, but I do hope to bring a unique spin to the area of structured light projections by approaching it from the context of a digital signal processing problem. Much of the research that I have read seems to neglect comparing suggested solutions to others' past suggested solutions [1] [2] [3] [4] [5]. I hope to not only test some of these structured light patterns against each other, but learn about what makes an effective projected light structure in the process so that I can attempt to refine a current light structure and gain experience in the field of digital signal processing along the way.

4 Learning Objectives

As I research and implement my proposed project, I hope to learn:

- how structured light 3D imaging is best implemented.
- about common problems faced when digital signal processing moves from a theoretical realm to a practical realm.
- if basic signal processing methods (such as frequency filtering) will allow me to gain more information from a projected light structure.
- what characteristics of structured light projections allow for the fastest and most accurate 3D imaging.

5 Description of Project

In my proposed project, I will aim to effectively and efficiently 3D image an environment with a refined structured light projection pattern by following the basic procedural steps of structured light 3D imaging, as shown in Figure 1.

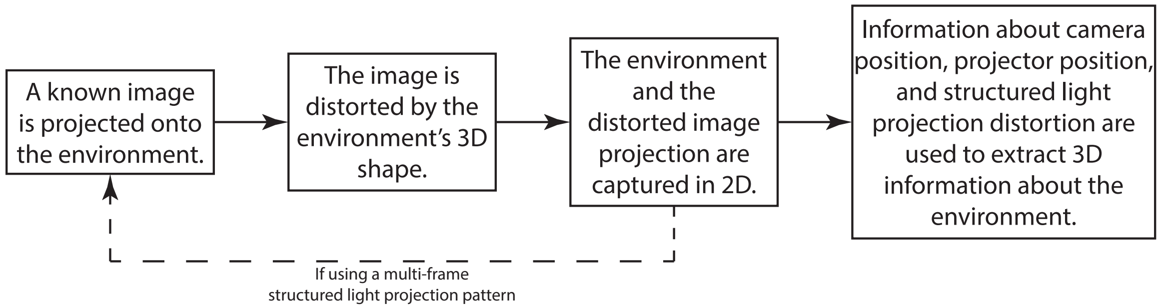

Figure 1: A flow diagram depicting the process of single-frame structured light imaging and multi-frame structured light imaging (Author 2016).

In order to create an intelligently designed structured light projection pattern, I will compare at least three already developed projection patterns, attempt to understand what gives them each their strengths and weaknesses, and then use the gathered information to refine a pattern that I have implemented.

I will run testing and development of structured light projection patterns in a controlled environment such as the one depicted in Figure 2.

Figures 3 and 4 show the coordinate systems that I have defined in order to find 3D position of the environment. Figures 5 and 6 show my first attempt at scanning an environment (in this case, a wall) using the most basic structured light system that I could create.

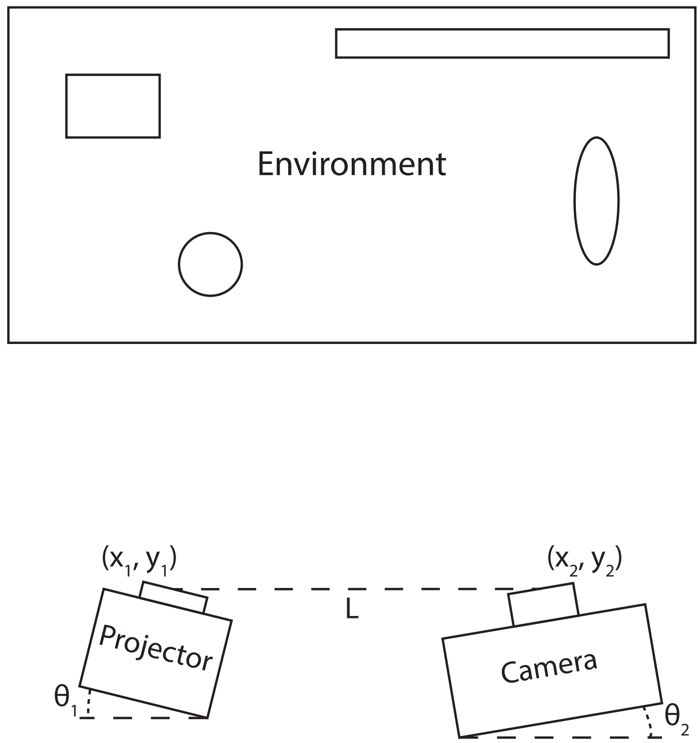

Figure 2: A depiction of a basic structured light setup and the position and angle values that must be known in order to pinpoint the environment in 3D space (Author 2016).

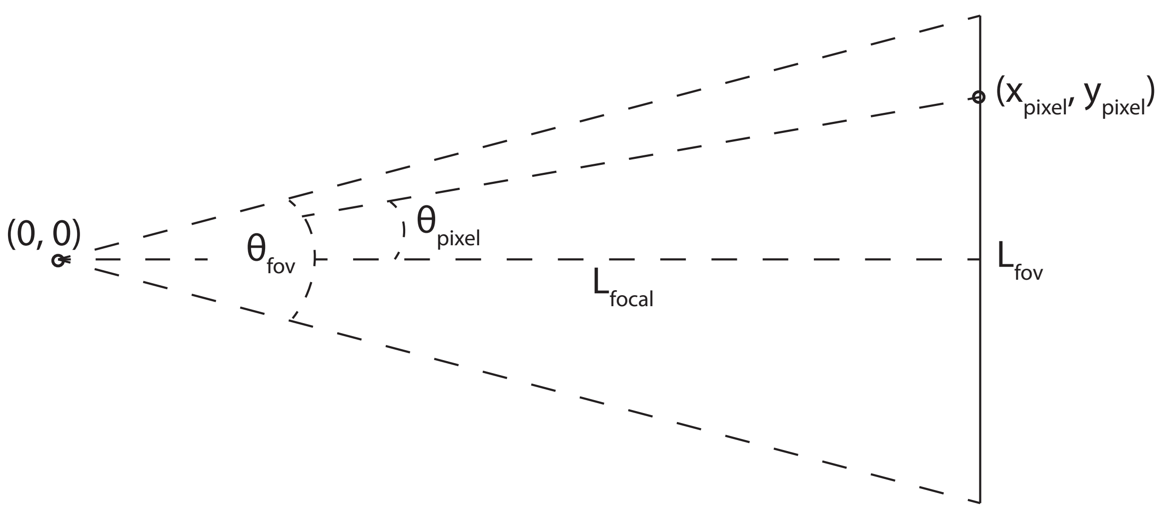

Figure 3: This figure shows important quantities for finding a pixel's angle from the camera's or projector's point of view given its 2D coordinate location (Author 2016).

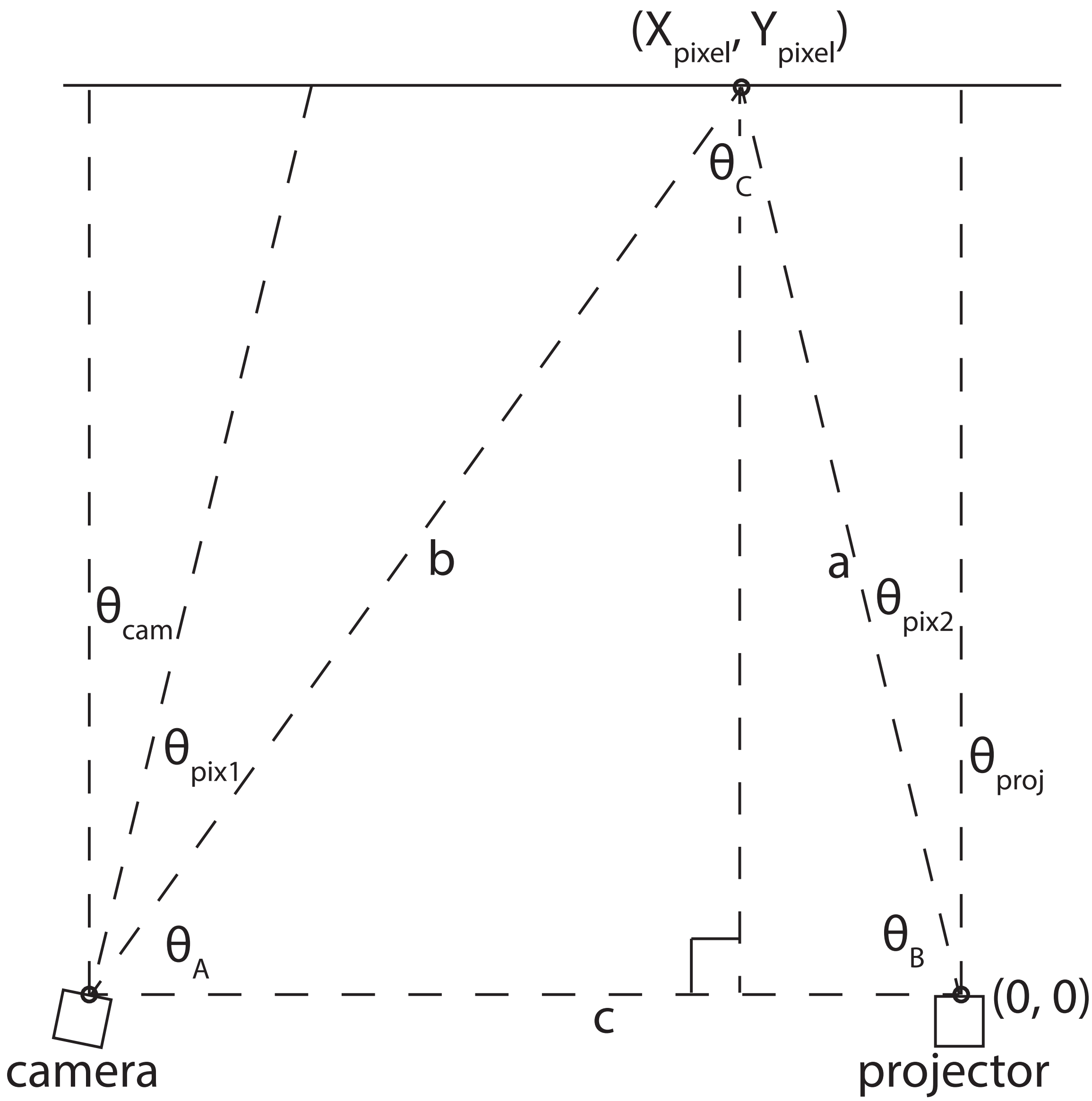

Figure 4: This figure shows important quantities for finding the position of a pixel in 3D space given its calculated angle from the camera's or projector's point of view (Author 2016).

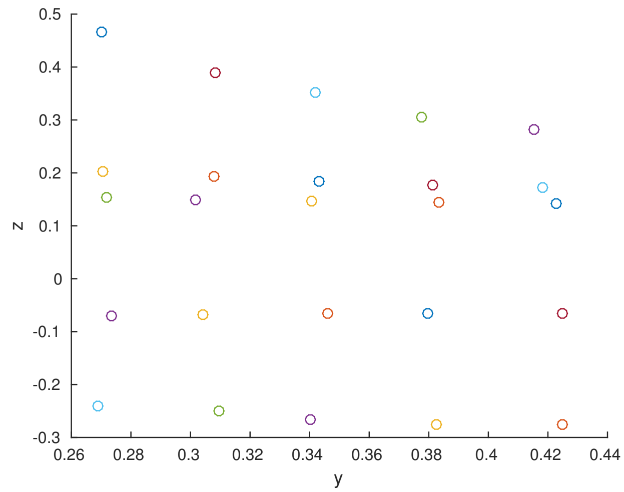

Figure 5: The first 3D image I captured using structured light. The environment scanned was a flat wall. (Author 2016).

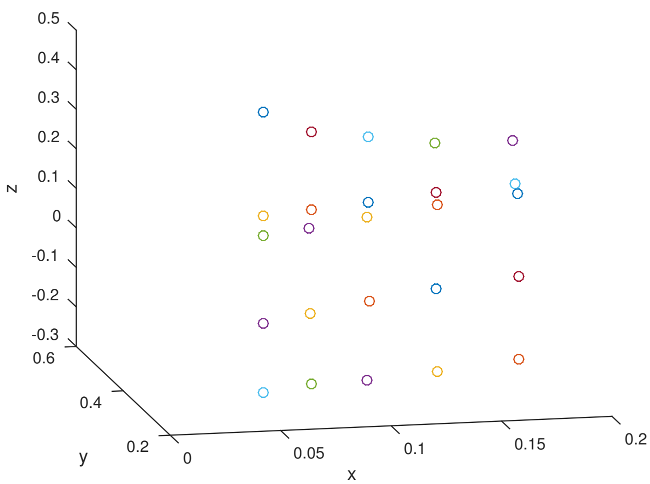

Figure 6: The first 3D image I captured using structured light, from another angle (Author 2016).

6 Diagnosis

Upon first proposing this project, I was worried that I would not be able to find a dark place to set up a camera and projector for long periods of testing, but during this last week I found that the photo studio is a nearly perfect spot for just that. Another concern that I had at the beginning of this project, and still have, is that the quality of projector and camera that I am using for my project might not meet the standards of accuracy that are required to used structured light effectively. After initial testing, I realize that I am going to have to be very intentional about the structured light patterns that I attempt to implement in order to compensate for my lack of research-grade equipment. A new problem that I have encountered after running my first structured light setup is that the computer vision portion of this project is much more intensive than I previously imagined. Finding an approximate pattern of pixels within an image is quite difficult to do and I have now recognized it as a non-trivial part of structured light implementation.

7 Improvement

As mentioned before, this project proposal could be improved by specifying an exact camera and projector to use that would give me accurate projection and imaging results. But, given my current resources, I don't think it is realistic to purchase equipment to match university research standards for a project that is just a few weeks long. Another great improvement to this project proposal would be to list out the exact projected light structures that I am going to compare. This list is something I am going to have to determine after I set up my own projector and camera so that I know what patterns are possible with my resources.

8 Timeline

- 11/08: Complete rough draft of project proposal.
- 11/11: Complete project proposal final draft and have a basic structured light setup that can capture an environment in 3D.
- 11/18: Compare three distinct structured light projections.
- 11/25: Refine one of my three compared structured light projections.
- 12/02: Finish first draft of project report.
- 12/07: Finish final draft of project report.

9 Budget

This project will revolve around a stable setup of a projector and camera. I can borrow both a projector and a camera from Olin's IT department during testing time, so I should not need a budget. If IT has projectors or cameras in low supply I can make due with a projector from any Olin classroom and a phone camera.

References

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[2] Garcia, Ricardo R., and Avideh Zakhor. "Multi-view Dynamic Geometry Capture Using Structured Light." SPIE Newsroom (2013): n. pag. Web.

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