ECE 445

SENIOR DESIGN LABORATORY

PROJECT PROPOSAL

Thermo-Camera based energy consumption monitoring system

Team #445

YUTAO ZHU
(yutaoz2@illinois.edu)
ZHEYANG JIA
(zheyang5@illinois.edu)
BOYAN LI
(boyanl3@illinois.edu)
LINGJIE ZHANG
(lingjie3@illinois.edu)

Sponsor: Pavel Loskot

March 6, 2023

Contents

1 Introduction

1.1 Problem

In the field of chip and circuit research, power consumption is an important indicator. Thermal imaging is a method to analyze power consumption.

For example, thermal analysis can assist designers to determine the electrical performance and reliability of components on PCB and help determine whether components or PCB will fail or burn out due to overheating.

A circuit board contains many components. We want to simulate the power consumption related to temperature.

At present, due to the different thermal properties of each circuit element, the current thermal imaging equipment is not necessarily flexible and accurate for analyzing circuit power consumption.

Our goal is to design a convenient, dedicated, and accurate thermal imager to assist in the research of chips and circuits.

1.2 Solution

To solve the problems mentioned above, we plan to design a thermo-camera and corresponding software to analyze the temperature distribution over a circuit board such as the motherboard of a computer.

The product has 4 parts: a thermo-camera, a cuboid frame, a control system, and an image analyze system.

More specifically, the thermo-camera should be able to record the thermal distribution of the circuit in real time. The mechanical structure of the whole system is very straightforward. Just a cuboid frame with a board and a mechanical lever to control the thermo-camera. In addition, a control system for the camera is required. The hardware of the control system is a self-designed circuit together with an electro machine. The software of the control system is a self-designed image processing software, which can calculate the power consumption after we take screenshots of the required components. Then we can use data lines such as Type-C line to connect the hardware and the software. According to what circuit components we want to analyze, the camera can move to the corresponding location. Knowing the temperatures over the board, we will estimate how much energy is consumed at different parts of the board. Furthermore, we can try to view the temperature distribution from outside of the laptop, and use the image of motherboard when the laptop has been opened. To achieve the estimation, we will refer to the data sheet of electronic components and base the formula between temperature and power.

In conclusion, through such a system, we can obtain real-time thermal images to analyze the power consumption of the circuit.

1.3 Visual Aid

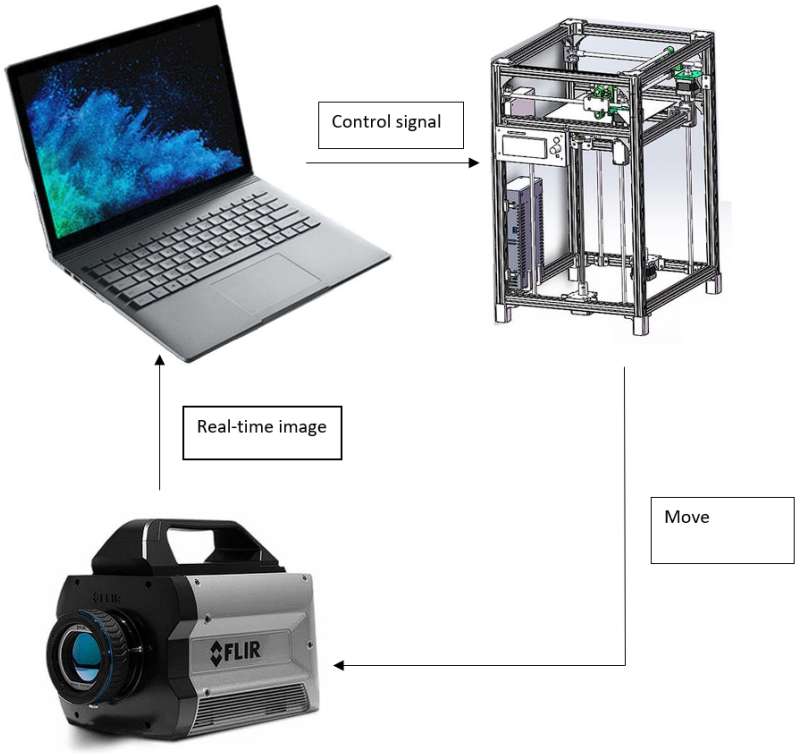

Figure 1: visual aid

1.4 High-level Requirements List

1. Accuracy: Thermo-cameras should be accurate and reliable, with a minimum margin of error, to ensure that the results are useful and actionable.

2. Sensitivity: Thermo-cameras should be sensitive enough to detect small temperature differences to help identify potential health risks.

3. Resolution: Thermo-cameras should have a high resolution to capture detailed images of individuals and objects, enabling better analysis and decision-making.

4. Speed: Thermo-cameras should be able to capture and process images quickly to enable real-time monitoring and response.

5. User-Friendliness: Thermo-cameras should be easy to use and operate, with simple controls and clear instructions, to enable efficient and effective monitoring.

6. Mobility: Thermo-cameras should be easily moved vertically and horizontally to locate specific electronic components.

7. Energy estimation: Computer should calculate the energy consumption based on the temperature image.

2 Design

2.1 Block Diagram

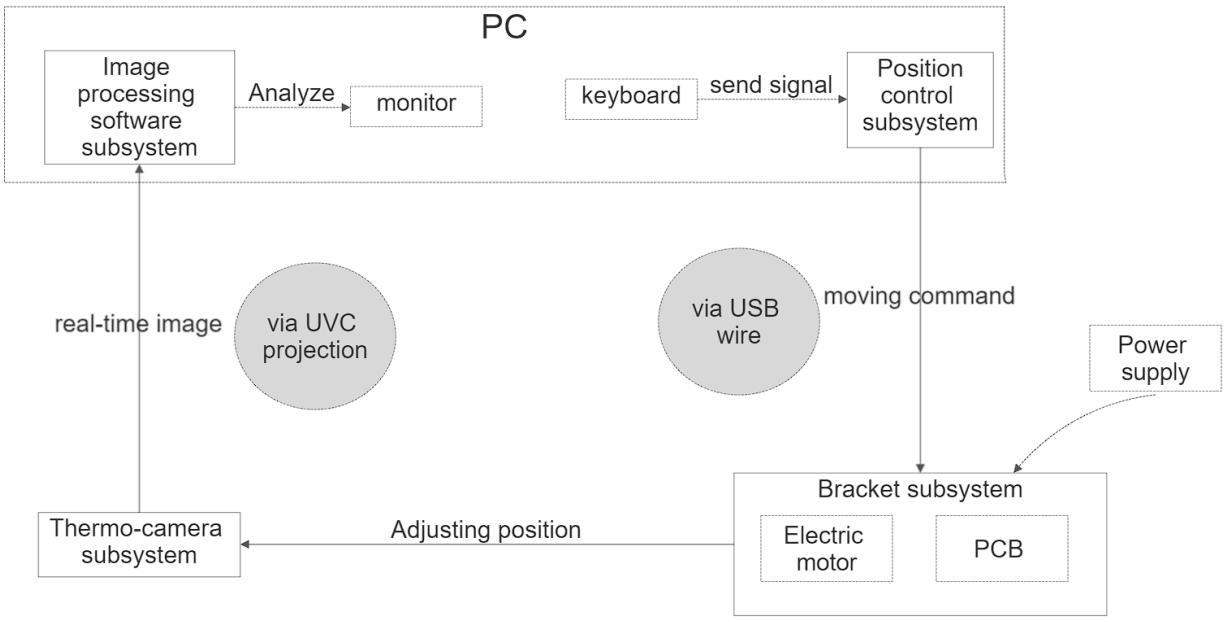

Figure 2: Block Diagram

2.2 Subsystem Overview

The whole product has four main subsystems as shown on the block diagram above.

1. A thermo-camera that sends images to a computer in real-time.

2. A bracket capable of three-dimensional movement for placing the thermo-camera.

3. Image processing software to inform physics-based models of energy consumption in electrical circuits.

4. A control system for the mobile camera, which is very useful for adjusting its position and zooming to obtain the correct real-time image.

2.3 Subsystem Requirement

2.3.1 thermo-camera subsystem

The thermo-camera needs to be able to transmit images in real time and have a macro lens to ensure that the components of the circuit board can be seen clearly. In addition, the temperature range of temperature measurement should at least include the working

temperature of the circuit board, such as 0 °C to 100 °C. Some common thermo-camera is at - 10 °C to 400 °C, which is sufficient for use.

2.3.2 Bracket subsystem

The Bracket subsystem is composed of upper and lower bases. After receiving the movement command from the Position control subsystem, the upper base can complete the movement in X and Z directions, and the lower base can complete the movement in Y direction, thus forming the three-dimensional movement of the camera relative to the chip.

2.3.3 Image processing software subsystem

Thermo-image analysis is the process of analyzing the temperature distribution of an object or scene captured by a thermal camera. It mainly consists of 3 steps. Image preprocessing: This step involves filtering, enhancing, and correcting the raw thermal image to improve its quality and accuracy. Feature extraction: This step involves identifying and extracting relevant features from the thermal image, such as temperature gradients, regions of interest, and thermal signatures. Feature extraction can be done using computer algorithms. Data analysis: This step involves analyzing the extracted features to draw conclusions about the object or scene being analyzed. Data analysis may involve statistical analysis, pattern recognition, or machine learning techniques. We then use those data to compute the formula in energy consumption. For example, an energy consumption formula is as follows.

$$T_j = T_a + (\theta_{JA} \times P_D)$$

where T_j is the estimate of chip junction temperature, T_a is the package ambient temperature, θ_{JA} is the thermal resistance of P-N junction to environment (given by component data sheet), and P_D is the total on-chip power consumption.

2.3.4 Position control subsystem

The position control system is composed of a position control program and the mechanical camera bracket. It can transmit the information of three-dimensional position movement to the bracket through the computer, and then complete the corresponding position movement by the mechanical bracket, thus changing the shooting position of the thermal camera.

2.4 Tolerance Analysis

1. The thermo-camera takes Infrared images of the circuit. It can move as desired through the control system. But the control process may produce delay because of the control signal transmission. And then the thermal images will be transmitted to the computer which may also result in some delay. However, a certain amount of delay is tolerable,

since we will take a screenshot of the real time image to analyze the power consumption, which does not require high precision.

2. Because we only take pictures on circuit board, the reachable location of the two-axis base of this product does not require long range. The acceptable result is that the workspace of the camera meets the corner of circuit board.

3. For image processing software, we need to determine the tolerance limits for component segmentation. The software can tolerate the edges of component are not clear while still achieving the desired performance metrics because we only care about the temperature.

4. For the control system, we must ensure that it is stable so that the thermo-camera can remain stationary to capture stable images. This is a crucial aspect. Fortunately, our control system is simple enough to control its displacement, and it is controlled by our own computer input, so there will be no obvious back and forth vibration.

3 Ethics and Safety

3.1 Ethics

3.1.1 Ethics of our product

Our group guarantees that the monitoring system will not use dangerous systems that can harm people. Thermo-Camera technology can capture sensitive information of individuals, including their temperature and personal characteristics. Developers and users of this technology must respect personal privacy and ensure that the collected data is properly and safely used.

3.1.2 Ethics of research and development

Security: Thermo-Camera technology must be used safely to prevent unauthorized access to data or technology itself. Developers and users of technology must take appropriate measures to protect security and integrity.

Statement of non-plagiarism: Our team declares that this product will not use any existing codes and products and will not duplicate any existing modeling solutions.

3.2 Safety

(1) Our team guarantees that we will have more than two people in the laboratory.

(2) Our team guarantees that we will complete a mandatory online safety training in order to be allowed to work in the lab.

(3) Our team guarantees that we will complete additional safety training, r Safe Current Limits, and read, understand, and follow guidelines for safe battery usage before we are working with those things with electricity safety risks.

(4) Our team guarantees that we will use safe mechanical structure and pay more attention to mechanical structure safety.