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. In structured light, this time-of-flight distance sensor is replaced by a projector and a camera, which are able to project a known image onto the surface of the environment, capture the environment with the overlaid projection in 2D, and calculate a 3D render of the environment. The 3D render of the environment's characteristics, such as accuracy, reliability, and time of calculation, depend almost entirely on the chosen projected light structure [2]. For my project, I will create my own structured light rig, implement the leading structured light projections, compare them across these characteristics, and attempt to create my own structured light projection based on what I learn.

2 Background

2.1 Key Terms

<u>Environment:</u> 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 which allow for effective and efficient 3D imaging.

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 [4]. 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 layered sinusoidals [2], and allowing for projected light pattern adaptation based on environmental factors such as color and variability [3].

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

[4]. 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 design my own novel 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 my own structured light projection pattern by following the basic procedural steps of structured light 3D imaging, as shown in Figure 1.

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 inform my own pattern.

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

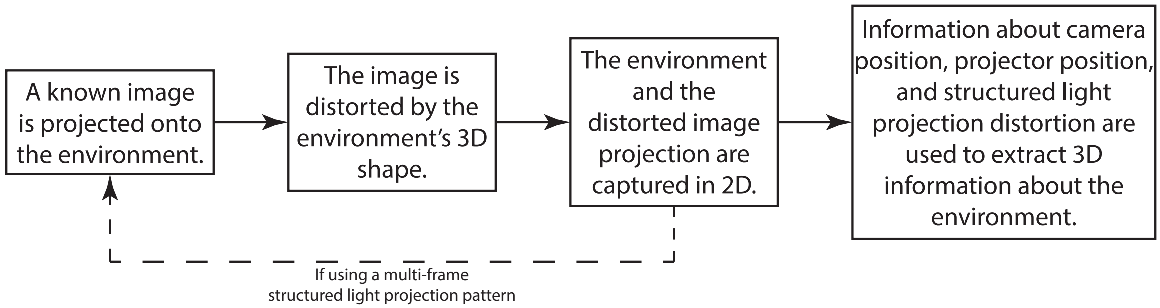

Figure 1: A flow diagram depicting the process of single-frame structured light imaging and multi-frame structured light imaging.

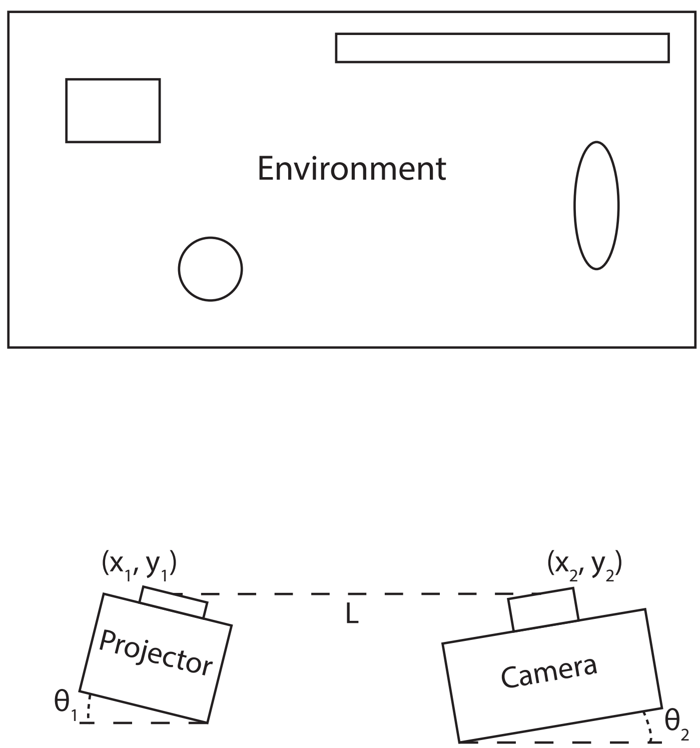

Figure 2: A depiction of a basic structured light setup and the position and angle values that must be known in order to pinpoint the environment in 3D space.

6 Diagnosis

The main problems that I could see occurring during my proposed project are related to the setup of the camera and projector. If I want to accurately compare different structured light projections, then I will need a decently-sized space where a projector, camera, and environment will all be undisturbed between tests. If I can't find such a space, then I will need to create a deployable space that can be accurately replicated each time I want to test. I also worry that the quality of projector and camera that I acquire for my project might not meet the standards of accuracy that are required to used structured light effectively. I can hopefully get around both of these problems with careful setup and intelligent use of my equipment to get the most out of what I have.

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

- 11/11: Have a basic structured light setup that can capture an environment in 3D.
- 11/18: Compare three distinct structured light projections.

- 11/25: Create my own structured light projection.
- 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] Geng, Jason. "Structured-light 3D Surface Imaging: A Tutorial." Advances in Optics and Photonics Adv. Opt. Photon. 3.2 (2011): 128. Web.

[3] Koninckx, Thomas P., and Luc Van Gool. "Real-Time Range Acquisition by Adaptive Structured Light." IEEE Trans. Pattern Anal. Mach. Intell. 28 (2006): 432-45. Web.

[4] Scharstein, D., and R. Szeliski. "High-accuracy Stereo Depth Maps Using Structured Light." 2003 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 2003. Proceedings. (n.d.): n. pag. Web.