Design Concept Proposal

Pretinning Process

Design Proposal Document

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2. Project Description:

Kennametal is an American supplier of tooling and industrial materials that has a plant in Victoria, British Columbia, Canada that manufactures saw tips and prepares them for attachment to a handle through a process known as pre-tinning. In this process a dab of flux is applied to the surface of a carbide saw tip and then two silver wires are carefully placed in the flux, oriented along the major diagonal of the saw tip. Once this process is complete, tinning can occur, in which the wires melt onto the saw tip in an oven.

The process of pre-tinning saw tips is laborious and meticulous because of the size of the saw tips and wires that are handled. This work also can have negative health effects as the repetitive motion can cause strain injuries. Our objective is to design and build a mechatronic system capable of pre-tinning saw tips, removing the need for this task to be accomplished manually. In doing so the potential for worker injury will be greatly reduced, the small wires can be placed with greater accuracy, and there is the potential that the machine may be able to perform the task significantly faster than a worker.

3. Design Requirements

3.1 Explicit Design Requirements:

- 20 parts must be processed in <=5 minutes
- Flux dab must be centered on the part-top centroid and cover ¼ to ⅓ of the part-top's surface area
- Must be able to handle at least two different part sizes
- Machine fits within 2'x2'x2'
- The two wires must be placed side by side in the flux dab such that: a) their orientation is along the major diagonal to w/in 5°; b) there is no space between them laterally; c) their longitudinal misalignment is <=10%
- The parts will be deposited on a flat output tray in 4 rows of 5 parts each, with the part-tops facing up. Part edges should be at least ½" away from the tray edge, and there should be at least ¼" spacing between the edges of adjacent parts.
- No more than 5% of wires detached or wrongly positioned

3.2 Implied Design Requirements:

- Machine is durable enough such that it can endure a harsh factory environment
- The machine will have a robust design to accommodate any changes or additional requirements of the pre-tinning process
- Design is simple enough such that the basics of the machine will be understood by an assembly worker

- Design will allow easy access for a worker to fix the machine in the event of failure
- Designed such that if a local failure occurs within the machine the remaining functions of the machine will not be compromised

4. Functional Architecture

Information containing part location and orientation must be continually determined and transmitted continually. A part leaves the separator and arrives at the camera in one of four possible orientations. Vision processing determine both when the part has arrived and it's orientation. When the part arrives the part separator must be told to stop while the part is being handled. Also, the part placer must receive part orientation from vision processing in order to move the part correctly. The part placer must command the tray positioner into the proper position since the part placer only has freedom to move in the x axis and the tray can only move in the y axis. Once the part is in place the part placer notifies the flux and wire dispenser that the part is available. The flux and wire dispenser also can only move along the x axis so it too must command the tray positioner

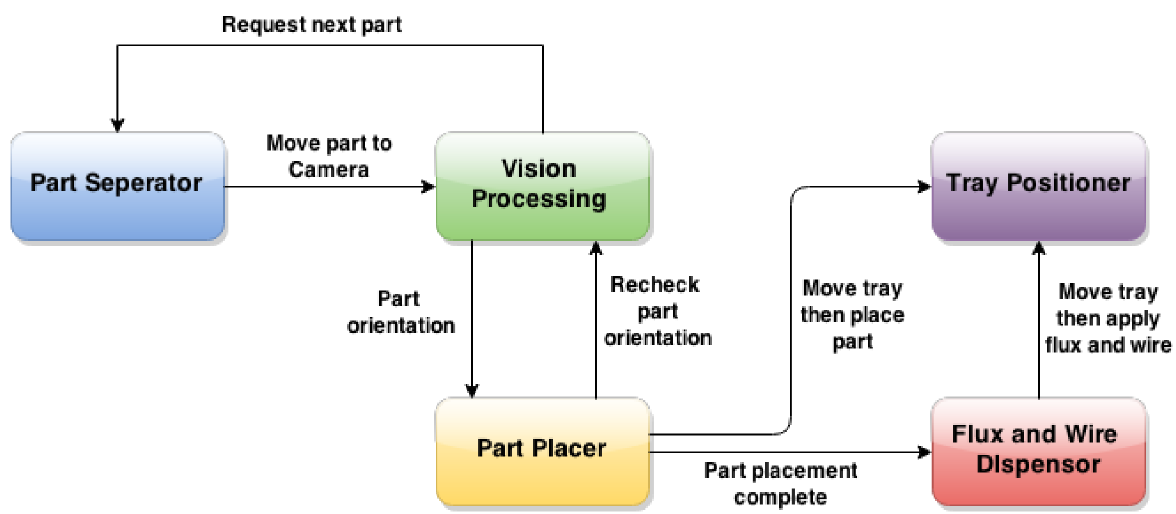

Figure 1: Visual of Functional Architecture

5. Design Trade Studies

5.1 Electromagnet over Mechanical Gripper:

Our parts in use for this project has the capability of being magnetized. So we are presented with the choice of using magnets to pick up parts or to use a mechanical gripper to pick up the parts instead. Mechanical grippers takes more time to use since it will need to provide torque in order to pick up the parts, which provide a tradeoff against speed. Thus with our speed design requirement, we resorted to use the magnetism plan, which makes the orientator arm use electromagnetism to pick up the parts instead. The tray, where the parts go, is magnetized. So, we can't simply apply any amount of magnetism to pick up the parts. So, we have to deal with the complexity of being able to figure out how much magnetic strength will be needed in order for the arm to be able to pick up the part without being stuck to the surface or picking the tray.

5.2 Two rails over one rail

Two choices which we have considered for where we orientate the parts and apply the flux was to use one rail for both of them or two rails where one rail has the orientator and the other apply the flux. In the one rail system, we risk the process to be lagged down to the slowest arm of the arms if we don't use multithreading or collisions if we use multithreading. Thus with the fact that multithreading speeds up the process, we considered to have the two rail plan, which addresses that problem, in order to minimize the time of preparing the part to reach our 15 second for each part requirement, and to enable full use of parallelism as a speed boost.

5.3 Tray Move in y axis, Arms move in x axis

The initial design for the part placer system was to have a single arm with three axis of movement. The arm would be moved into the correct x and y coordinates then the arm would be capable of extending and retracting to pick up and place parts. For this approach the arm would have to be mounted on a rail in the x direction that would carry a second rail in the y direction. The alternative solution which will be implemented is instead to have the part placer only move in the x axis and to have a second system that would move the tray in the y axis. Together the part placer and tray positioner would have the same number of degrees of freedom as the initial design of the part placer. However, there are several advantages of this setup. To begin with, the weight of the arm is significantly reduced since now there is no need to carry additional rails and motors for movement in the y axis. Additionally, if the arm would be positioned at y_{min} or y_{max} a large torque could cause the rail to twist (see figure 2).

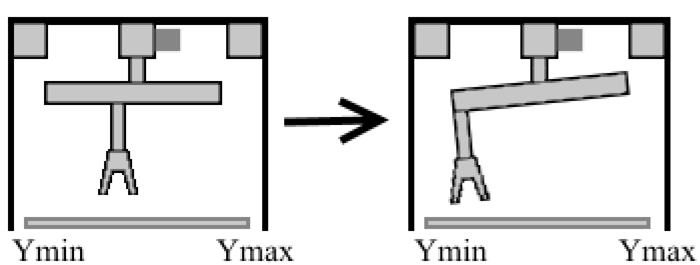

Figure 2: X-Y axis break down when positioned close to extremities

5.4 Why use a Camera

One of the most challenging design decisions was deciding how to reorient parts after they left the hopper. When a part leaves the hopper it could be a combination of forwards, backwards, rightsideup, or upside down. Using a mechanical system to reorient the parts so that they are forward and rightside up is possible but there are many difficulties. Such a system would have to give the parts four slots that they could enter, then reorient the parts depending on which slot they entered. The slots would have to be manufactured with precisely since the parts are small and the orientations do not differ dramatically. Also, at least four motors and tracks would be required to move the parts and sensors would be needed to identify which tracks are in use as well as monitor where all the tracks will ultimately converge. Much of this complexity can be reduced by instead using a camera to look at each part to determine orientation. Doing so moves complexity away from the physical system and places it in software. With this solution the reorientation of the parts can be done using the part placer system once the orientation is determined by the camera.

5.5 Flux application through a mechanical actuator over pneumatics

Although the flux dispenser provided by Kennametal appears to utilize pneumatics to extrude flux, we intend explore the use of a linear actuator to push the flux. In designing an autonomous mechanical system to pre-tin the saw tips we want to ensure that the same amount of flux is dispensed onto every saw tip. By using a stepper motor to control the positioning of a linear actuator, we will be able to achieve precise and easily repeatable flux dispensing. Moving away from pneumatics also removes some complexity from our system as we do not need to be concerned with having an air tank or any sort of air compressor attached to our system. One drawback of using a mechanical actuator to dispense the flux is the need for a slight redesign of the flux container provided by Kennametal. Ultimately we will have to decide whether the provided container can be modified so that our actuator can apply force to push the flux out or if it will be more cost and time effective to introduce a new container that it better suited for the task.

5.6 Cutting wire ourselves instead of using pre-cut wire

When presented with the task of pre-tinning the saw tips, we were given the option to be provided either pre-cut pieces of wire or with a spool of the wire which we would have to cut ourselves. Although choosing the spool option means that we have to measure and cut each piece of wire that we need, we decided that this approach would be easier than its alternative. Being provided pre-cut wires would mean that our system would need to be capable of isolating a single wire at a time and positioning it correctly on the dab of flux. Both of these tasks would be challenging to complete, especially considering the size of the wire. By opting to work with the spool of wire, we have complete control of where the wire is at all times and we can position the wire correctly before cutting it, removing any complication that may arise from handling such small pieces.

5.7 Conveyor belt over gates

One of the downsides of having the parts drop through a specified hole size as a sorting method was the issue of the parts falling right after another before the gate had a chance to close. This was very problematic because our design would not be able to determine the orientation of the part through computer vision (the next step of our process) if there was more than one part being looked at. We considered trying to separate the parts by using two gates but we were still not convinced that this method would be able to separate two parts falling through the hole closely together. In order to overcome this problem we decided to use a conveyor built. Upon falling through the sorting hole the parts will be dropped onto a conveyor belt. The conveyor belt will displace the parts horizontally and once one part falls over the edge of the conveyor belt, the conveyor belt will momentarily stop as the computer vision process deals with the single part. Through this method, permitting unforeseen errors, multiple parts will not fall into the computer vision process of our design at the same time.

5.8 Hopper Agitation Methods

In order for all the parts to fall through the sorting hole we will need to agitate the hopper so that the parts continuously re-orientate themselves until they are are able to fit through the sorting hole. Initially we thought to simply vibrate the hopper. But we felt that simply vibrating the hopper would not be able to reposition the parts perpendicular to the desired orientation enough so that they would be able to fall through the sorting hole. Our idea of the best agitation method would be to first agitate the hopper vertically so that we could significantly re-orientate most of the part, stop, and then agitate the hopper horizontally so that we could create minor changes in the orientation of the parts that will help the parts close to the desired orientation fall through the sorting hole. We plan on using a sinusoidal to agitate the hopper vertically and a motor connected to a rack and pinion to agitate the hopper horizontally.

6. Cyberphysical Architecture

The primary controller for the pretinning machine is the Arduino Microprocessor which responsible for interpreting all feedback from sensors and sending all commands to motors and other physical devices. The Raspberry Pi Microcomputer is dedicated entirely to image processing for the camera. The Raspberry Pi sends information about part location and orientation which is derived from image processing back to the Arduino so that correct movements can be made.

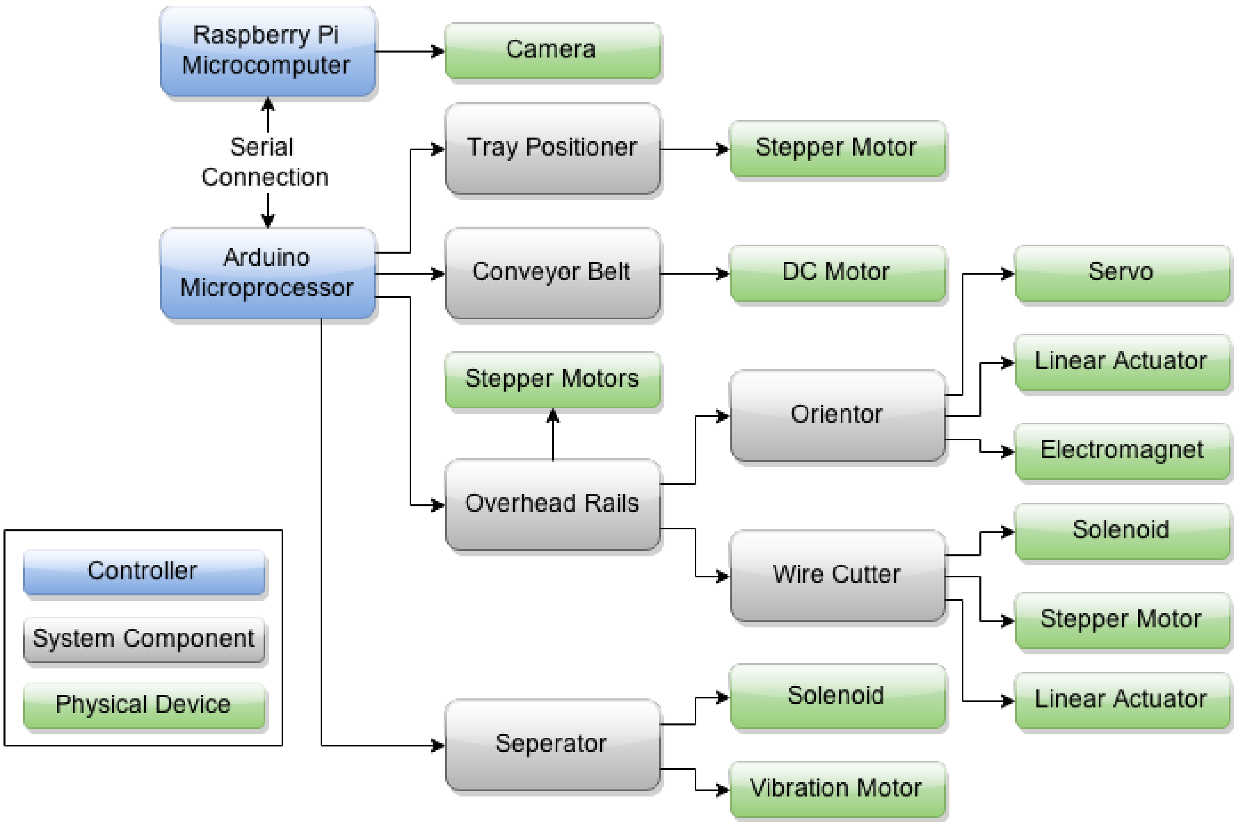

Figure 3: Visual of Cyberphysical Architecture

7. System Description/depiction

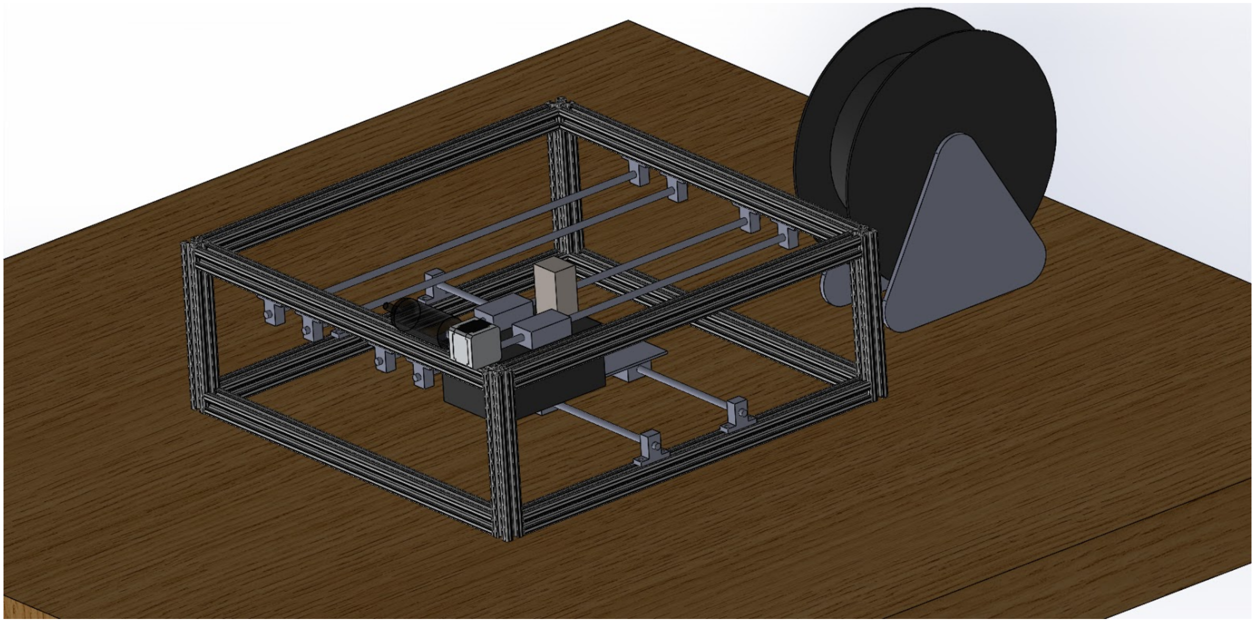

Figure 4: CAD Model of our system

7.1 Part Separator

The Part Separator is responsible for isolating individual parts from the set of 20 poured into the hopper. There is a sorting hole at the bottom of the hopper where individual parts will fall through. The hole is shaped such that parts will fall through in one of four orientations. In order for the parts to align correctly we will apply continuous agitation to the hopper. We plan on applying a vertical agitation to the hopper using a sinusoidal. We also plan on applying a horizontal agitation using a motor-powered rack and pinion. Once parts fall through the hole they will be dropped onto a conveyor belt. The conveyor belt will be about the width of the parts that fall through the hole and the conveyor belt will have walls along the sides so that the parts will not deviate from the orientation in the stage before. The hopper will continue to be agitated as the rest of the machine functions and enough room will be allocated as parts fall through the sorting hole to be put into a queue for the next process of the design. The parts move along the conveyor belt and once an individual part falls off the conveyor belt, the conveyor belt will momentarily stop as the part orientation stage deals with the part that just fell off the conveyor belt. Once the vision processing stage deals with the individual part, the conveyor belt will run again until the next part falls over.

7.2 Vision Processing:

The vision processing system determines the orientation of a part after it has left the part separator system and relay this information to the part placer system so that the part can be reoriented if necessary then placed. The first step in this process is to command the conveyor belt to move until a part has arrived in front of the camera. Short burst of movement are sent to the conveyor belt until a part is detected. The conveyor belt then remains completely stopped until the handling of this part is complete.

The camera then creates an image from the part (see figure 5: Orientation A). The image is compared to a template image stored in memory. There are four different templates that will be applied one at a time to determine which of the four orientations the part is in. A processed image is created by the combination of the image from the camera and a template image using color burn. The amount of black in the processed error represents the error (see figure 5: Processed Image). Summing the RGB values of all the pixels in the processed image will indicate the total amount of white and black pixels and thus give an idea of the amount of error between the camera image and the template Image.

Once the error is calculated, a template is shifted slightly in four directions: dx, -dx, dy, and -dy. Then the error is recomputed for each case. If the resultant processed image has a smaller error the template is moved by that amount. The shifting continues until the error can no longer be reduced. Once a minimum error is found the next template is applied and the process is repeated until there is a minimum error for each of the four templates. Whichever template has the lowest error indicates the orientation that the part is in.

Due to the large amount of computation needed to complete the vision processing quickly a Raspberry Pi microcomputer will be used solely for this system. The Raspberry Pi will communication with the Arduino via a serial connection. The Raspberry Pi has the added benefit of easily communicating with the Playstation Eye camera that will be capturing the images of the parts.

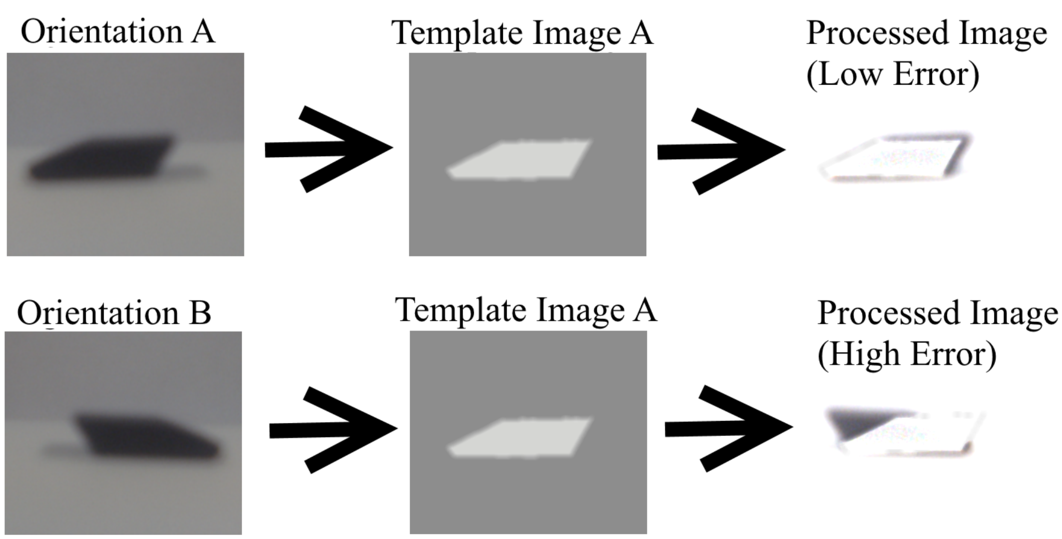

Figure 5: Example of image processing applied to differently oriented parts

7.3 Part Orientator and Placer:

This subsystem is responsible for correctly orienting the parts and placing the parts into the tray. This subsystem only moves in the X direction and picks up the parts by inducing electromagnetism, but must deal with most of the complexities in this project. One such complexity is orientating the parts itself given the information given from the camera. If the part is not upside down, then the orientator can quickly fix the part by picking it up and rotating 180 degrees. If the part is upside down, the subsystem will attempt to flip the part over by grabbing it and inserting it into a horizontal U shaped conveyor belt so the part comes right side up. In addition, this system strongly relies on the use of software accuracy and programming to decide upon which of these actions should it take. Another complexity it introduces, as shown before, is the tuning of its electromagnetic strength in order to prevent it from being stuck to the surface or picking up the tray. This subsystem is an arm attached to a railing that is operated with a servo for rotation, linear actuator of X position movement, and an electromagnetic material for placing and picking.

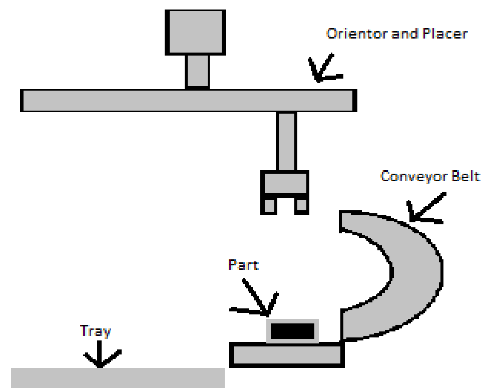

Figure 6: Crude version of Part Orientator and Placer subsystem

7.4 Tray Positioner

The tray positioning system works in conjuncture with the part placer and the flux and wire dispenser to allow for movement of parts in the x and y axis. The tray positioning system is solely responsible for all movement in the y axis where the part placer and flux and wire dispenser are responsible for all movement in the x axis. Every time a part needs to be moved or accessed first the tray will move to the correct y position before any other system moves to get to the correct x position.

The tray is placed on two sliding rails with rubber mounts to prevent the tray from sliding while moving. The sliding rails are driven by a stepper motor that is geared with a rack and pinion to allow for linear movement. The gearing will support a slow, high torque motion which is important since any large accelerations would slide the parts on the tray. Also, to ensure that part do not slide the motor will use a ramp acceleration and deceleration profile. A slide potentiometer will be connected to the rail so that the microcontroller can receive feedback on the current position of the rail.

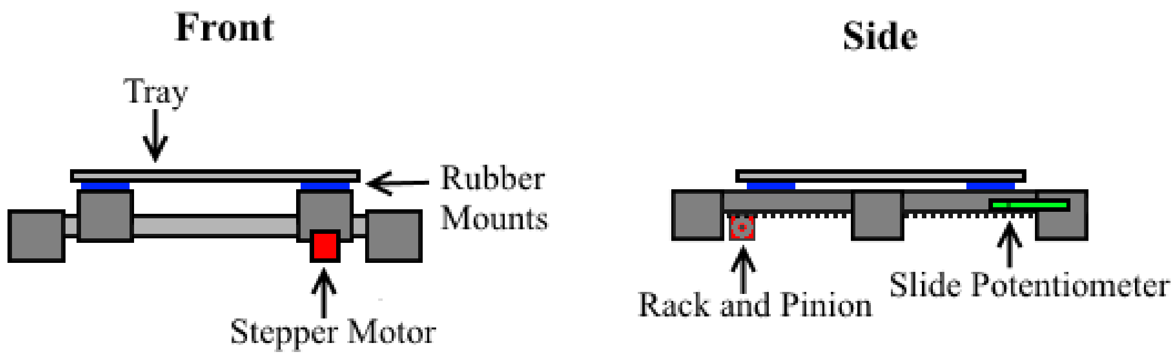

Figure 7: Front-Side layout of the tray mount.

7.5 Flux and wire dispenser

The purpose of this subsystem is to apply a dab of flux and two pieces of wire to the surface of each saw tip. The subsystem is mounted on a linear bearing platform, allowing it to move in the x direction so that it may reach each saw tip after they have been laid down. A precise amount of flux is dispensed by a linear actuator pushing on the rear of the flux container, pushing the flux through a plastic tube and out of an applicator tip that will be positioned directly above the surface of each saw tip. This linear actuator will be powered by a stepper motor with a threaded rod attached to its shaft, allowing for complete control of how far the actuator moves while also providing a significant amount of force to overcome the high viscosity of the flux [1]. A spool of wire will also be mounted to this subsystem. A motor will control the unspooling of the wire, feeding the wire into a channel in which it will be cut. The cut pieces will then be pushed out of the channel which will be positioned such that the pieces come to lay on top of the dab of flux on the saw tip. The wire will be cut by a modified pair of wire cutters that are actuated by a solenoid attached to one of the handles. By having the wire contained in a channel while it is being cut, we eliminate the possibility of the cut piece flying away in an unwanted direction from the shear forces exerted on it. This subsystem is the final subsystem that will interact with the saw tips in pre-tinning process, completing their preparation to be tinned.

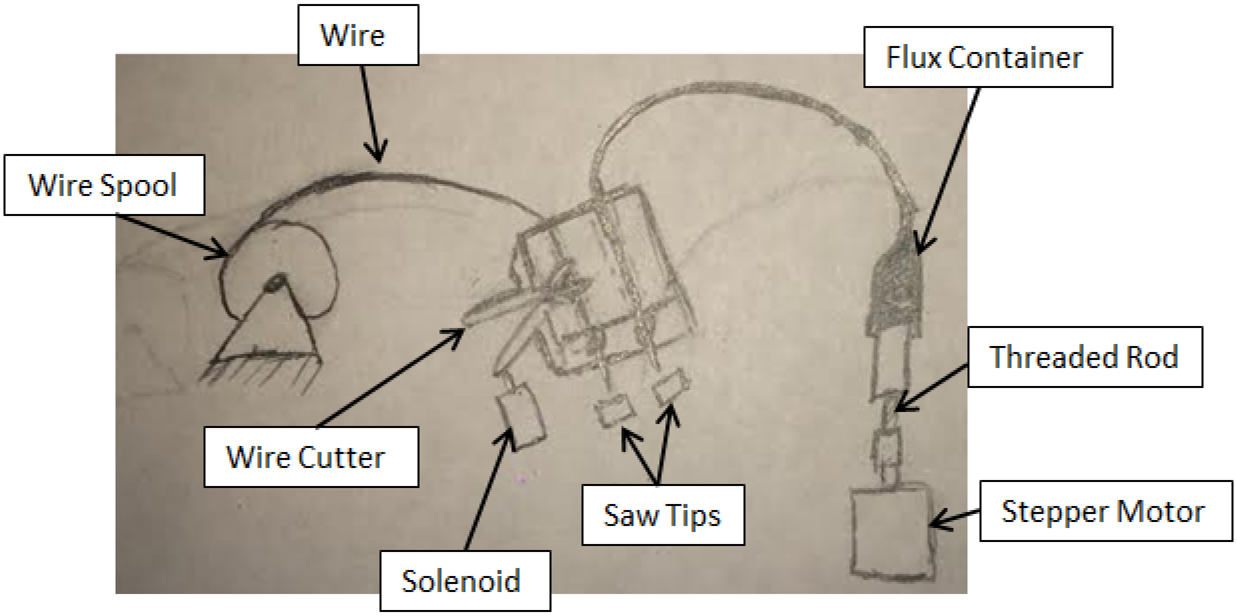

Figure 8: Sketch of the flux and wire dispenser system

8. Project Management

8.1 Schedule

Due Date	Project	Leader
Feb 1	Complete parts order	All
	Prototype hopper	Christian Heaney-Secord
Feb 8	Migrate design proposal information to website	Eric Newhall
	Test vision processing system	Eric Newhall
Feb 15	Serial communication between RP and Arduino	Guillermo Cidre
	Build and test electromagnet part placer	Christian Heaney-Secord
Feb 22	Wire and test stepper motors	Guillermo Cidre
	Complete part re-orientator and integrate with hopper	Christian Heaney-Secord
March 1	Complete conveyor belt	Christian Heaney-Secord
	Finalize vision processing	Eric Newhall
	Midsemester Presentation	All

March 8	Complete rail systems	Michael O’Connor
	Complete tray positioner	Christian Heaney-Secord
March 15	Spring Break	Off
March 22	Prototype flux extruder	Michael O’Connor
	Complete and integrate part placer	Christian Heaney-Secord
March 29	Test wire cutting mechanism	Michael O’Connor
April 5	Integrate flux extruder and wire cutter onto rails	Michael O’Connor
April 12	Test and calibrate system	All
April 19	Replace original prototypes with refined/3d printed parts	Michael O’Connor
April 26	Re-calibrate and test extensively	All
May 3	Prepare final report and presentation	All

8.2 Team Member Responsibilities

Eric Newhall - Vision processing software and website design.
Michael O’Connor - Flux dispenser and wire cutting and placement
Christian Heaney-Secord - Hopper design and part placer/positioner
Guillermo Cidre - Electronic wiring and analog design

8.3 Budget and Parts List

Part	Supplier	Quantity	Unit Cost	Cost
Arduino Mega 2560 R3	Sparkfun	1	45.95	45.95
DC Motor	Sparkfun	2	24.95	49.90
DC Motor with Encoder	Pololu	1	34.95	34.95
Stepper Motor - 125 oz.in (200 steps/rev)	Sparkfun	3	23.95	71.85
Stepper Motor - 68 oz.in (400 stepps/rev)	Sparkfun	2	16.95	33.90
Solenoid	Sparkfun	1	14.95	14.95
Grove Electromagnet SKU: 811014001	Seeed	1	8.90	8.90

Linear Rail Shaft Guide	Adafruit	12	3.95	47.40
Linear Bearing Platform (Small)	Adafruit	12	6.95	83.40
Aluminum 80/20 (4ft)	McMaster	5	14.20	71.00
Aluminum Flex Shaft Coupler	Adafruit	6	4.95	29.70
Aluminum Rod (6ft)	McMaster	3	4.88	14.64
Timing Pulley	Adafruit	3	11.95	35.85
Timing Belt	Adafruit	3	9.95	29.85
Acrylic Sheets (12”x24”)	McMaster	4	15.62	62.48
Power Supply	Lab Equipment	1	0	0
OPA569 Op Amp	Mouser	10	7.89	78.9
Hardware	Assorted	1	100.00	100.00
Playstation Eye	Already Owned	1	0	0
Raspberry Pi	Already Owned	1	0	0
Servo	Already Owned	2	0	0
			Total	813.62

8.4 Risk Management

We have identified what we believe to be the greatest areas of struggle and setbacks in our design and positioned them to be our first priorities to complete. Finding a hopper design capable of sorting all pieces in a timely manner and a part reorienter that flips the parts over will likely be challenging tasks that will take several iterations. By beginning these tasks at the start of the semester and identifying problems and potential solutions early on, we will have the time needed to order, to redesign, order new supplies, and re-build. Easier tasks were placed towards the end of the semester as these can most likely be completed easily and the harder tasks can be worked on concurrently.

As a fallback, if we are unable to successfully prototype either the hopper or re-orientater, we plan to be able to still show the functionality of the rest of our system by manually loading the saw tips. This will allow us to still show the ability to place the saw tips and apply flux and the two wires to each saw tip as these subsystems can operate independently of the hopper and re-orientater.

The most complex and challenging piece of software is the code for the vision processing system. The vision processing consumes a Large amount of resources but it is difficult to predict the amount of time the algorithm will take ahead of time. It is possible that the vision processing will take too long for the system to meet the time requirement of finishing in under five minutes. There are several methods that could be used if such a problem occurred. To begin with, the algorithm could be changed so that the part is assumed to alway be in the center of the image frame. This assumption eliminates the need to continually shift the image frame and recalculate error until the error is minimized. Alternatively, the Raspberry Pi could be replaced with a laptop which would greatly increase the speed at which the algorithm could be completed.

Another concern we have with our project is going over-budget. Some features of our design are based upon a fair bit of assumption and may require a lot of trial and error in order to function properly. With this in mind we plan on creating our parts such that we can easily alter their purpose or functionality without spending too much money. We will also be careful not to compromise our parts through too much trial and error. This will hopefully limit our spending and allow us to stay under budget.

9. References

[1] "Making a Powerful Linear Actuator." *Instructables*. N.p., n.d. Web. <http://www.instructables.com/id/Making-a-Powerful-Linear-Actuator/>.