Tina Paper In Development

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Abstract

This is the abstract of your paper. Briefly describe the purpose of the research, the main results, and the conclusions.

1 Introduction

The study of tree rings has proven useful across multiple fields, proving to be a reliable subject for reconstructing past climates of regional and local environments, as well as a mechanism to understand tree growth response [?] [?] [?] [?]. To obtain these data from the tree rings, it is necessary to measure tree rings from a tree cookie or core. The first high precision tool for this purpose was a stage micrometer, involving a trained technician to incrementally shift a tree core under the objective of a microscope - informing a computer when a new ring is encountered [?]. While this method has very high precision, the data is only as accurate as the experience and knowledge of the technician at the time of recording [?]. The desire to remove repetition of errors in sampling and sampling bias across to individual technicians led researchers to an alternative - image analysis.

The first step in measuring tree ring width from images requires the digitization of the sample from one of two major methods. The original technique was as a flatbed scanner which can digitize the entire sample at once [?]. With a top of the line scanner, like the Epson Perfection V850 Pro, it's possible to scan at maximum resolutions of 4800 dpi and scan an area of up to 8.5" x 11.7". Analysis which relies on higher resolution larger samples require a different digitization approach.

The second digitization model was introduced with ATRICS [?]. Rather than scanning a whole sample at once, a high resolution camera takes multiple images across the surface of the sample and uses image stitching software techniques to combine them into one ultra high resolution image [?]. This methodology is often seen in other fields such as mineralogy and cellular biology [??]. This method requires either the camera objective to move relative to the sample, or the sample move underneath a stationary camera. For ATRICS and a more modern do-it-yourself alternative, CaptuRING, the sample is moved relative to the camera [?]. Gigapixel takes a different approach by moving the camera relative to the sample, allowing for multiple samples to be recorded in sequence. While these machines can all digitize cores, none have been shown to digitize cookies.

Tina was made to combine the defining features of the previously mentioned machines into one while making the code open-source and chassis open-hardware device. We designed Tina to digitize both cookies and cores, extend the maximum sample length, perform image stitching without user intervention, while minimizing cost. The only specialized piece of equipment needed to build Tina is a 3D printer, but the parts can be readily ordered through 3D print shops if preferred. Excluding 3D printed parts, the total cost of the machine is approximately $2,200 USD compared to the $70,000 USD of the Gigapixel [?]. The total cost of the machine is almost comparable in price or less to many professional camera and macro lens combinations. Additional savings can also be made when factoring in the cost of a professional stitching software license such as PTGui.

2 Methods

The functionality of this system allows for the major steps in tree cookie and core digitization to be automated. Capturing images and stitching them together is handled without the need for user intervention. To do this, the system traverses the surface area of the sample after being given its dimensions. After the capturing process, the images are stitched and are stored on the device along with metadata of relevant machine settings and sample parameters.

The frame, camera, computer, software, and sample leveling tables, work cohesively to address the nuances of digitizing both cookies and cores. Each of these subsystems will be reviewed along with the design considerations involved to make a complete machine. Considering Tina is an imaging machine, we will start off by looking at the camera and move outward.

2.1 System Overview

Camera, computer, software, XYZ frame, adapters.

2.2 Camera

In the Gigapixel and CaptuRING, a professional handheld camera was used to capture images. While this benefits from a wide variety of lens and camera choices - and principally autofocus - they come at a cost. Beyond its literal price tag, a professional camera also carries a significant weight, demanding a more robust and therefore more costly machine frame. These cameras are also optimized for handheld use, not for integration into computer driven machines. This results in clunky access to images from software. Designing around a machine vision camera such as the 12MP Raspberry Pi HQ Camera drastically reduced the camera cost while improving the access to the data stream coming from the camera sensor. Pairing the Raspberry Pi HQ Camera with a high magnification C-Mount lens allows for images with very high resolution in dots-per-inch (DPI) to be captured. (THIS IS AN ESTIMATE, GET THE REAL VALUES FROM TINA) If the field of view of the image could be optically zoomed to 5mm x 3mm, the resolution can reach a theoretical 32,000 DPI.

2.2.1 Focusing

Normalized variance process goes here.

Achieving a focused image across the entire surface area of the sample is the basis for an accurate stitch and effective analysis. By saving costs on a fixed focus camera and lens, it was necessary to implement a method to focus the images. Focus is solely a function of distance to the subject in the regime. With this high magnification lens, having an image go from in-focus to out-of-focus was sensitive to sub millimeter variation in distance to the lens. This requires cores and especially cookies to be as close to orthogonally aligned to the lens as possible. A 3D printed levelling table and bullseye level were used to correct plane misalignment of up to 10 degrees in cookies (CALCULATE THIS?). Slight sample misalignments are corrected within a closed loop automatic control PID algorithm.

3 Results

3.1 Scans of Cookies and Cores

The microscope lens greatly improved the maximum resolution of the digitization. Resolutions of up to 13,400 DPI were achieved, a large improvement when compared to both high resolution flatbed scanners (Epson® Perfection v750 PRO) and CaptuRING.

3.2 Functional Limits

With such high resolution, multiple logistics concerns arise. First is the file size. With such a high resolution, the size of the images can become extremely large. A cookie 5 inches in diameter would result in an image with 67,000 pixels squared. This easily exceeds the 2.5 GB maximum file size in a TIFF - most software for viewing the file will also be incompatible with any file this big as well.

4 Discussion

Discuss the implications of your results here.

4.1 Strengths and Opportunities

4.2 Opportunities for Improvement

5 Conclusion

Summarize your key findings here.