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 [Fritts, 1971] [Williams et al., 2010] [Guibal and Guiot, 2021] [Sheppard, 2010]. 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 [Robinson and Evans]. 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 [Levanič, 2007]. 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 [Guay et al., 1992]. 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 [Levanič, 2007]. 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 [Muhlich et al., 2022]. This methodology is often seen in other fields such as mineralogy and cellular biology [Ro and Kim, 2021, Mohammadi et al., 2024]. 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 [García-Hidalgo et al., 2022]. 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 [Griffin et al., 2021]. 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.

$$\frac{1}{MN\mu}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}(f(x,y)-\mu)^2$$

2.0.1 Automatic Control

While the image stack provides a basis to obtain an in focus image, it is statically limited to the 1mm range in the Z axis. Instead of spending significant time guaranteeing that the sample is within the the Z axis range across the entire surface area, a PID control algorithm takes the wheel [O'Dwyer, 2000]. The information previously calculated in the image stack is sufficient to inform the PID controller of how to adjust the initial the Z axis for the next image stack. The controller is constantly trying to make the most in focus image be at the center of the image stack, index value 5. This allows for the most flexibility moving to the next location of the image grid.

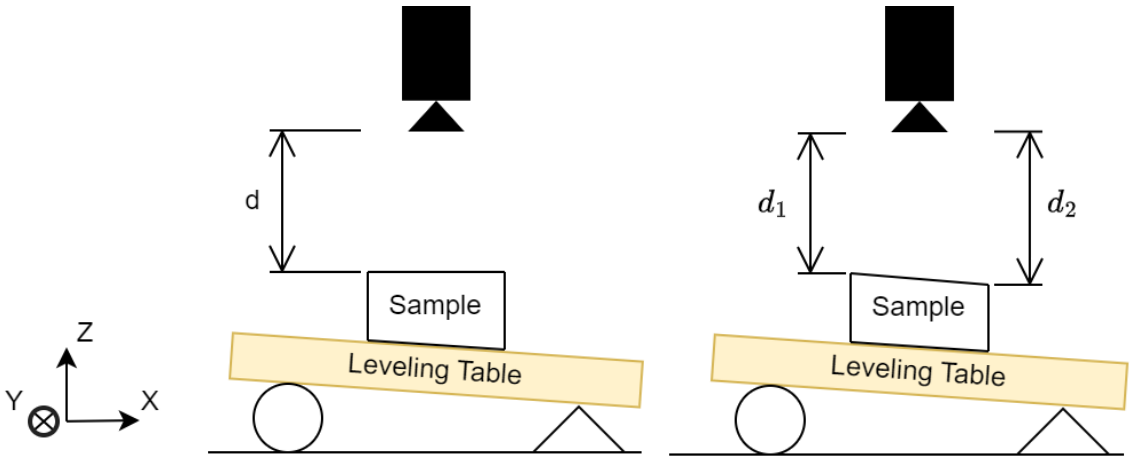
3 Results

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



(a) Ideal sample leveling (b) Realistic sample leveling

Figure 1: Side view of the camera and sample on top of a leveling table. The ideal sample leveling shows a uniform distance d at all (x,y) coordinates on the sample. This is impossible to achieve in reality, the true sample leveling has a non uniform distance at unique (x,y) coordinates.

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.

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