A Comparison of Chronology Development Methods in Dendrochronology

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Introduction to Dendrochronology as a Climate Proxy

The analysis of tree ring growth in a given area can provide a greater understanding of the historical environmental conditions and disruptive natural events in that particular region. While major aspects of climate have been measured and recorded for roughly the past 150 years, this short period in history often does not provide enough data to detect large-scale environmental patterns and trends.[1] By utilizing climate proxies to reconstruct unrecorded climates of the past, we can gain a better understanding of the current environment and more accurately predict conditions in the future.

Dendrochronology and Chronology Development

Dendroclimatology approaches the challenge of climate reconstruction through trees, which can provide information on historic climate conditions based on the growth of their rings. In order for analyses to be matched to the correct year, the rings must first be counted, crossdated, and measured – constituting the field of dendrochronology. Dendrochronology aims to identify ring patterns across trees to create chronologies.[2]

Technology and Chronology Development

Chronology development has historically been conducted using a microscope and micrometer. However, dendrochronology labs have begun to acquire images of tree rings and analyze this images using computer software.

Purpose

The purpose of our research is to improve the chronology development process in our research lab. We also strove to find a way to implement image analysis more economically than other labs that use expensive proprietary software.

Research Questions

Of the chronology development methods available to us (traditional, proprietary software, open source software), we sought to understand what the merits and restrictions of each with regards to:
[1] Efficiency
[2] Precision
[3] Economic value
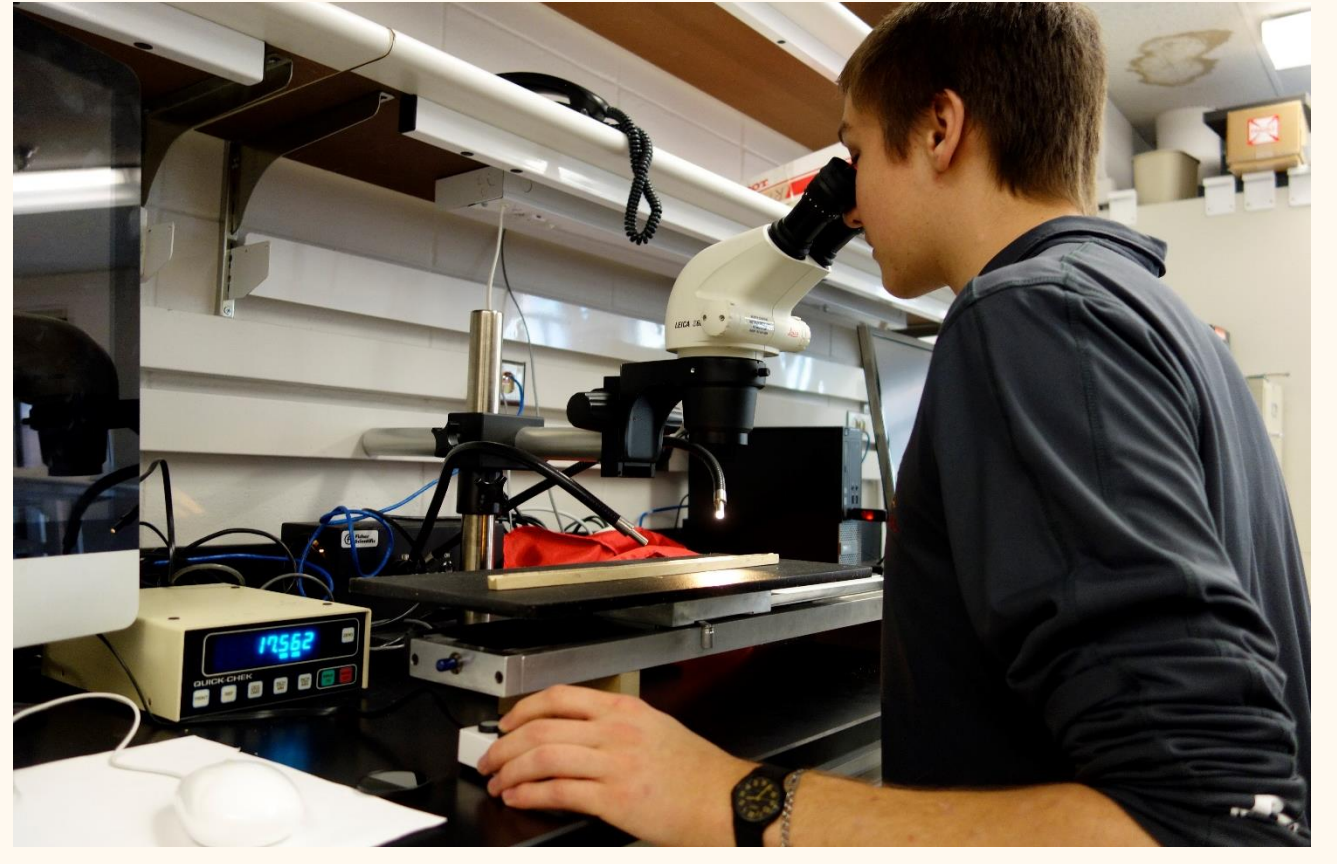
Research Impact and Goals

From this research, we have gained a clearer understanding of the benefits and concessions of image analysis for chronology development, created an image analysis process flow for our laboratory, and found alternative solutions to costly proprietary software.

Previous Method of Chronology Development: Stage Micrometer

Stage micrometer setup

A specimen is traditionally placed on a stage micrometer, a sliding platform connected to an encoder box which communicates with a computer. In this setup, a lab technician views the tree core through a microscope while advancing the stage micrometer. When the crosshair in the eyepiece of the microscope aligns with the end of a ring, the technician presses a button and the computer records the width of that ring. Once measurements are complete, the technician creates a text file containing all the ring widths and their corresponding years.

Benefits and drawbacks of measuring ring width with a stage micrometer

Benefits:
- The stage micrometer is calibrated to the micron (1/1000 mm). This makes the method incredibly precise given there are no user errors.
- The process of measuring with a stage micrometer is fast and simplistic. There is no image acquisition, picture processing, or image stitching involved.

Concessions:
- If an error is made in measurement, the technician must re-measure the entire decade surrounding the mistake. This can be time-consuming if multiple errors are made during measurement
- The crosshair of the microscope must be perpendicular latewood of the tree rings. If rings are diagonal on the core, the core must be constantly readjusted during measurement. This increases measurement time and introduces a greater possibility for human error.

Figure 1: Stage micrometer setup
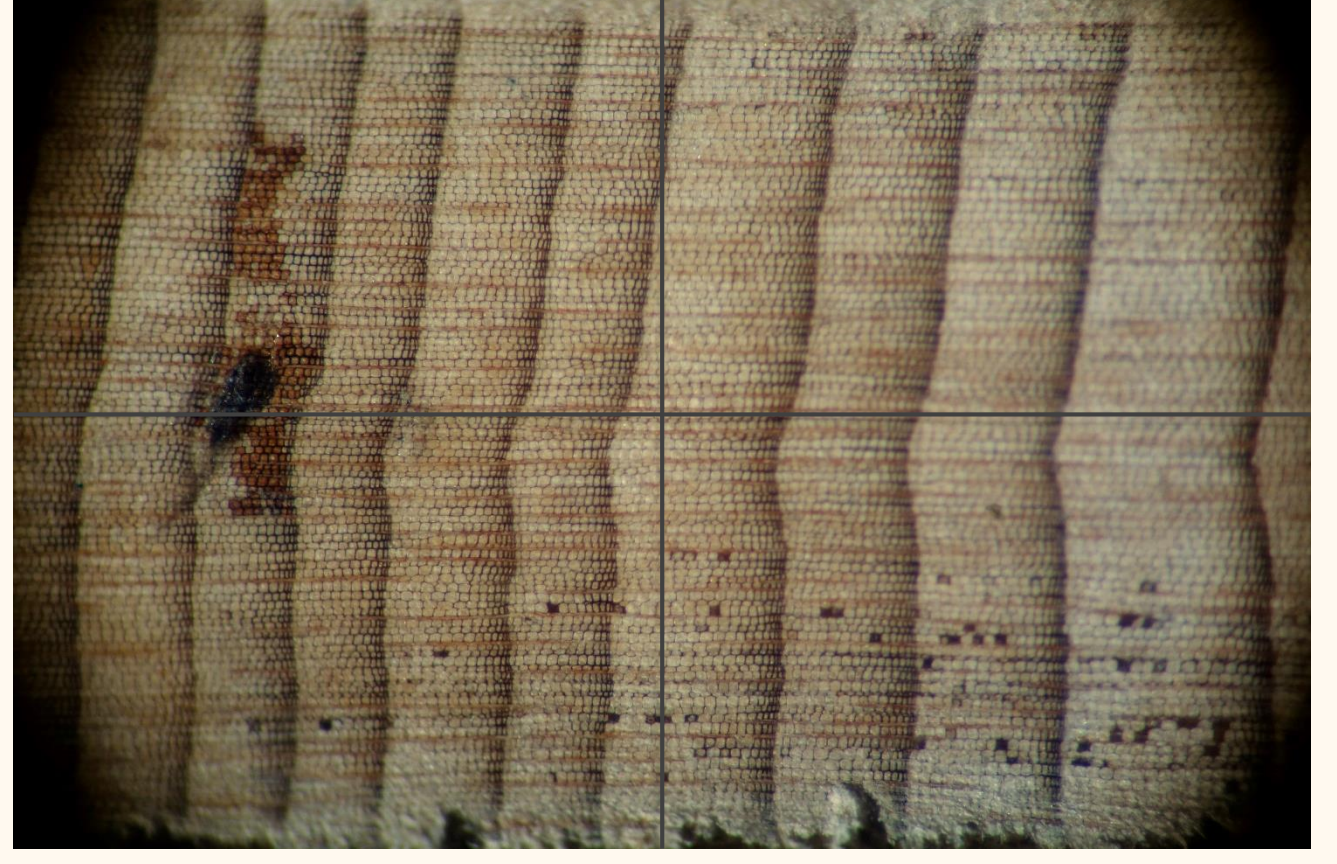

Figure 2: View through a microscope

Image Analysis Methods and Technology

In this process, images of the core are acquired using a camera or scanner. If a camera is used, many images of each core must be taken, processed, and stitched together. Software programs are then used to determine the ring widths on the core.

WinDendro

WinDendro is a prevalent proprietary software application used to find the ring widths of tree rings. However, WinDendro costs upwards of $8,000. We also found WinDendro's user interface to be unintuitive and difficult to use.

CDendro and CooRecorder

CooRecorder is an affordable alternative to WinDendro, costing only $80. It provides the dendrochronology technician with an intuitive and fast user interface. CooRecorder was much easier to learn and use than WinDendro, and allowed us to analyze images much more quickly. CooRecorder also allows the user to ensure that rings are measured orthogonally, a feature that WinDendro lacks.

Image Processing Software

Image processing software was used for magnifying color contrast, decreasing the file size of images, and cropping unnecessary parts of images that would make photo stitching more difficult. Adobe Photoshop was used for all image processing.

Image Stitching Software

Since many close-up images were taken of each core, image stitching software was required to compile these pictures into one image per core. Although we attempted to use open source programs, they were not sufficient. PTGui was the ultimate program used.

Figure 3: High resolution stitched image analyzed in CooRecorder

Figure 4: Low resolution scanned image (same specimen as above)

Observations on Precision and Efficiency

Precision: Room for human error in image analysis and micrometer measurements

With micrometer measurements, user error can result if the lab technician accidentally moves the core on the stage micrometer. In addition

With image analysis, measurement errors can result from poor image acquisition, which can cause images to be disproportionately stitched together. It can be difficult to maintain a consistent lighting environment and camera angle when imaging cores. In addition, all images have to be scaled when they are analyzed by software. If scaling is done incorrectly, the software will interpret the specimens as the wrong size.

CHRONOLOGY DEVELOPMENT PROCESS
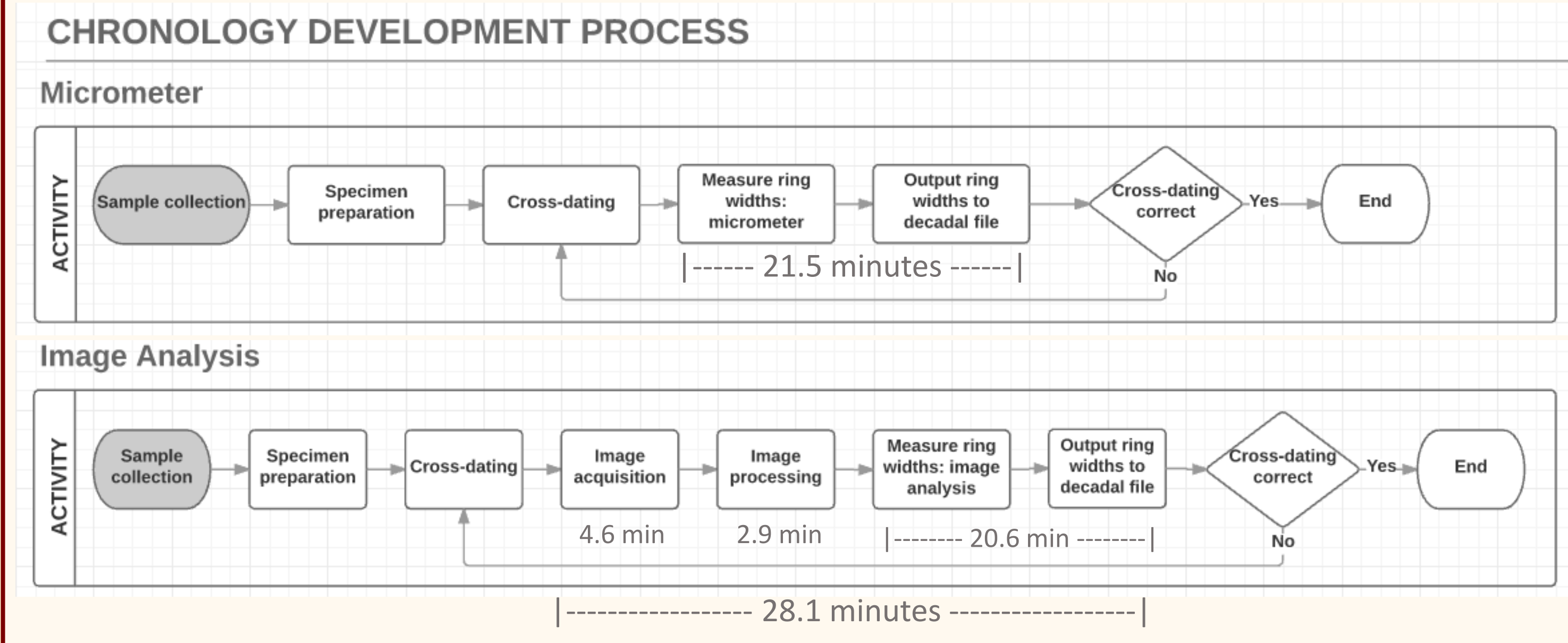
Efficiency: Ring width measurement was slower with image analysis

The entire process of image analysis was about 1.4 times slower than with a micrometer. Although the actual measurement process using image analysis took less time per core, image acquisition and processing account for an average of 7.5 minutes per core.

Image analysis had a faster learning curve than measuring with the micrometer. In addition, image acquisition times would likely decrease with more repetition.

Conclusions and Future Application

We have learned valuable lessons in image analysis that will likely be implemented into the dendrochronology lab at the University of Minnesota. In the future, a GIGApixel macro may be used to automate the process of image analysis and stitching.

Image analysis can provide many benefits to our research lab

- Ability to save measurements. This provides a record of how a tree core was measured and allows anyone in the lab to access it without starting over.
- Provides a digital image archive that is easier to organize and access than physical samples.
- Opens the possibility for future image analysis in addition to ring width, including: wood density (temperature), analysis of vessels in the wood, etc. that can't be done otherwise.

There are a few key issues to avoid when using image analysis to develop chronologies

- Provides room for user error in image taking and lighting inconsistencies.
- Image stitching can alter or warp images, potentially resulting in inaccurate dimensions and ring width measurements.

References

1. "NOAA Paleoclimatology." NOAA Satellite and Information Service. National Climatic Data Center, 20 Apr. 2008.
2. Beniston, Martin. "Climate modeling at various spatial and temporal scales: where can dendrochronology help?." *Dendrochronologia* 20.1 (2002): 117-131.

Acknowledgements