University of Arkansas – CSCE Department
Capstone II – Final Report – Fall 2022

AMBOT Calibration

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Abstract

AMBOT is a tech startup based in Fayetteville that is developing swarm 3D printing that aims to revolutionize 3D printing and manufacturing. They currently have working systems that they are refining. Currently, their printing speeds are slowed because they have to manually calibrate the position of the printing arm to achieve the precision necessary for printing.

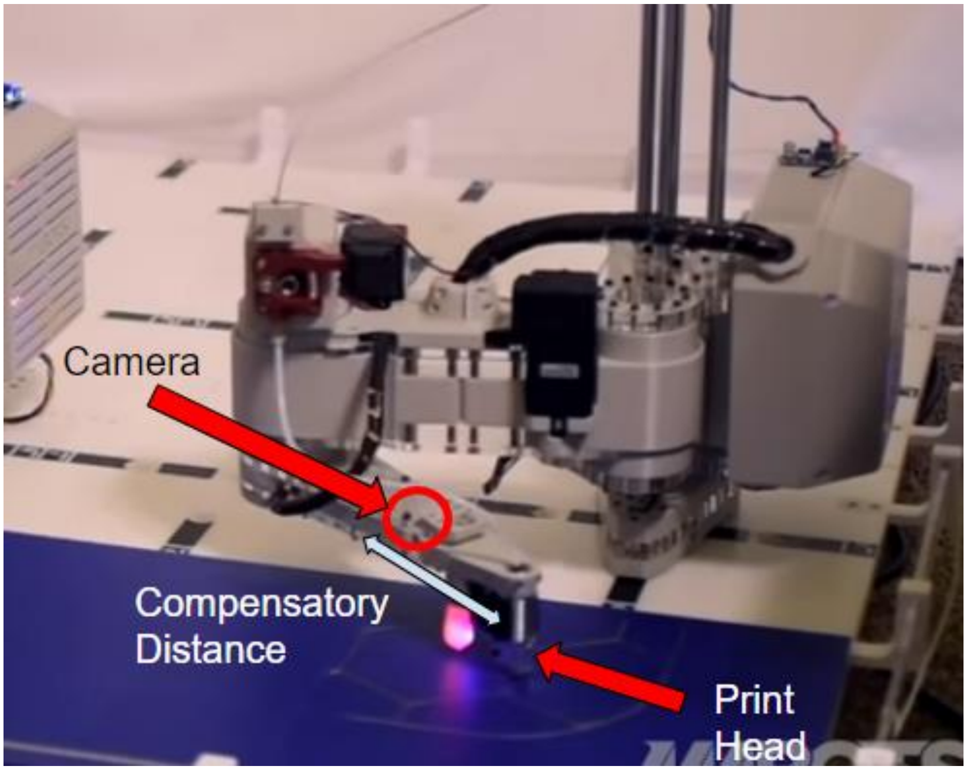
Our goal is to automate the calibration of the arm using a camera and the OpenCV computer vision package. We would like to integrate this with the new framework AMBOTS will be using, ROS. ROS Stands for Robot Operating System, which despite its name, is not actually an operating system; rather it is a framework for developing robotic processes. If this process can be automated, then the printing can be done more efficiently and with less oversight. This automated implementation would also save a non-trivial amount of time for the engineers as AMBOTS that could otherwise be spent doing more useful work.

1.0 Problem

A few paragraphs focused on *the problem* (not the solution approach), its importance, and the *impact* of not having a solution

A large factor in the viability of AMBOTS is the precision of its 3D printing. Currently, the robots move along a surface according to a virtual grid. This virtual grid will get desynchronized with the physical grid it moves along over time. The current solution involves a person manually entering coordinates into the system before it starts a print.

This means that a trained person must be present to calibrate the robot before each print. This means less efficiency and scalability in the product which reduces the commercial viability.



2.0 Objective

The objective of this project is to build an automatic calibration system for the AMBOT swarm 3D printing arm.

3.0 Background

3.1 Key Concepts

OpenCV is an open-source computer vision library that is widespread and well tested. This library will allow us to identify certain markings on the print-space with only a simple camera. OpenCV will allow us to utilize advanced computer vision algorithms that have been heavily abstracted to allow for simple use.

To interface with the robot itself, we will use ROS (Robot Operating System) which is a set of software packages that helps users' program various robotic systems. We will be using ROS to move the arm of our robot after we have calculated the correct position.

3.2 Related Work

What other researchers or developers have accomplished in this project area including references in [ref number] format, e.g., [1]. What are the problems with those implementations that yours will solve or why will yours be better or different?

[1] Kulkarni, P., Magikar, A., Pendse, T. (2020). A Practical Approach to Camera Calibration for Part Alignment for Hybrid Additive Manufacturing Using Computer Vision. In: Reddy, A.,

Marla, D., Simic, M., Favorskaya, M., Satapathy, S. (eds) Intelligent Manufacturing and Energy Sustainability. Smart Innovation, Systems and Technologies, vol 169. Springer, Singapore. https://doi.org/10.1007/978-981-15-1616-0_21

The approach used here is very similar to what we will be doing, with a few notable exceptions:

- They are using 3d vision during the printing process to identify parts and locate based off of those, not off existing markers within the printing platform

- Our solution will be better because there is less introduced error

4.0 Design

4.1 Requirements and/or Use Cases and/or Design Goals

List of requirements and/or Use cases. This should grow into a comprehensive list which represents all of the requirements that your project must meet which may be described as a list of requirements, a full set of the use cases it will/does satisfy, etc.

- Must be robust

- Must save time over the existing manual method

- Must have an 80% success rate

4.2 AMBOTS Computer Vision Architecture

- ROS implemented on printers
- OpenCV computer vision used for locating markers
- Camera provided by AMBOTS

4.3 Risks

Risk	Risk Reduction
Potential bugs once we leave	Increase testing
Could slow down production if it breaks	Increase reliability rate

4.4 Tasks – Create a comprehensive list of the tasks to be performed from initial understanding and design, through implementation, testing, etc. Define your own set of tasks, do not use the following which is just an outline of an example. Your task list should be much, much more detailed with tasks broken down so that none require more than around 2 weeks

See Trello Board : https://trello.com/b/RCtXUBg5/kanban-board-ambots-capstone

1. Analyze existing code

2. Familiarize ourselves with ROS and OpenCV

3. Analyze what needs to be done (fix existing code or start from scratch?)

4. Take robot measurements

5. Create a backlog of work items and user stories

6. Prioritize backlog

4.5 Schedule – Create a schedule which reflects the proposed timeline for each of the tasks listed in section 4.4. Each task should be scheduled, and the schedule should have more detail than the example below (e.g. break timeframes down into weeks or months).

For More Detail, see Trello Board : https://trello.com/b/RCtXUBg5/kanban-board-ambots-capstone

Tasks	Dates
1. Analyze existing code	9/8 - 9/14
2. Familiarize ourselves with ROS and OpenCV	9/8 - 10/1
3. Analyze what needs to be done	9/8 - 9/14
4. Take robot measurements	9/12
5. Create a backlog	9/14 - 9/23
6. Prioritize backlog	9/14 - 9/23
7. Start development	9/23
8. Testing and Improvements	10/14-11/30

4.6 Deliverables – Give a thorough listing and description of each item which will be submitted with your final, working project. Each major component should be described. The below is just an example list which should be replaced with your own.

- Code for robot calibration
- Final Report

5.0 Key Personnel

Jared Shepherd – Jared is a Senior Computer Engineering major in the Computer Science and Computer Engineering Department at the University of Arkansas. He has completed relevant courses such as: system synthesis and modeling, embedded systems, computer architecture, operating systems, and programming paradigms. Jared worked for JB Hunt as a software development intern/QA intern/Product Owner intern at JB Hunt for 4.5 years and then took a summer off to do electro-mechanical design and engineering internship with Honeywell Federal Manufacturing and Technology in Kansas City, MO, now he works at SupplyPike as a Product Manager Intern where he has accepted a full time offer upon graduation this December to continue on the same path. Jared will be responsible for putting together the backlog and website, prioritizing the backlog, interfacing with the end users, and testing the software.

Justin Boyce – Justin is a senior Computer Science major in the Computer Science and Computer Engineering Department at the University of Arkansas. He has completed relevant courses such as: Artificial Intelligence, Data Mining, and Algorithms. Justin has been a software engineering intern at JB Hunt since 2021 and has been an integral part of the teams he has been on as well as leading multiple new initiatives and has accepted a full time offer to return to JB Hunt as a Software Engineer 1 upon graduation in December. Justin will be doing backlog review/grooming, interfacing with the end user, testing, and developing.

1.0 Facilities and Equipment

AMBOT's proprietary swarm 3D printing setup.

Located at the University of Arkansas technology center off Cato Springs Rd in Fayetteville, AR, the AMBOTS headquarters is a high-tech facility stocked with the latest and greatest tools used in the 3D-Printing sphere. With multiple workbenches for fixing physical and mechanical issues, along with Wi-Fi integrated printers for real time adjustment and testing of the 3D printers; our team has everything we could need to complete this project for AMBOTS.

7.0 References

[1] Kulkarni, P., Magikar, A., Pendse, T. (2020). A Practical Approach to Camera Calibration for Part Alignment for Hybrid Additive Manufacturing Using Computer Vision. In: Reddy, A., Marla, D., Simic, M., Favorskaya, M., Satapathy, S. (eds) Intelligent Manufacturing and Energy Sustainability. Smart Innovation, Systems and Technologies, vol 169. Springer, Singapore. https://doi.org/10.1007/978-981-15-1616-0_21

[2] https://www.ambots.net/company