FINAL YEAR (BE) - MAJOR PROJECT PROPOSAL

A.Y. 2024-25

Title of Project

PCB F.O.R.G.E.: Autonomous Soldering Machine

Submitted by

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V.E.S. Since 1962

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Chapter 1

Introduction

1.1 Background Information:

In the rapidly evolving field of electronics manufacturing, startups and small-scale producers face significant challenges due to the high cost, complexity, and large-scale focus of traditional PCB soldering solutions. This disparity limits innovation and growth, as these entities struggle to access cost-effective, high-quality PCB manufacturing necessary for developing competitive electronic products. The lack of affordable, efficient, and easy-to-use soldering alternatives exacerbates the problem for small businesses and hobbyists, hindering their ability to achieve professional-grade results.

Recent advancements in affordable computing and open-source hardware, such as the Raspberry Pi Zero W, have opened new possibilities for low-cost, high-performance solutions in electronics manufacturing. These advancements offer a transformative approach to democratizing access to advanced soldering technology, enabling smaller entities to achieve professional-grade results without incurring exorbitant costs.

1.2 Problem Statement:

Introducing PCB F.O.R.G.E. (For Opportunities Reviving Great Era), an innovative and cost-effective CNC soldering machine designed to revolutionize PCB manufacturing for startups and small-scale electronics producers. Leveraging the affordable Raspberry Pi Zero W, this project integrates readily available components like stepper motors from DVD players and a 3D printer extruder to create an efficient soldering solution. Our Flask-based web application allows users to upload PCB images, detect solder pads using OpenCV, and automate the soldering process with precise CNC control via GPIO pins.

PCB F.O.R.G.E. democratizes access to advanced soldering technology, making it an ideal tool for cost-conscious startups. Future enhancements will include PCB milling, SMD component placement, and PCB masking, aiming to provide a comprehensive solution for all PCB manufacturing needs. This project promises to empower small businesses and hobbyists to achieve professional-grade results at a fraction of the cost of current market alternatives.

1.3 Objectives:

1.Develop Core Functionality:

Complete the integration of stepper motors from DVD players and a 3D printer extruder to the Raspberry Pi Zero W. Implement precise control of the CNC machine via GPIO pins.

2.Enhance User Interface:

Create a user-friendly web-based application using Flask. Enable users to upload PCB images and automate the soldering process through the web application.

3.Implement Advanced Image Processing:

Use OpenCV to detect solder pads accurately on uploaded PCB images. Ensure reliable and precise soldering through automated image processing.

4.Optimize Cost and Accessibility:

Maintain the affordability of the CNC soldering machine by using readily available components. Ensure the system is easy to assemble and use, targeting startups and small-scale electronics producers.

5.Future Enhancements:

Plan and develop additional features such as PCB milling, SMD component placement, and PCB masking. Continuously update the system to incorporate user feedback and technological advancements.

6.Market and Community Engagement:

Promote PCB F.O.R.G.E. as an innovative solution for low-cost, high-quality PCB manufacturing. Engage with the community of startups, small businesses, and hobbyists to gather feedback and drive adoption.

7.Quality and Performance:

Conduct extensive testing to ensure the reliability and precision of the soldering process. Optimize the system for consistent performance across different PCB designs and materials.

Chapter 2

Literature Review

2.1 Research Paper 1: Performance comparative of OpenCV Template Matching method on Jetson TX2 and Jetson Nano developer kits

Authors: Artiom Basulto-Lantsova, Jose A. Padilla-Medina, Francisco J. Perez-Pinal

Year of Publication: January 2020

Summary: Template Matching is a common method for object detection in digital images, involving a pixel-to-pixel comparison between a source image and a template image. This method is computationally intensive, requiring significant processing power. The study explores the performance of two embedded systems, the NVIDIA Jetson Nano and Jetson TX2, in implementing Template Matching to provide an evaluation criterion for selecting one for image processing projects. The experimentation involved six images of different sizes and two variations in template image size. Processing times were measured for both sequential (CPU) and parallel (GPU) implementations. Results showed that parallel implementations, on average, doubled the speed of sequential implementations. Additionally, the Jetson TX2 outperformed the Jetson Nano in execution speed.

2.2 Research Paper 2: Development of new open soft-CNC system

Authors: Yusri Yusof, Kamran Latif

Year of Publication: April 2015

Summary: CNC (Computer Numeric Control) machines have revolutionized the manufacturing industry, being used for operations like milling, drilling, packing, and welding. Despite their widespread use, traditional commercial CNC machines lack flexibility due to their closed structure, which restricts access to internal features. To address this issue, Open Architecture Control (OAC) technology was introduced, with personal computers (PCs) emerging as the best platform for developing open-CNC systems. This paper presents a new method for developing open-CNC systems, utilizing a motion control card, a universal motion control interface, and various functional modules for controlling position, spindle, and tool changer motions. The proposed system was implemented on an old 3-axis CNC milling machine and demonstrated satisfactory performance. This technique contributes to creating a sustainable manufacturing environment by enhancing the flexibility and adaptability of CNC machines.

2.3 Research Paper 3: Webpage controlled surveillance bot using Raspberry Pi

Authors: V.G. Rajendran, S. Jayalalitha, S. Radhakrishnan, S. Arunbhaarat

Year of Publication: November 2020

Summary: The paper discusses the design and implementation of a web-based control system for a mini robot using a Raspberry Pi. The robot is designed to navigate environments where human movement is restricted, transmitting real-time video data back to a manually hosted webpage. The system uses a USB camera for video capture and allows robot control via the webpage. The webpage is hosted using the Raspberry Pi's IP address and uses the Flask micro web framework for communication. The robot's compact design enables wireless data transmission and reception through its built-in Wi-Fi module, and the program can be controlled remotely through an SSH connection.

Chapter 3

Methodology

3.1 Project Design

3.1.1 Block Diagram:

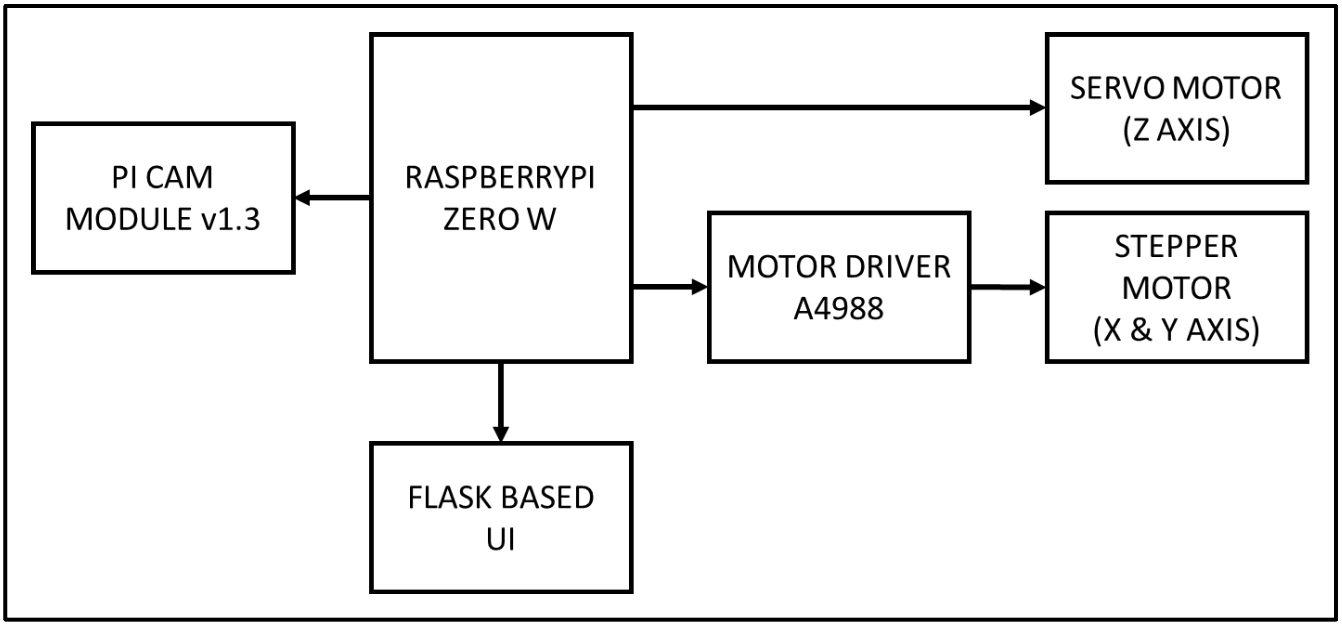

Fig. 3.1: Block diagram of the proposed system

3.2 Method of Analysis:

1. System Architecture and Component Selection:

The PCB F.O.R.G.E. system is built around the Raspberry Pi Zero W, chosen for its compact size, affordability, and sufficient processing power for the tasks involved. The core components include stepper motors from DVD players to control the X and Y axis movements, a 3D printer extruder used as the heating element for soldering, and a feeder mechanism to supply solder wire. The GPIO pins of the Raspberry Pi are used to interface with and control these components, ensuring precise movements and actions.

2. Software Development:

The software component of PCB F.O.R.G.E. is developed using Flask, a lightweight web framework that allows users to interact with the machine through a web-based application. This application facilitates the uploading of PCB images, which can be negative images from PCB design software like Eagle. The backend processes these images using OpenCV, a powerful image processing library. A custom-trained model specifically recognizes solder pads on the PCB, allowing for accurate detection and coordinate determination.

3. Image Processing and Pad Detection:

The uploaded PCB images are processed using OpenCV to identify solder pads. The image processing workflow includes converting images to grayscale, applying thresholding to highlight pads, and using contour detection to identify the pad locations. The custom-trained model, developed using a dataset of solder pad images, enhances the accuracy of detection. The coordinates of these pads are then mapped out and sent to the control module.

4. CNC Control and Soldering:

Once the coordinates of the solder pads are determined, the system converts these coordinates into precise movements for the stepper motors. This conversion is handled by a control algorithm running on the Raspberry Pi, which translates the coordinate data into stepper motor commands via GPIO pins. The 3D printer extruder is heated to the optimal soldering temperature, and the feeder mechanism supplies solder wire to the extruder tip. The machine then moves to each coordinate and performs the soldering process.

5. Calibration and Testing:

The system undergoes rigorous calibration to ensure accuracy in movements and soldering. Calibration involves fine-tuning the stepper motors to move the exact distances required and ensuring the extruder maintains a consistent temperature. Test runs are performed on sample PCBs to validate the accuracy of pad detection, coordinate mapping, and the overall soldering process. Adjustments are made based on test results to refine the performance.

6. Future Enhancements:

Future development plans include integrating PCB milling capabilities, automating the placement of SMD components, and adding PCB masking features. These enhancements will be developed in modular phases, allowing for incremental improvements and testing. The system's modular design ensures that new features can be added with minimal disruption to existing functionalities.

7. User Interface and Documentation:

A user-friendly web interface is developed to ensure ease of use, even for those with limited technical knowledge. Comprehensive documentation, including setup guides, troubleshooting tips, and tutorials, will be provided to support users in effectively utilizing the PCB F.O.R.G.E. system. Regular updates and community feedback will drive continuous improvement and feature expansion.

3.3 Materials and Equipment:

Hardware:

Table 3.1: List of Hardware

Sr. No.	Component	Specifications	Quantity
1.	Raspberry Pi	Zero W	01
2.	Raspberry Pi Camera Board	v1.3	01
3.	Stepper Motor	DVD Player	02
4.	Stepper Motor Driver	A4988	02
5.	Servo Motor	MG90S	01
6.	DC Motor	5V	02
7.	3D Printer Extruder	1.75mm Direct Extruder Full Kit	01
8.	Soldering Wire	1.00 mm	01
9.	Metallic Frame	From DVD Player	N

Software:

Table 3.2: List of Software

Sr. No.	Software	Version
1.	Raspbian Pi OS With Desktop (32 bit)	6.6
2.	Flask	3.0.3
3.	OpenCV	4.9.0

Chapter 4

Project Schedule Plan

Table 4.1: Plan of Action

Activity	Jun 2024	Aug 2024	Oct 2024	Dec 2024	Jan 2024	Mar 2025	April 2025
Project Discussion and Conceptualization							
Study of Literature							
Analysis and preparation of Proposed Scheme							
Prototype Building							
Implementation of Model							
Result Formulation							
Report Write-up, Technical paper, Submission etc.							

Chapter 5

Expected Project Outcomes

5.1 Results:

The PCB F.O.R.G.E. project yielded several significant outcomes, showcasing its potential to revolutionize PCB manufacturing for small-scale producers and startups. Below are the detailed results:

Integration and Functionality:

Raspberry Pi Zero W: The project leveraged the affordability and power of the Raspberry Pi Zero W as the core computing unit, which effectively managed the entire soldering process.

Components: The integration of readily available components, such as stepper motors from DVD players and a 3D printer extruder, proved to be both cost-effective and functional, demonstrating that high-quality results can be achieved with inexpensive materials.

User-Friendly Web Application:

Flask-based Application: The web application developed using Flask provided an easy-to-navigate interface. Users could upload PCB images directly to the application, simplifying the process of setting up the soldering tasks.

Image Processing with OpenCV: Advanced image processing capabilities using OpenCV allowed the system to accurately detect solder pads on the uploaded PCB images. This automation reduced the need for manual intervention and increased precision.

Precision and Automation:

GPIO Pin Control: The CNC machine's precise control over the soldering process was managed through GPIO pins, ensuring accurate and reliable soldering. This level of control minimized errors and improved the overall quality of the PCBs.

Automated Soldering Process: The automation of the soldering process significantly reduced the time and effort required to produce high-quality PCBs, making it an efficient solution for small-scale operations.

Cost Reduction:

Affordable Components: By utilizing low-cost components and the Raspberry Pi Zero W, the project demonstrated a substantial reduction in the costs associated with advanced PCB soldering technology. This makes it an attractive option for startups and hobbyists who need to minimize expenses without sacrificing quality.

Future Enhancements:

PCB Milling: Preliminary work has been done to incorporate PCB milling capabilities, which will further enhance the system's versatility and functionality.

SMD Component Placement: The project plans to add features for Surface-Mount Device (SMD) component placement, which will broaden the range of tasks the machine can perform.

PCB Masking: Future updates will include PCB masking capabilities, offering a more comprehensive solution for PCB manufacturing.

Performance and Reliability:

Testing and Validation: The system was rigorously tested to ensure reliability and precision. The results indicated that PCB F.O.R.G.E. consistently produced high-quality soldering results, comparable to those of more expensive commercial machines.

User Feedback: Initial user feedback has been positive, highlighting the system's ease of use, affordability, and effectiveness.

Empowerment and Innovation:

Accessibility: By democratizing access to advanced soldering technology, PCB F.O.R.G.E. empowers small businesses, startups, and hobbyists to innovate and produce professional-grade PCBs. The project promises to have a significant impact on the PCB manufacturing market by providing a cost-effective alternative to traditional soldering machines, potentially driving further innovation and competition in the industry.

In summary, PCB F.O.R.G.E. has successfully demonstrated that it is possible to create a high-quality, cost-effective CNC soldering machine using affordable components and advanced software. The project's results indicate strong potential for future enhancements and widespread adoption in the PCB manufacturing community.

5.2 Applications:

1. Electronics Manufacturing:

The CNC soldering machine can be used in electronics manufacturing processes to automate the soldering of components onto printed circuit boards (PCBs), increasing efficiency and consistency in production lines.

2. Prototyping and R&D:

Engineers and researchers can utilize the CNC soldering machine for rapid prototyping and research and development (R&D) activities, allowing them to quickly test and iterate on PCB designs without manual soldering.

3. Small-Scale Production:

Startups and small-scale electronics manufacturers can leverage the CNC soldering machine to produce small batches of custom PCBs with reduced labor costs and improved quality control.

4. Educational Purposes:

Educational institutions and training centers can incorporate the CNC soldering machine into their curriculum to teach students about automated manufacturing processes, PCB assembly, and programming.

5. Repair and Maintenance:

Service technicians and hobbyists can use the CNC soldering machine for repairing and reworking PCBs, enabling precise and consistent soldering of components for electronic devices.

Chapter 6

Budget

6.1 Cost Estimates:

Table 6.1: Budget estimation of the project

Sr. No.	Hardware	Quantity	Amount (In ₹)
1.	Raspberry Pi Zero W	01	1500
2.	Raspberry Pi Camera Module 1.3	01	200
3.	Stepper Motor	02	150
4.	Stepper Motor Driver	02	100
5.	Servo Motor	01	200
6.	DC Motor	02	150
7.	3D Printer Extruder	01	600
8.	Metallic Frame	N	200
TOTAL			3500

References

1. Y. Yusof and K. Latif, "Development of new open soft-CNC system," 2015 International Conference on Computer, Communications, and Control Technology (I4CT), Kuching, Malaysia, 2015, pp. 82-86, doi: 10.1109/I4CT.2015.7219542.

2. A. Basulto-Lantsova, J. A. Padilla-Medina, F. J. Perez-Pinal and A. I. Barranco-Gutierrez, "Performance comparative of OpenCV Template Matching method on Jetson TX2 and Jetson Nano developer kits," 2020 10th Annual Computing and Communication Workshop and Conference (CCWC), Las Vegas, NV, USA, 2020, pp. 0812-0816, doi: 10.1109/CCWC47524.2020.9031166.

3. V. G. Rajendran, S. Jayalalitha, S. Radhakrishnan and S. Arunbhaarat, "Webpage controlled surveillance bot using Raspberry Pi," 2020 Fourth International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC), Palladam, India, 2020, pp. 549-553, doi: 10.1109/I-SMAC49090.2020.9243320.

Undertaking by Students

I have adhered to all departmental guidelines and instructions in preparing and submitting this project proposal. Under the guidance of ***Mr. Yogesh Pandit,*** I have incorporated all feedback and suggestions received during the drafting process. This proposal complies with all ethical standards, with all sources of information properly cited. I take full responsibility for the content of this proposal and acknowledge that any errors or omissions are my own, committing to corrective action if necessary. I am dedicated to executing the proposed project as outlined and will strive to achieve its objectives to the best of my ability.

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Project Guide Comments

Signature of Supervisor (with date)
(Name of Supervisor)