Open-Source Semi-Autonomous Computer Vision Controlled CNC Welding Machine

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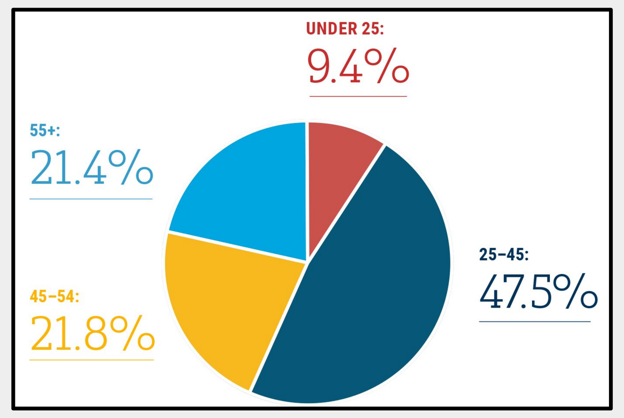
Why?

There is a shortage of skilled welders.

Current robotic welding cells, programmable and autonomous, are expensive.

The high upfront costs of robotic welding creates a barrier to entry for smaller businesses.

The goal of this project is to develop a platform for semi-autonomous 2.5D welding to prove that low cost automation is possible with basic off the shelf hardware and open source software.



https://weldingworkforcedata.com

Design Approach

Machine Hardware:

The CNC machine hardware is built from low cost off the shelf parts and uses aluminum extrusion and MDF to reduce cost.

Vision System Hardware:

A monocular UVC camera is used from Arducam. The camera uses a 16MP sensor with autofocus capabilities.

Machine Software:

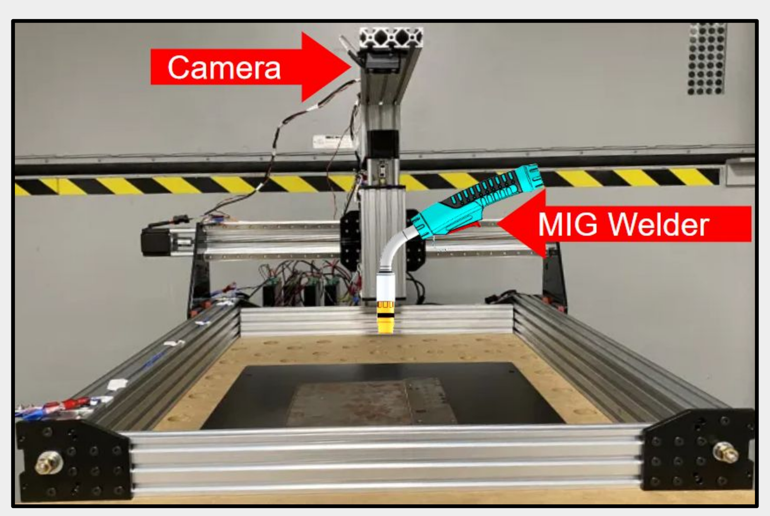
The CNC machine is controlled using an open-source firmware GRBL that runs on an Arduino.

Vision System Software:

OpenCV with Python is the computer vision library being used to identify weld joints.

grbl

OpenCV



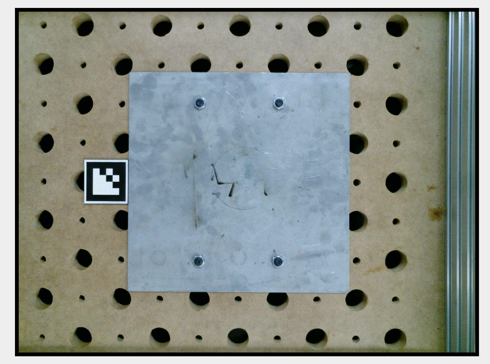
MIG Welder Integration:

A non-invasive control system uses a 3D printed mount that clamps to a Lincoln Electric MIG welding torch and mounts a solenoid to actuate the trigger.

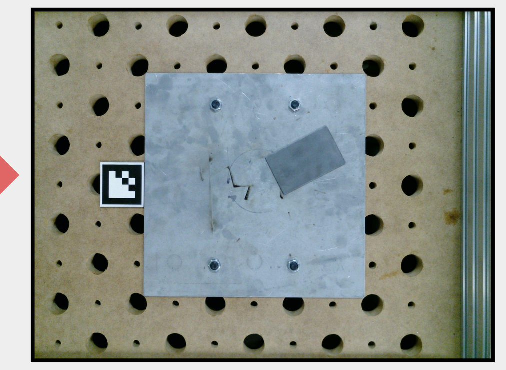
Cost:

The hardware for the physical CNC machine was ~$1,500 and the vision system camera was $50. The MIG welder was used from Sears Thinkbox.

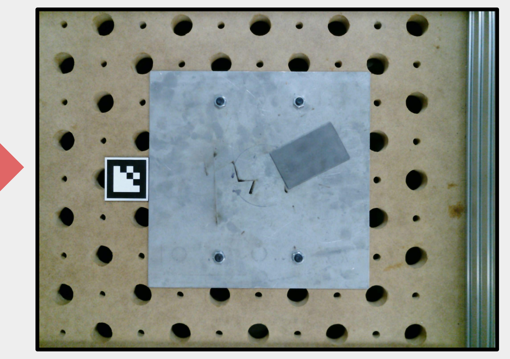
Image Processing and Joint Identification



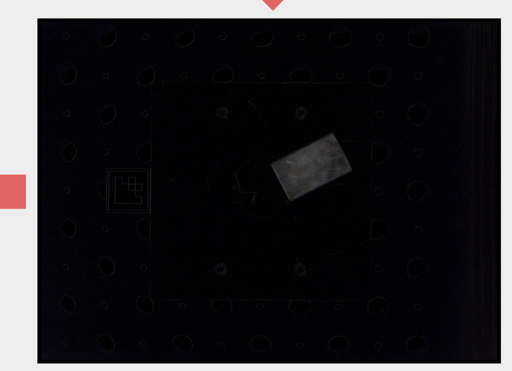
1. Background frame captured when GUI starts



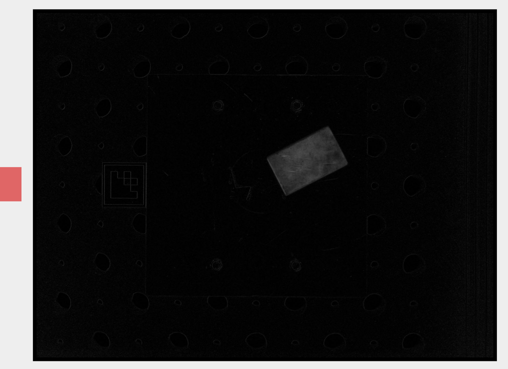
2. Capture current frame when piece of steel is placed down



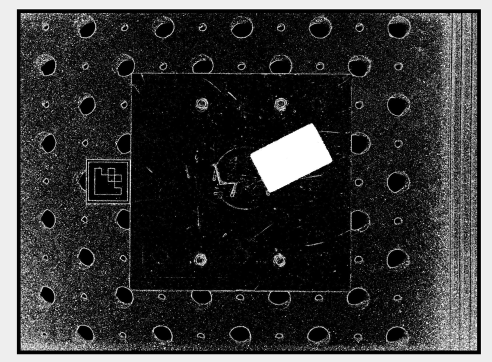
3a. Bilateral Blur to remove noise while maintaining edge definition



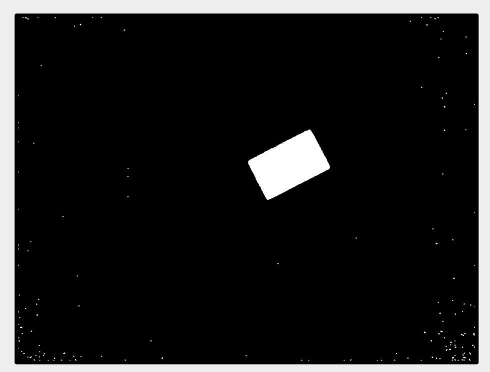
3b. Absolute difference calculated between **3a** and **1**



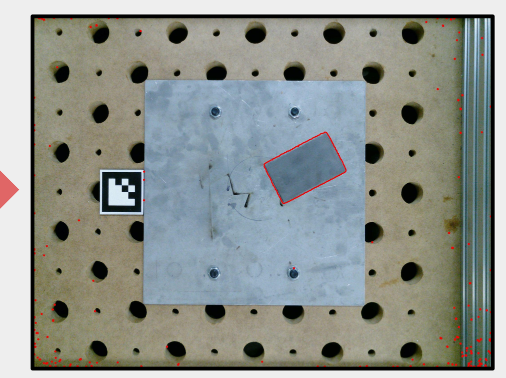
3c. Grayscale image conversion



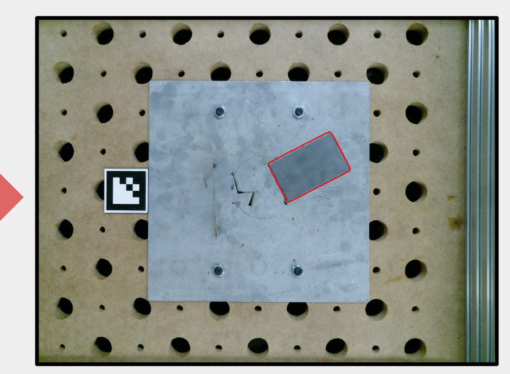
3d. Binary Threshold for edge detection



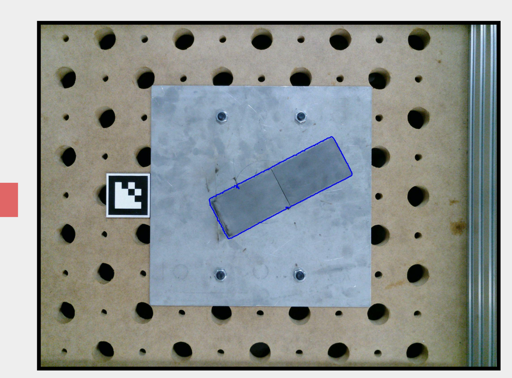
3e. Erosion followed by dilation to remove noise



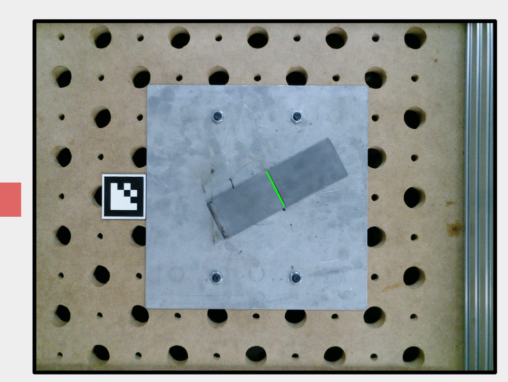
3f. All contours are drawn



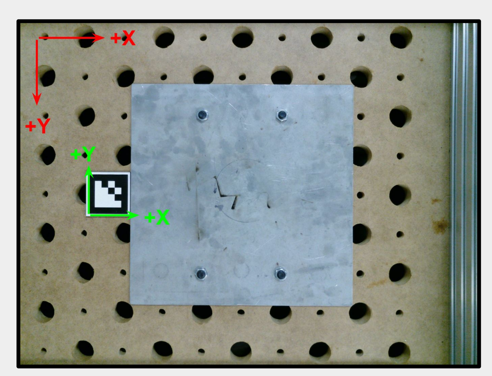
3g. Largest contour filtered out as target



4. Step 3 repeated on image with both pieces of metal

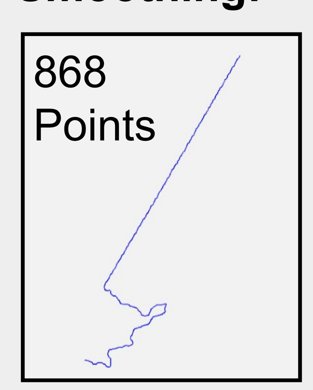


5. Intersection is calculated and drawn

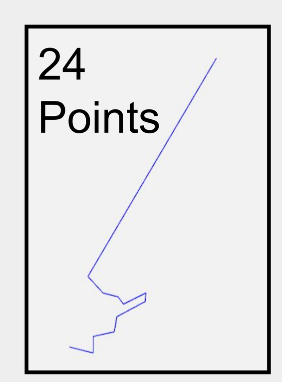


6. Intersection points are translated, rotated, scaled and smoothed before being sent as G-Code to the CNC

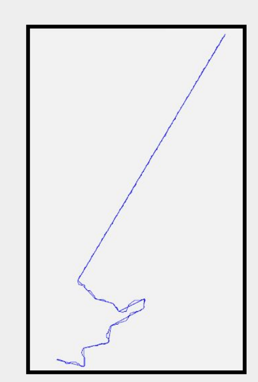
Smoothing:



Original Path

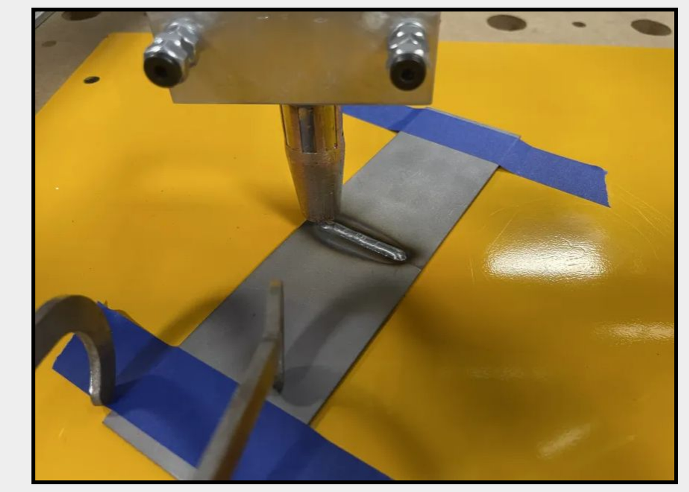


Ramer-Douglas-Peucker Algorithm



Overlay

Results

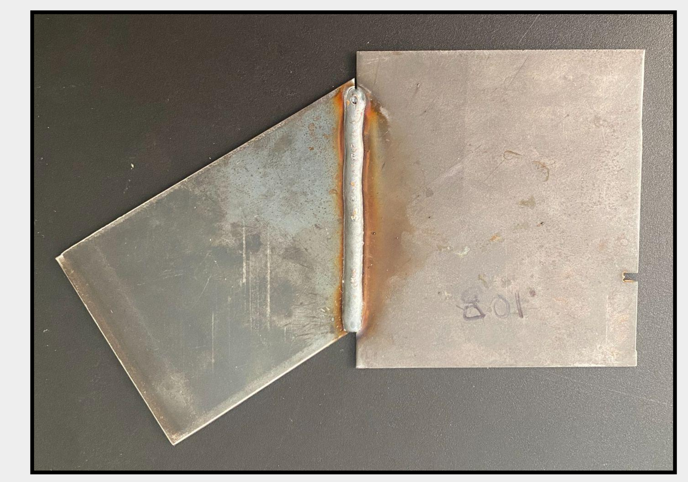


Initial Testing:

Initial testing performed used image thresholding based on Hue, Saturation and Value (HSV). This meant that the background had to contrast greatly with the color of the metal being used. The powder coated plate was not conductive and burned during welding.

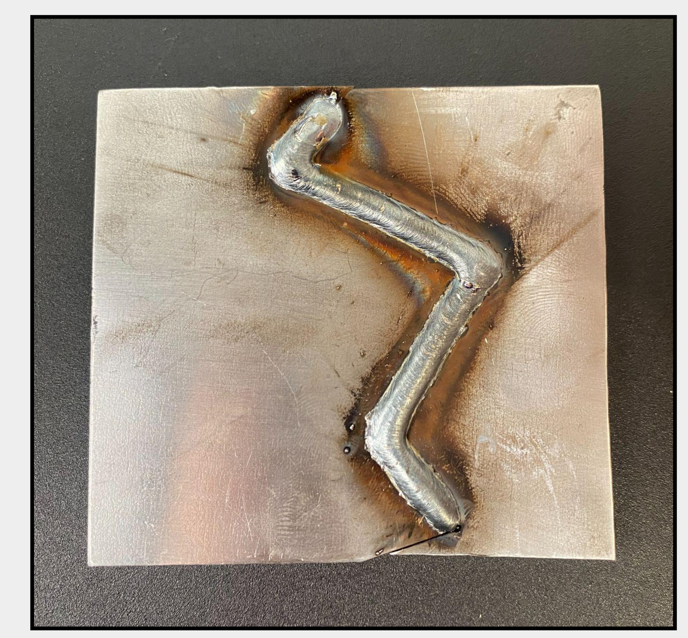
Welding Video

Github



Final Results:

With a consistent background, background subtraction enabled the use of a conductive aluminum base plate and provided enough contrast to detect edges. A straight, zigzag, and curvy joint were all tested successfully.



What Next?

Current Design:

- Fine tune current image processing settings
- Switch from GRBL to Linux CNC
- Convert to 24V logic system
- Improve system robustness against shadows and lighting changes
- Implement machine learning techniques to improve system robustness.

Next Design:

- Most welding needs to happen in full 3D space, a robotic arm is necessary to achieve this.
- Implement similar techniques with a 4-6 axis robotic arm, multiple cameras and machine learning computer vision techniques.