

Design Issues Paper
Hot Strip Mill Centerline Tracking
ECE 480 – Design Team 4
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Introduction

The design analyzed in this document involves a Logitech C920 camera which will export live video feed to a BeagleBone Black microcomputer. The camera will monitor the centerlines of steel strips running in steel companies' hot strip mills by implementing edge detection image processing through an OpenCV software solution. In the process of designing hot strip mill centerline tracking, Team 4 has encountered numerous challenges in addition to technical specifications required by the sponsor. These challenges are product lifecycle management, product standards, and intellectual property. It is important to address these issues to find rooms for improvement.

Product Lifecycle Management

Currently, the product has a limited customer base. It applies specifically to industries that use hot strip or cold strip milling processes; however it is possible such a product could be adapted to be used for other visual data gathering systems as well. Equitable use for other markets could be capitalized by offering various software packages for separate applications. Other systems that could benefit from such a system would be other manufacturing industries. In manufacturing, sensors and vision systems are used to check labels, ensure quality of products, and detect defects. With some software changes, this product could accomplish such goals and greatly expand the marketable population of this device. Beyond manufacturing uses, this product could also be adapted for security. The camera system could be used as a visual confirmation system for doors and windows and could potentially be used for motion detection and facial recognition.

Unless this product is expanded to have more applications than in the steel strip mills, it has a small customer base. Therefore, large scale mass production line is not necessary for this product. Assembly is not overly complicated. It is as simple as mounting the camera in place and connecting the USB and micro HDMI cords into the BeagleBone microcomputer. The BeagleBone included in the finished product would be shipped with the centerline detection software pre-installed. However, the user will have the capability to write or upload new software to realize other uses for the camera system. This can be done by connecting the BeagleBone Black microcomputer to another computer via USB and using OpenCV to load the program. The future of this product includes dozens of software structures to complement the use of the camera system in a variety of ways.

The product is expected to last for a couple decades or longer. If any major component such as the BeagleBone microcomputer, the camera, or any of the wiring, is to fail sooner than expected it would not be difficult to replace that component. The software systems should work as they did before once any equipment is replaced. It would require no changes or very little changes to the software to update the camera to a newer model. If

new features are to be used with new camera technologies this might require more extensive software updates. The company could provide technical support and software package updates as needed in the future. If the BeagleBone microcomputer needs to be replaced in the future with a more powerful system, the new controller would simply need to be compatible with OpenCV code for the system to remain functional. A new microcontroller would also need to use USB inputs and micro HDMI to prevent unnecessary changes in connection types between hardware. It is expected that USB and micro HDMI will still be widely used throughout the PLM of the product.

One major risk that threatens to drastically shorten the lifespan on the product is if it sustains physical damage from the steel strip mill operations. When the steel strip mill has a wreck, the employees need to quickly clear the line of the steel that has run off of the line. Heavy duty cranes are used to accomplish this. With lack of care, the cranes could knock the cameras out of place or destroy them. A good way to prevent this product lifecycle issue is to reduce the chance of damage from the normal operations within the steel mill. By mounting the camera in an ideal location, the chances of destruction or focal point being moved are minimized. The product would be better if a thin and compact camera is used. Mounting the camera flush with the steel mill would be the best way to keep it from being damaged and prevent the need for a protective housing. This solution would be different based on the designs of the rollers that various customers have. Installation would have to be assessed on a case by case analysis. Offering multiple camera choices might be suitable for different roller designs. Another way to prevent the camera from being destroyed or moved would be to reinforce the design. A heavy duty safety box to house the camera in would keep it safe from being damaged by the cranes or steel pieces being removed from the mill. If mounting position and camera housing fail, warranty support could be implemented to ensure quality.

The equipment used in the steelmaking process is reliable and much of the technology has been in place for many years without replacement. The rate at which equipment is retired from use in the milling process is typically multiple decades. The camera system must be able to survive operation for a similar amount of time in order to be considered a

feasible, relevant option for monitoring steel strip centerlines.

Product Standards

Another important design issue is to maintain a high standard of products. The standard for the design addresses requirements that must be met to ensure the highest quality of product can be delivered. These requirements include ease of use, sampling rate, and video resolution as well as impact and heat resistance.

First, the data that will be output by the camera system must be easy to read and understand in order for the operators to be able to make adjustments to the mill quickly and accurately. A constant stream of numbers is not adequate for an operator, and a user-friendly design is a necessity. The operator will not need to be constantly monitoring the program data used by the camera system. Rather, the live feed of the steel strip's shape will be displayed onscreen in the mill control room. In addition to displaying a live feed, an alarm system will be used to alert operators when the steel centerline error crosses a certain threshold. When this happens, the distance will be displayed so that proper adjustments can be made. Making an operator search for errors is not up to today's standards and, by implementing an automated alarm system; the live video feed will not require constant operator surveillance. Many other tasks must also be completed during a normal work day and our product must be designed to only require operator attention when adjustments must be made.

Second, the sampling rate of the camera system must be quick enough as to detect the entire strip of steel. Steel strips run through finishing mills in excess of fifty miles per hour (nearly 75 feet per second). Given the short distance between the finishing stands, approximately six feet, the camera system will need to sample at least twelve times per second (12 Hertz) in order to capture the entire strip without leaving unmonitored gaps. The Logitech C920 camera is made to capture images at a rate of 30 frames per second. This means that the camera is fast enough to show the entire strip. The concern for sampling rate in this design pertains to the BeagleBone Black microcomputer. The clock speed of the microcomputer is one Gigahertz, which is significant for the design.

However, image processing software takes time to process information completely and, if not programmed efficiently, could output information too slowly for the entire strip to be displayed uninterrupted. The design may require the use of a separate Digital Signal Processing (DSP) board that can facilitate image processing. This would allow the BeagleBone Black to focus on receiving and displaying the video feed while the DSP processes the images and employs the designed edge detection software.

Third, the video resolution of the camera system is crucial when tracking the centerline of steel in the hot mill. The design's purpose is to detect variations in the location of the strip and alert operators when the strip is curved. The curve of the steel strip could potentially go unnoticed if the resolution of the camera system is too low. The American Institute of Steel Construction's Code of Standard Practice for Steel Buildings and Bridges states that 1/8 inch of curvature per every ten feet of steel length is acceptable. As the video resolution increases, the images will be more defined and smaller discrepancies in centerline will be detected. However, increasing the resolution of the video feed also increases the amount of time the image processing software takes to detect the edges of the steel strip. If the resolution is too high, the design may not be able to sample images of the strip at the required frequency of twelve Hertz mentioned above. The recording resolution of the Logitech C920 camera is 1080p at its highest and includes several selectable lower resolutions. Finding the highest possible video resolution (while maintaining an acceptable sampling frequency) is pivotal to the success of the design and must be determined through testing of the system.

Also, the camera system must be durable enough to survive long term operation in a plant environment. Impact resistance (mentioned in Product Lifecycle Management section) is required for the success of the design in that the camera will not be able to be repaired, replaced, or adjusted without first halting the production line. Production will not stop if there is a malfunction of the camera and the operators will simply run the mill without the camera system. Minimizing required maintenance will ensure that the operators always have the camera system to aid them in the monitoring of the steel strip and allow accurate

adjustments to be made. Making sure that the camera is not damaged by wreck-removing cranes is required to make the design reasonable.

Finally, proximity to the hot steel strips requires that the camera be somewhat resistant to heat. The Logitech C920 camera is largely made up of plastic and has a risk of melting. In addition to this, the glass lens of the camera could crack under extreme heat. While it is believed that the camera could survive given the distance to the strip (twelve to fifteen feet), heat testing will need to be done to discover the heat limits of the camera. It is possible that the camera will require a cooling system and heat shielding to remain operable. The shielding would consist of an aluminum (quicker heat dissipation than other metals) enclosure that the camera would be mounted in with a tempered glass front for visibility. A heat sink would be mounted on the back of the enclosure, shielded from the radiated heat of the strip. Fans could be used to dissipate heat from the sink at a higher rate.

While these standards are all critical to the success of the design and must be upheld to ensure functionality, other standards may be discovered throughout the design process that will better the secondary functions of the camera system, such as data storage and battery backups.

Intellectual Property (IP)

There is one aspect engineers tend to overlook once they have a finished product and are ready to disclose it to the public. That is, engineers do not seek to protect their intellectual property (IP). There are different types of intellectual property: patents, trademarks, registered designs, plant breeder's rights, copyright, and circuit layout design rights. The profession of engineering and its relationship to intellectual property cannot be disregarded; every schematic, diagram, or a piece of code has intellectual property rights. In other words, if the engineers were to lose legal rights to their hard work, then their work loses all its values. Consequently, software codes that are unique to the design which interface between the BeagleBone Black microcomputer and the camera to track the centerline of steel strip must be protected. Not all codes are copyrightable. For instance, general fragments of code or an idea to execute certain program faster or to increase efficiency of the program are excluded. It may be difficult to identify which fragments of code should be under copyright protection, yet a crucial step prior to releasing the product to the public. A protection of intellectual property will improve competitiveness in domestic and international marketplace and increase profitability of engineering firms. Therefore, the most effective method to protect the software codes of the design will be to seek protection under copyright laws, ensuring the team's success.

Much of the design's code templates will be taken from Derek Molloy, professor of Electronic Engineering at Dublin City University. Doctor Molloy completed a series of programs compatible with the BeagleBone Black to aid with image processing. The success of this design will be largely credited to his previous research and design. Along with protecting the team's own intellectual property, measures must be taken to protect the property of Dr. Molloy. If the design is taken and used by another customer, all of the software will include the name Derek Molloy, alongside team 4, so that proper credit may be given. From a coding standpoint, intellectual property is easy to label and recognize in the comment sections, eliminating much of the need to seek further protection.

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