3D Printing Error Detection System

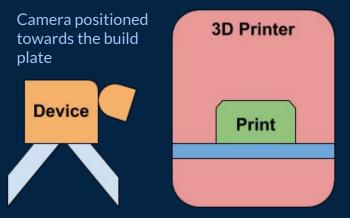
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Closing the Loop on 3D Printing

• Status Quo:

- Printers are open loop devices
- Standard printers have no built in error detection
- Current camera systems are "dumb" simply for human monitoring
- Our device will monitor active 3D prints
- Will detect errors as they occur, and alert users

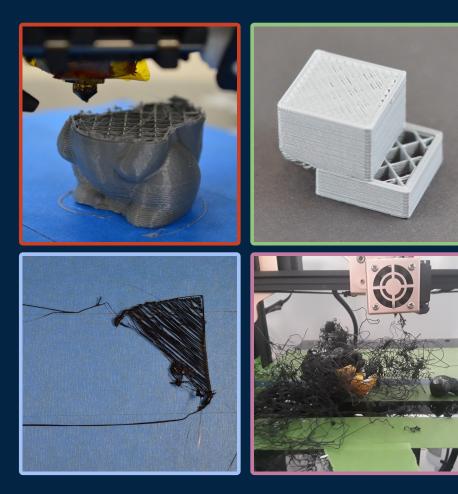




Error Classes

Key Target Error Types:

- Extrusion stops mid-print
- Layer shifting
- Failing to adhere to the print bed
- "Hairball"



Software Component

- 3D render function to translate g-code into 3D model
- Initializing the two to match up in size / dimensions
- Performing edge detection on live images of the active print
- Comparing the edge detection to the 3D render
- If error occurs \rightarrow notify the user

Software Requirements

Error check upor
completion of
each layer, or
each second

- Implementation specific
- Based on known g-code and printer speed, device will know when each layer is complete
- If layers finish too fast, device will resort to error checks every second

Accuracy of error detection

- 70-75% detection rate
- Will develop custom confidence threshold
- Will poll users/makers

Error occurs and error is discovered

- Based off of frequency of checks
- Error should be discovered and reported within 5 checks (~0.5 mm)

Software Testing & Verification

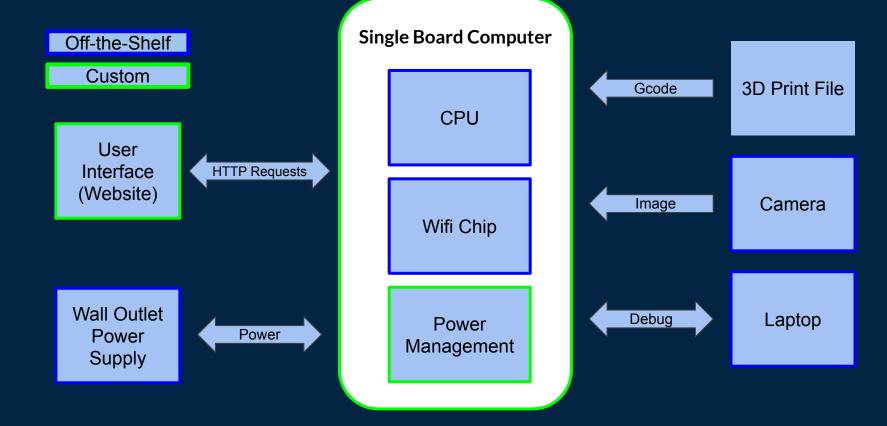
3D Printer System

- Compare g-code based model to original model
- Compare g-code based model to actual prints
- Test edge detection on active prints
- Purposely create faults to test error detection
- After integration with hardware -- repeat last 2 tests

User Experience

- Test user reception of different commands/statuses from the system
- User testing for intuitiveness of setup and use

Hardware Component



Hardware Requirements

Device must be able to run for at least 6 hours uninterrupted

• 6 hours is the average time to complete a test print



SBC area within 6 x 3 inches	• Based on the size of iPhone 11 Pro for ease of use
Device must weigh less than 4 lbs	• Based on the weight of the Macbook Pro 15"
Camera view covers a 8.9L x 6.7W x 6.7H inches build plate	 Based on rough average of dimensions from three target printers: Dremel 3D40: 10L x 6W x 6.7H inches Ultimaker 3: 7.8L x 8.5W x 7.9H inches Makerbot Replicator+: 8.9L x 5.7W x 5.9H inches

Hardware Testing and Verification

- Test power consumption via meter and current shunts
 - Including power consumed by camera
- Develop watchdog system to monitor power, temperature, and heartbeat on the SBC
- Survey end-users for weight, size, and usability constraints
- Ensure computer vision algorithm successfully runs on SBC
- Develop WIFI communication test plan
 - Send commands back and forth fast enough to stress test system

Division of Labor / Areas of Knowledge

• Hannah: Signals / Software

- Computer Vision
- Image Processing
- Joshua: Hardware / Software
 - PCB Design
 - Custom-Designed SBC
 - Embedded Systems & Power Management
- Lucas: Hardware / Software
 - Embedded Systems & Firmware
 - 3D Printing / Rapid Prototyping
 - Custom-Designed SBC



Schedule & Gantt Chart

	Week of 1/19	Week of 1/26	Week of 2/2	Week of 2/9	Week of 2/16	Week of 2/23	Week of 3/1	Week of 3/8	Week of 3/15	Week of 3/22	Week of 3/29	Week of 4/5	Week of 4/12	Week of 4/19	Week of 4/26
Preliminary Research															
Trade Study for WIFI chip						Joshua	Hannah	Lucas	Team						
Project Proposal						Joshua & Lucas	Joshua & Hannah	Lucas & Hannah							
Research translating g-code into images															
Trade Study for Camera															
Trade Study for CPU															
Prototype of Hardware System Using Dev Boards															
Write g-code to 3D render function															
Explore Remote 3D Printer Access Via Our Hardware System															
Testing 3D render															
Design Preliminary SBC Schematics															
Write edge detection function with CV															
Design WIFI Output Subsystem															
Design Power Management Subsystem															
Design Presentation															
Test edge detection function															
Implement Preliminary SBC															
Preliminary SBC Assembled															
Preliminary SBC Tested, Issues Found/Documented															
Implement UI (Website)															
Implement Embedded Firmware Subsystem															
Implement Output Subsystem															
Implement Power Management Subsystem															
Final SBC fully implemented, sent to board house															
Final SBC Assembled/Populated															
INTEGRATION															
Run Final System on Multiple Printers															
Make Video Documentation															
Make Poster Board/Presentation															
Final Presentation															

Some Fun Stretch Goals

- Sense additional error types such as warping, stringing, oozing, and layer separation
- Automatically sense camera orientation and distance via integrated accelerometers and IR range finders
- Sense extruder overheating
- Build out a custom 3D printer that better has our camera-based error detection system baked in