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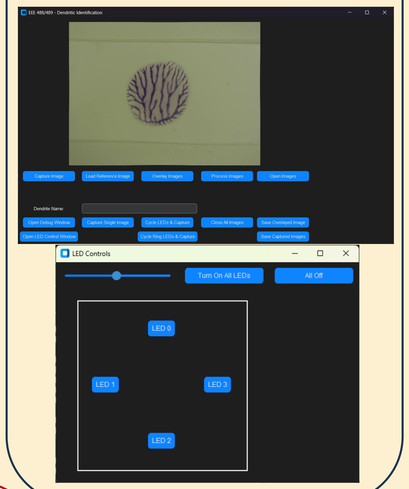
Group 19: Dendritic Identification

Introduction

Counterfeit electronic components have infiltrated global supply chains, posing severe risks to defense systems, commercial aviation, medical devices, and everyday consumer products. These fakes cost industries billions annually and compromise safety, reliability, and national security. Traditional anti-counterfeit measures like RFID tags, QR codes, and barcodes suffer from high cost, easy replication, and the need for additional surface area or power. In contrast, Dendrite Identifiers (DIs), developed by Dr. Michael Kozicki, leverage random microscopic mica flakes embedded in a polymer mixture to form a physically unclonable, optically unique “constellation” pattern. This senior design project builds a low-cost authentication device using a camera, LED ring, and 3D-printed enclosure to capture high resolution images of these dendrite patterns, align them via ArUco fiducials, and compute a match score against a reference database. The system enables rapid verification at any supply chain checkpoint, from manufacturer to end user.

GUI



Results

Over two semesters, the team designed, prototyped, and refined a fully functional authentication device. Hardware evolution began with unstable early prototypes and progressed through multiple 3D-printed iterations to a final enclosed build featuring: a precision-machined camera mount, LED ring with fixed 45 mm height, friction-fit stabilizing legs, integrated Arduino Nano for LED control, and full wire management within a compact housing. Ray-tracing validated light distribution, and empirical testing confirmed repeatable dendrite imaging. Software development produced a PyQt-based GUI with live camera preview, real-time LED brightness and height sliders, CSV data logging, and a debug console. The matching pipeline-> ArUco alignment -> masking -> SIFT/FLANN -> RANSAC + Astrolign, achieved 81% initial match rate. Improving to 95% under varied conditions. The system successfully authenticates dendrite samples in under 3 seconds, demonstrating feasibility for real-world deployment.

Build

Theory

Saffman-Taylor Effect

- Identifiers are created using the Saffman-Taylor effect, air contacts a thin disc of vicious fluid in a chaotic manner. This causes the unique branching structure.
- The flakes are distributed at unpredictable positions with a variety of orientations, making them impossible to replicate inside the branching structure.

Reflections & Raytracing

- Due to the randomness of the flakes, shining a light on a dendrite will result in different reflections at different angles.
- Raytracing simulations were used to determine the hardware design, including the elevations and angles of the lights as well as the camera distance.

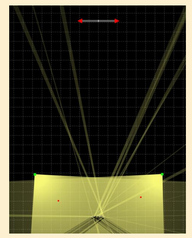
Astroalign Point Comparison

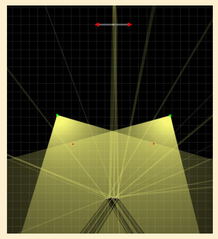
- The reflections produced at different angles appear similarly to constellations in the sky, allowing the use of an astronomy-inspired algorithm called Astroallign for image analysis.
- Astroallign can be combined with an iterative method called RANSAC, which reduces outliers and performs transformations, to analyze and compare dendrites.

ArUco Marker Correction

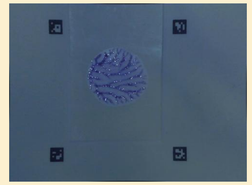
- It is important for comparing dendrites that they are compared at the same scale and rotation, ArUco markers can be used to provide references for image transformations

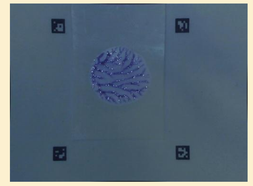
Ray Tracing

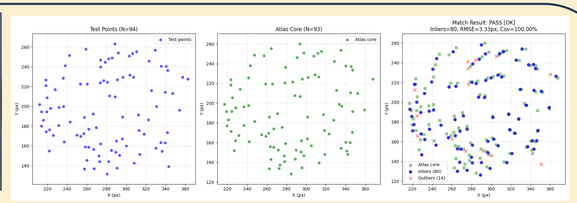


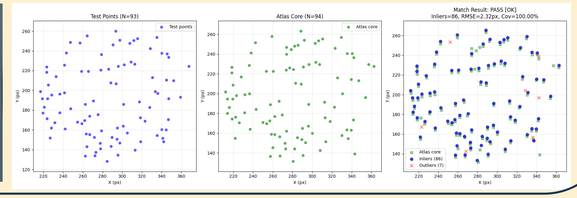


Testing

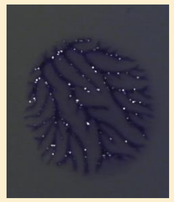








Identifier



Conclusion

This project successfully demonstrates a compact, USB-powered device capable of authenticating Dendrite Identifiers with up to 95% accuracy using open-source vision tools and 3D-printed hardware. Proving a scalable, low-cost solution to the global counterfeit component crisis. The system outperforms traditional methods in security, cost, and incorporation. Key milestones achieved include stable hardware design, robust image alignment under real-world variations, and a functional software interface. This technology lays the foundation for trusted, transparent supply chains across electronics, aerospace, and beyond.