ETCH A SKETCH ROBOT

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Introduction

Inspired by CNC machining, this project creates an automated drawing machine using an Etch A Sketch board[1].

It first introduces a software pipeline that transforms digital images into continuous-line drawings. By employing edge detection techniques and a specialized depth-first search (DFS) algorithm, our system generates optimized G-code instructions tailored for our custom-built drawing machine.

The hardware system interprets these instructions and uses two stepper motors to precisely control the Etch A Sketch knobs, allowing the machine to replicate digital images as physical sketches.

Methodology

System Design:

- Implemented an MVC structure, separating the controller from the data model to ensure modularity.
- Designed a host-peripheral computing setup for future hardware upgrades and scalability.

Hardware Development:

- Used an Arduino Uno to control two stepper motors via A4988 drivers.
- Designed a custom 3D-printed frame for precise Etch A Sketch knob rotation.

Software Development:

- Python-based image processing generates a plotting scheme, using OpenCV for edge detection. The processed image is converted into G-code instructions[2].
- Programmed the Arduino to interpret G-code and send step pulses to A4988 motor drivers via serial communication.

Hardware

Components:

- Microcontroller: Arduino Uno – controls the motor system and executes G-code instructions.
- Motor Drivers: A4988 stepper motor drivers – regulate motor speed and direction.Stepper
- Motors: Two stepper motors – precisely control the Etch A Sketch knobs for drawing.
- Power Supply: 12V, 5A – provides stable power for motor operation.
- Frame & Mounts: A custom 3D-printed frame ensures stability and precise motor alignment

Figure 1. A4988 Driver

Working Principles:

- The Arduino Uno receives G-code commands via serial communication.
- The commands are processed, and step signals are sent to the A4988 drivers.
- The A4988 drivers convert signals into precise step movements for the stepper motors.
- The motors turn the Etch A Sketch knobs, translating digital paths into physical drawings.

Software

The host computer runs a fully automated pipeline to transform digital images into precise, single-line sketches.

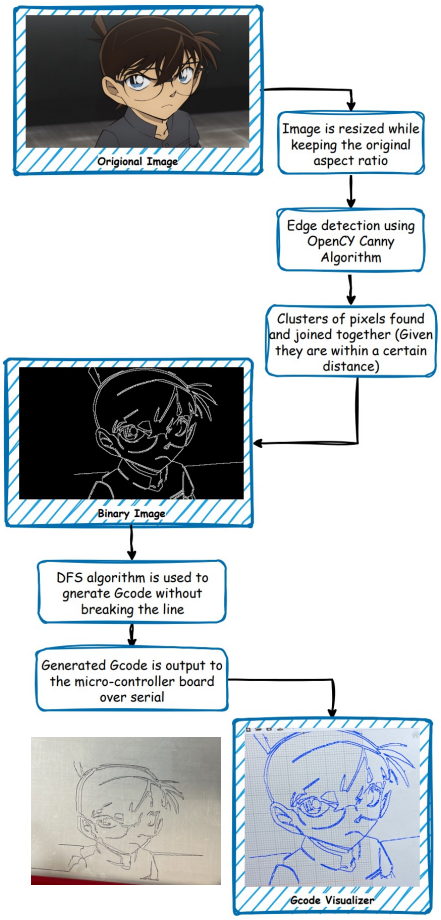

Figure 2. Software Pipeline Diagram

Image Processing & Path Generation

- The input image is processed using OpenCV's edge detection to extract key contours.
- A depth-first search (DFS) algorithm reconstructs the path into a continuous single-line drawing, ensuring smooth and natural sketching.

G-code Generation

- The optimized drawing path is converted into G-code instructions (coordinates), acting as a precise movement script for the hardware.[3]

Motor Control & Execution

- The G-code is sent to the Arduino via serial communication. A self-developed script is used for messaging and receiving feedback.
- The driver program on peripheral device achieves features including
  - Asynchronous, non-blocking motor motion, ensuring independent movement.
  - Asynchronous communication with the host computer, allowing continuous execution without delays.

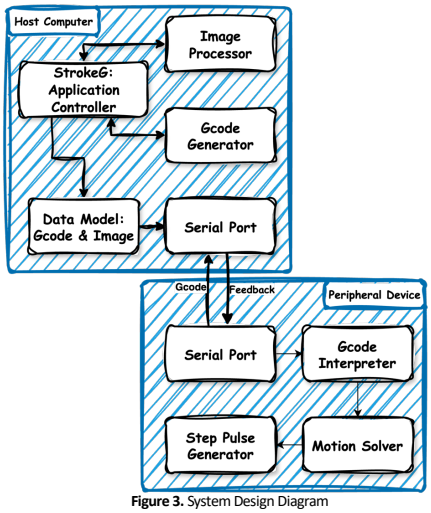

Figure 3. System Design Diagram

Result

Image processing and generative algorithm:

- Software successfully demonstrated image vectorization and path optimization.
- Software demonstrated the ability to join clusters of pixels to form an image out of a single line.

Figure 4. Cluster Linking Result

Figure 5. The Forbidden City

Motion control and execution

- Successful control of stepper motors and independent motion of motors using an Arduino microcontroller.

Drawbacks:

- The system is open loop and the etch a sketch is not perfect, therefore feedback control is not achieved, resulting in a drifting in the physical sketched image.

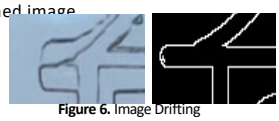

Figure 6. Image Drifting

Conclusions

In conclusion, our project successfully met the predetermined requirements, demonstrating the integration of edge detection and path optimization to generate a given image for a CNC-based plotter.

However, some challenges remain. Specifically, since the system operates in an open-loop configuration without feedback, it cannot track the exact position of the pins during the drawing process. As a result, there is a potential risk of double images appearing in the physical output.

References

[1]Every Flavor of Robot, " This Etch-A-Sketch Animates VIDEOS," YouTube, Dec. 20, 2024. [Online]. Available: https://www.youtube.com/watch?v=p4cUWCG7fM4&t=1316s.

[2] A. Hodel, G-code Optimizer, GitHub repository. Available: https://github.com/andrewhodel/gcode-optimizer. [Accessed: 21-Feb-2025].

[3] "Writing your own G-code interpreter," Arduino Forum, Aug. 19, 2014. Available: https://forum.arduino.cc/t/writing-your-own-g-code-interpreter/258828. [Accessed: Feb. 21, 2025].