Leonardo Bot Vinci: Orthographic Projection Robot
(Technical Paper)

Rethinking the SAT: The Role of Standardized Testing in College Admissions

(STS Paper)

A **Thesis Prospectus Submitted to the**

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Technical Prospectus

Abstract

The Orthograph-bot is a device that will automate the process of creating two dimensional orthographic sketches of three dimensional objects. The device involves the design and construction of a machine that can take photos of a 3D object from different angles, scale the image up or down to fit on a standard sheet of paper, automatically detect edges and then draw orthographic projections based on the images the device has taken. This device combines many different aspects of important and emerging engineering tools like machine vision, image detection, microcontroller implementation, and robotic automation. In order to implement the Orthograph-bot an object will be placed in a box in front of a set of cameras oriented to take pictures of the object from different angles. The National Instruments myRio will process these images to record the relevant edges to create an orthographic drawing, determine the appropriate scaling to fit on a standard sheet of paper, and will control the Orthograph-bot's motors that will allow it to automatically draw these projections on a sheet of paper.

Background

Since the Christian Era artists and architects have been crafting drawings to communicate designs and ideas, however, the theory of projection views from imaginary planes was not fully developed until the late 1700s [1]. Leading up to the invention of orthogonal representation, renaissance men like the great Leonardo Da Vinci used perspective renderings to detail their designs. Modern engineers and builders had no standard way to convey their models and proposals until Gaspard Monge of the French military devised a system to communicate a three dimensional object around the world: orthographic projection.

The concept of an automated drawing robot is not new either. These devices are different from machines such as the printing press because of their relative freedom of movement: while the printing press can only reproduce images from stamps, a drawing robot is self powered and can move freely on the xy-plane, allowing the robot to mimic a human's drawing process. Patents for drawing robots go back to 1961 [2]. Some robots have been commercialized and are sold by companies as large as Bloomingdale's [3]. Today, with the widespread use of hobby boards like Arduinos, it is relatively simple for people to build their own devices. Likewise, edge finding in image processing is an old field and has patents as far back as 1990 [4].

Our project combines edge finding and drawing robots to construct orthogonal perspectives. While there are some robots that can reproduce an image on paper, many of them require digital images drawn on a computer or phone. Others may reproduce a live photo by drawing dark regions of the image [5]. Our project focuses on a more specific application of the drawing robot; since we plan to work on orthographic projections, our robot will draw the edges of physical objects instead of reproducing images based on dark regions. This focuses on edge finding in image processing, as opposed to determining relative color values.

Our project will heavily involve background from Professor Dugan's Mariobots class, which emphasizes the use of and tools available in LabView. Two of us took that class, and have experience integrating the MyRio with external devices. We also will use experience gained in Introduction to Embedded, especially with respect to the motor projects. That experience will help us integrate the motors with our microcontrollers. Finally, we expect to draw on knowledge from the Fundamentals series, especially PCB and analog design.

Description of Project

Deliverables

Overall, this project will consist of a lighting box and a robot able to draw orthographic projections on a piece of paper. First, an image of the object within the light-controlled box will be taken using two LifeCam cameras attached to the MyRio. Next, the outline of the image will be obtained via image processing using NI Image Acquisition. Finally, the XY aluminum frame robot will recreate the outline on a piece of paper.

The first deliverable for our project is the image processing. We will be using LabView and the MyRio for this. First, a still image will be taken by the camera. It will go through processing to optimize for edge detection, including changes of brightness and contrast. Next, the image will be changed to an 8-bit grayscale image. Some information will be lost in this step, but it will emphasize the edges of the object and allow us to use the built-in IMAQ edge detection tool. This tool provides an image made of only 0 (black) and 255 (white) pixels. This image can be made into a matrix for data processing. The goal will be to make groups of adjacent pixels, which will constitute a line. Once groups are created, they are then sent to a queue to be drawn. The flowchart for this program can be seen in Figure 1.

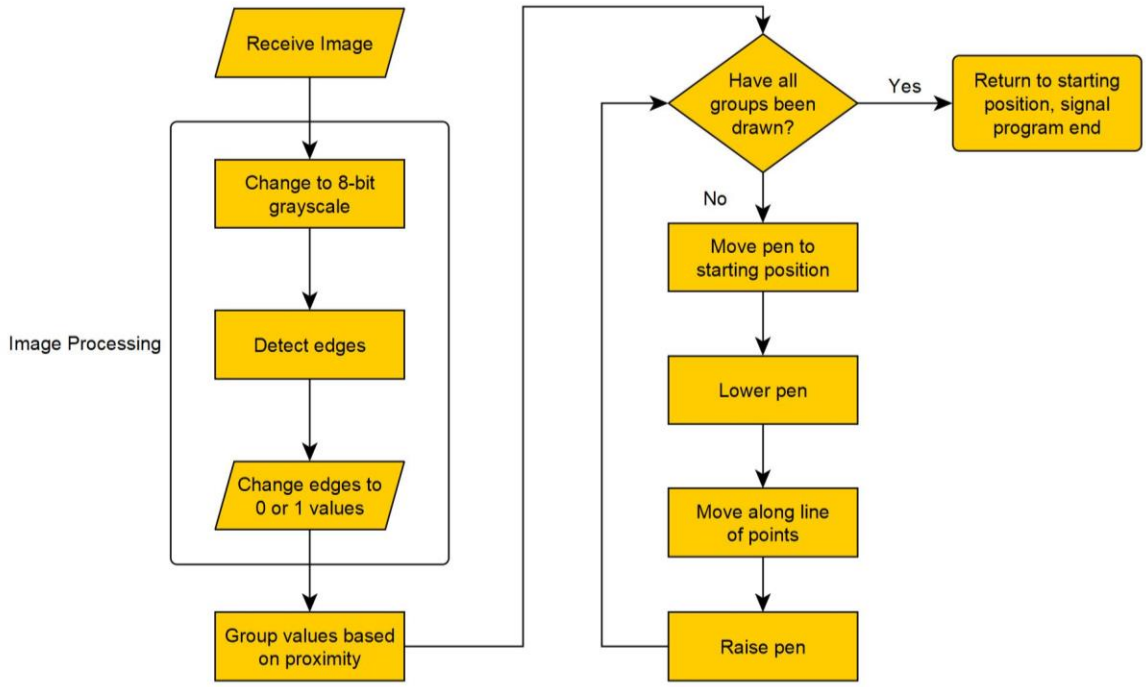


Figure 1: Image processing flow diagram

Our second deliverable, the drawing fixture, will be a rectangular fixture that can hold three adjacent pieces of paper and contains pulley systems that control movement in the X, Y and Z direction. The pulley gear and belt system will be moved using stepper motors, which are controlled by the PCB via the myRIO. These pulleys that control all axes will be connected to a drawing utensil fixture that will hold a pen. The fixture will then have the freedom to draw in any direction on a flat piece of paper and be lifted up as necessary. The PCB itself will contain AC to DC converters and voltage regulators to ensure the proper stepping down of voltages to power the stepper motors, motor driving chips, LED tape, and MyRio.

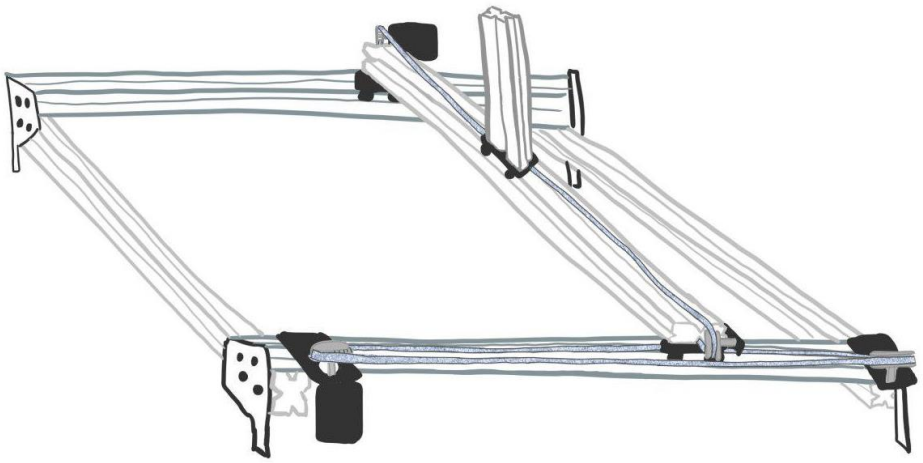


Figure 2: Sketch of the XY drawing fixture

The third deliverable is a box in which objects can be placed and photographed. The purpose of this box will be to maintain a controlled lighting environment. We anticipate that the lighting in the room will be changing over time and want to reduce that impact. The box will have a turntable upon which an item can be placed. The turntable will rotate via an attached motor. Due to the size of the box and camera scope, the biggest object we can draw will have to fit in a 6 inch cube. There will also be LED tape placed along the edges of the sides of the box that have cameras. The lights will turn on when the camera on that side is activated to properly illuminate the object. The flow chart for the box programming can be seen in Figure 3.

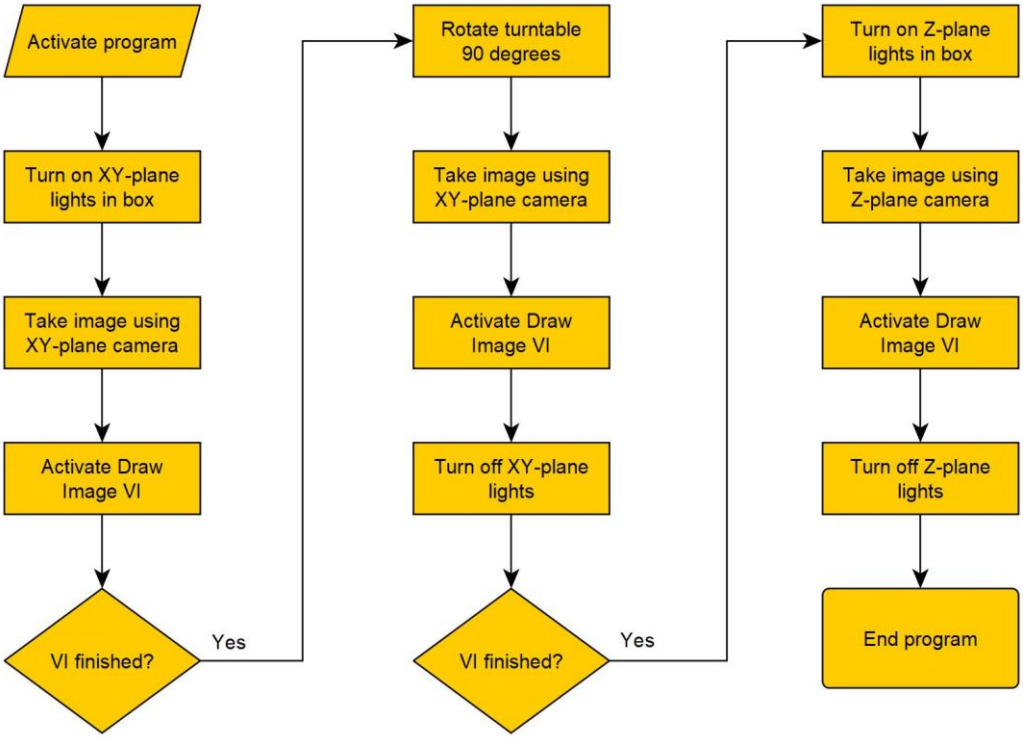


Figure 3: Box programming flow diagram

A flow chart of our overall system can be found below.

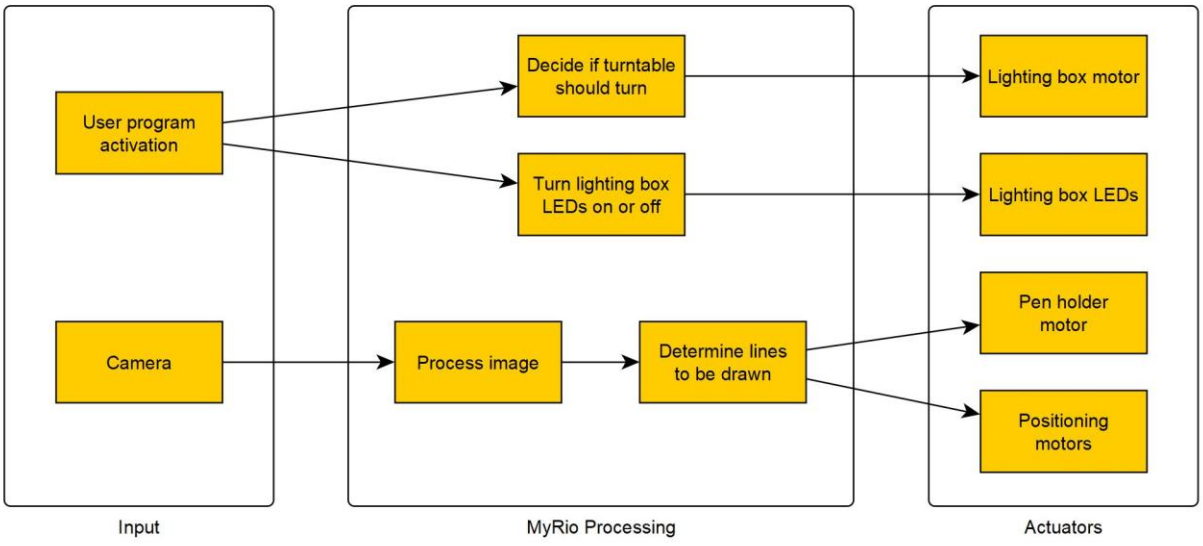


Figure 4: Subsystem flow diagram

Anticipated problems

A major problem we anticipate is grouping points in a "line" so the robot can draw them without lifting the pen. Determining what set of pixels constitutes a line will be extremely challenging, especially as we are not very experienced with data and array manipulation in LabView, which will be needed. From a group, we will also have to determine which pixels need to be drawn, as the lines will likely be more than one pixel wide. Another problem connected to LabView is image processing. We will need to develop a script that correctly processes all images, not just specific ones, which will require a lot of experimentation.

Making the platform to mount the pulley systems and connecting motors to control the pulleys will be another challenge. Additionally, the drawing fixture that holds the pen will have to be custom made with 3D printing. This will be a lengthy and difficult process since we have less experience with mechanical design. Fitting parts together and having all moving parts moving in the right way will require a lot of tedious calculations, work, time, and testing.

Additionally, we expect problems with optimizing our machine vision algorithm for many different objects. Since it will be on a turntable powered by a motor, there will also be a weight limitation on the object which we will need to calculate. We want to be able to draw objects of different colors, which means the background of the box will be one high-contrast color, such as bright green, and we will not be able to draw any objects of that color. We will also need to place the LEDs inside the box so they properly illuminate the object. Finding the best placement for the LEDs will take experimentation with both LED placement and LabView code.

Finally, we expect problems with testing discrete components of the project. Some parts of the project must be done in parallel to account for the time limits of the capstone. This

introduces difficulty in testing. For example, ensuring that groups of pixels are formed and queued correctly will be extremely challenging due to the large number of pixels and limited ability to view arrays in LabView.

Expected Outcome

We expect that the lighting box and image processing on the MyRio will successfully produce groups, or lines, for the robot to draw. Additionally, we expect that the robot will be able to move to those groups and accurately recreate them on a piece of paper. Once finished, the robot will move back to a starting position to allow the paper to be removed.

Resources Required

In terms of software and electrical equipment, we will require the following:

- National Instruments MyRio [6]
- 2x Lifecam Cameras [7]
- 3D printer and SolidWorks [8]
- LabView, especially NI Vision Development Module and NI Vision Assistant [9, 10, 11]
- Header pins for LED Tape and MyRio

In addition to that, we will need the following materials:

- 3x timing pulleys - 30 tooth
- 3x smooth idler pulleys
- 13 ft of rubber timing belt - 5mm
- 2x 39” aluminum rods to suspend the structure lengthwise
- 2x 26” aluminum rods to suspend the structure widthwise

- 6” aluminum rod to suspend the structure heightwise
- 4x Acrylic plates
- 4x Axis foot plates
- 8x Double Tee nuts and screws
- 3x Gantry Cart Kits
- At least 2400 in2 of wood to build the lighting box

External Considerations

Constraints

Many of the components needed for the project such as myRIO, a small robot that can be controlled by the myRIO, stepper motors, cameras, etc are available for use from previous capstone projects and materials in the ECE department. Some materials like a special or controlled power supply, a printed circuit board, and other various components for the project may need to be purchased for a total cost or around $100. The cost of the project will not be a big constraint since most parts are parts that have been worked with in other ECE labs and classes or are readily available from past projects.

Energy and Sustainability

One sustainability concern that this device hopes to address is a waste of paper to do these orthographic sketches. If the robot automated algorithm for drawing is not precise enough, the sketches may be unusable. If the image processing done by the myRIO is not distinct or deterministic enough, the drawings created by the robot would, again, be unusable. The goal of

this project is to cut down on the errors made by humans drawing orthographic sketches, as well as the time needed for this tedious task, which would in turn cut down on the waste of paper.

This device does have a small energy impact. Since the devices in use are on a smaller scale, the energy needed for the device to run would not be more than a couple watts at worst case. Cameras operating and the myRIO performing image processing and controlling a physical and mobile robot that contains motors and needs to process coordinates that are provided by the myRIO would have some level of energy consumption.

Health and safety

A major priority for this device is safety, since it is meant to be used by people to actively make orthographic sketches of self picked objects. Consumers should be able to safely use this device to take pictures and watch a robot create the sketches without any sharp, high voltage/current, or otherwise dangerous parts being exposed. The wiring between the cameras and myRIO as well as the robot must be neat and well insulated. No circuit boards or parts on the device can dissipate too much heat or energy as that makes the device dangerous to be around. The drawing device that the robot will use must be incorporated in a safe and controlled way so it may not cause any harm to some consumer using this device.

Manufacturability

This whole device will be sized to fit on a table in the NI Lounge. The device should be small enough as to not be intrusive or obnoxious for its purpose - namely, making orthographic sketches on standard 8”x11” paper. This device should be able to perform well under a variety of

lighting conditions since absolutely perfect lighting for image and edge detection can not be guaranteed, so a robust image detection algorithm will be needed to make this device versatile.

Ethical issues

There is an ethical issue of this kind of device putting mechanical designers or sketch specialists out of a job. If a device can automate the process of making orthographic sketches as well as scaling up or down, it means it could make a sketch for a variety of sizes of objects, in a controlled and automated way which would be often preferred compared to a human sketch designer or mechanical engineer. However, mechanical engineering is a very robust field, and making orthographic sketches of designs is a small cog in a big machine. Having a device that can do that automatically and reduce time and waste potentially, I believe, would only help improve the industry.

Additionally, using a live camera to draw orthographic sketches could result in privacy concerns, as people might be concerned about appearing in an image saved by the MyRio. To alleviate this concern, we plan to build a box to provide a controlled lighting environment as well as protect individual privacy.

Standards

We expect all aspects of our project to comply with relevant safety standards. For the box, we will need to follow National Electrical Manufacturers Association (NEMA) requirements for projection lamps and LEDs [12, 13]. With respect to the robot itself, the most important standard is likely to be NEMA's standards for stepper motors [14]. The PCB and other power routing equipment will have to be in a NEMA type 1 enclosure, since we expect little

debris and liquid to be around the device [15]. We will also need to comply with NEMA 5-15 when powering our laptops and the MyRio [16]. The camera and MyRio will be connected to each other and a laptop via USB cable. Since our device will have moving parts, they will need to comply with Occupational Health and Safety Administration (OSHA) standards [17]. Finally, we need to ensure that construction of the machine emphasizes safety by following safe construction procedures and avoiding any sharp edges or objects on the final product.

Deliverables

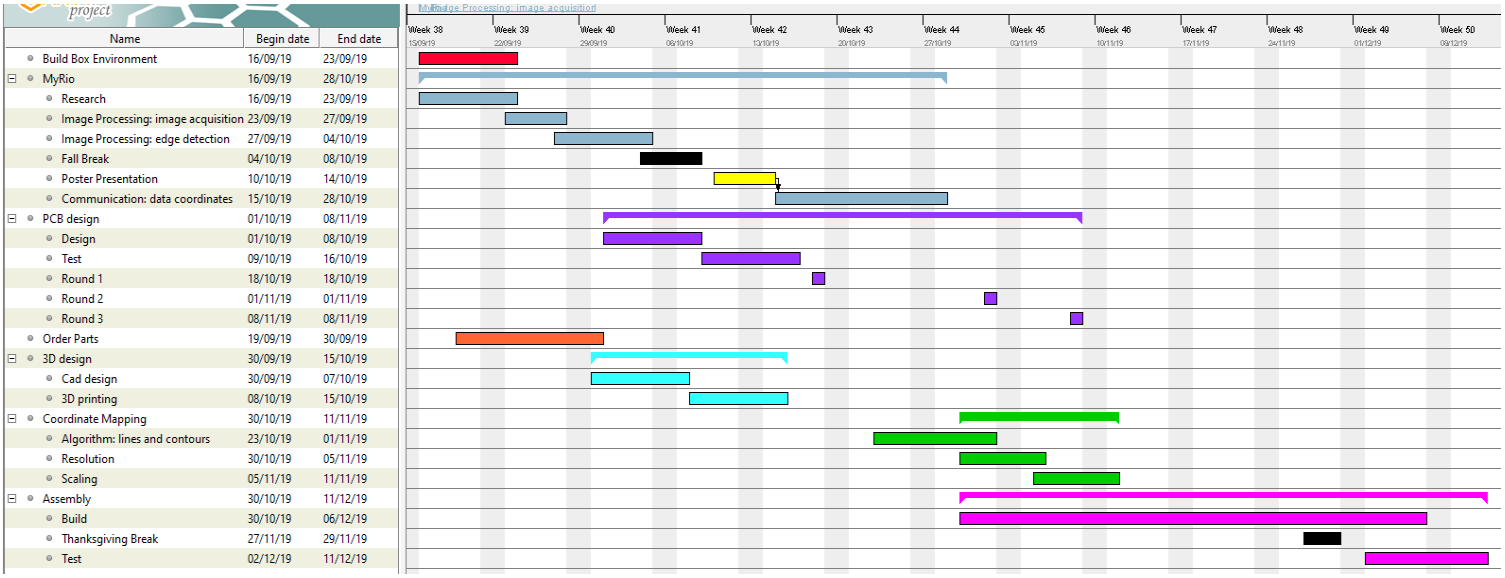
Our first deliverable will be the image processing on the MyRio, which will be able to detect edges and group edge pixels based on proximity. The edge pixel groups will then be queued. Our second deliverable will be the drawing robot itself, which will consist of fixtures to rig and move the pen around the paper, as well as the PCB used to power and drive the stepper motors, LED's and MyRio. Our final deliverable is the lighting box, which will house two cameras, LEDs, and a motor-controlled turntable. This deliverable facilitates the image processing deliverable.

Cost List

- 3 stepper motor driver chips ($5)
- 5 mm Timing belt ~13 feet ($3.50 per foot)
- Smooth Idler Pulley Kit ($6)
- AC-DC Power converter
- Xtension Limit Switch kit ($5)
- 40 mm Gantry Cart Kit ($32)
- Header Pins

- Ballpoint Pen ($3)
- Materials for an invariable box environment (~$20)
    - 4 20x20” wood panels
    - 18” diameter turntable
    - 1 stepper motor (for lighting box turntable) ($18) [18]
    - 7 ft LED Light tape (Lutron)
- NEMA standards ($175 for projection lamp standards, $87 for LED standards)
- ACRO Acrylic Plate Set ($27)
- 2 Double Tee Nuts ($0.69)

Timeline



Name	Begin date	End date
Build Box Environment	16/09/19	23/09/19
MyRio	16/09/19	28/10/19
Research	16/09/19	23/09/19
Image Processing: image acquisition	23/09/19	27/09/19
Image Processing: edge detection	27/09/19	04/10/19
Fall Break	04/10/19	08/10/19
Poster Presentation	10/10/19	14/10/19
Communication: data coordinates	15/10/19	28/10/19
PCB design	01/10/19	08/11/19
Design	01/10/19	08/10/19
Test	09/10/19	16/10/19
Round 1	18/10/19	18/10/19
Round 2	01/11/19	01/11/19
Round 3	08/11/19	08/11/19
Order Parts	19/09/19	30/09/19
3D design	30/09/19	15/10/19
Cad design	30/09/19	07/10/19
3D printing	08/10/19	15/10/19
Coordinate Mapping	30/10/19	11/11/19
Algorithm: lines and contours	23/10/19	01/11/19
Resolution	30/10/19	05/11/19
Scaling	05/11/19	11/11/19
Assembly	30/10/19	11/12/19
Build	30/10/19	06/12/19
Thanksgiving Break	27/11/19	29/11/19
Test	02/12/19	11/12/19

Figure 5: Gannt chart

The Gannt chart in the figure above outlines our proposed timeline including deadlines and holidays. The five key parts of our project include myRio programming, PCB design, 3D parts design, coordinate mapping and project assembly. Our goal is to begin three of those features; PCB design, MyRio programming and 3D parts design early in the project with each member taking the lead in one area. Then all work collectively to figure out the details of coordinate mapping and project assembly.

Em will take the lead regarding the MyRIO aspect of the project. Beginning with some preliminary research she will be able to determine the exact scope and capabilities of the MyRio and LabView system. Her tasks will include both image acquisition and edge detection all encompassed in image processing. She will then begin to determine how to associate contours and edges to a coordinate system.

Maansi will lead the team in the PCB area. The PCB will connect the three motors to a power supply and the MyRio in a manner that the MyRio will then be able to control properties concerning the motors including direction, speed and number of turns. It will also connect to and power the LEDs in the lighting box.

Sammy will use Solidworks to design the physical pieces needed to construct the platform holding the belt and pulley system. She will be in charge of successfully designing, printing and fitting the mechanical pieces together.

Then as a team we will tackle coordinate mapping. Using a language protocol we will communicate data of coordinates to the system that controls the motors. Together we will develop an algorithm for separating coordinates into lines and contours that are connected and those that are not connected. As a group we will attach the pulley system to the PCB and MyRio.

Finally the algorithm will need hands on trial and error testing we plan to conduct as a group until we have a working project.

Expectations

Letter Grade	**Criteria**
A	If device is able to: ● Employ machine vision to detect edges of an image ● Map the image edges to a set of coordinates ● Move robot to set of coordinates remotely ● Send coordinates of image and robot draws it
B	If device is able to: ● Employ machine vision to detect edges of an image ● Map the image edges to a set of coordinates ● Move robot to set of coordinates remotely
C	If device is able to: ● Employ machine vision to detect edges of an image ● Map the image edges to a set of coordinates
D	None of the criteria met for an “A”

References

[1] "Engineering drawing history | Gaspard Monge and orthographic projection." [Online]. Available: http://tolerancing.net/engineering-drawing/engineering-drawing-history.html. [Accessed: 19-Sep-2019]

[2] "Method of and a machine for writing," [Online]. Available: https://patents.google.com/patent/US3136594A/en. [Accessed: 16-Sep-2019]

[3] "Shop," Line-us. [Online]. Available: https://www.line-us.com/shop.html. [Accessed: 16-Sep-2019]

[4] "Edge finding method and apparatus," [Online]. Available: https://patents.google.com/patent/US5115476A/en. [Accessed: 16-Sep-2019]

[5] P. Tresset and F. Fol Leymarie, "Portrait drawing by Paul the robot," Computers & Graphics, vol. 37, no. 5, pp. 348–363, Aug. 2013.

[6] "myRIO Student Embedded Device - National Instruments." [Online]. Available: https://www.ni.com/en-us/shop/select/myrio-student-embedded-device. [Accessed: 26-Sep-2019]

[7] "Microsoft Webcam: LifeCam Studio | Microsoft Accessories." [Online]. Available: https://www.microsoft.com/accessories/en-us/products/webcams/lifecam-studio/q2f-

00013. [Accessed: 26-Sep-2019]

[8] "3D CAD Design Software." [Online]. Available: https://www.solidworks.com/home-page-2020. [Accessed: 26-Sep-2019]

[9] "What is LabVIEW? - National Instruments." [Online]. Available: https://www.ni.com/en-us/shop/labview.html. [Accessed: 26-Sep-2019]

[10] "Vision Development Module - National Instruments." [Online]. Available: http://www.ni.com/en-us/shop/select/vision-development-module. [Accessed: 26-Sep-2019]

[11] "Vision Acquisition Software - National Instruments." [Online]. Available: https://www.ni.com/en-us/shop/select/vision-acquisition-software. [Accessed: 26-Sep-2019]

[12] "American National Standard for Electric Lamps—Projection Lamps—Vocabulary." [Online]. Available: https://www.nema.org/Standards/Pages/American-National-Standard-for-Electric-Lamps-Projection-Lamps-Vocabulary.aspx. [Accessed: 16-Sep-2019]

[13] "American National Standard for Electric Lamps—Light-Emitting Diode Package Specification Sheet for General Illumination Applications." [Online]. Available:

https://www.nema.org/Standards/Pages/Light-Emitting-Diode-Package-Specification-Sheet-for-General-Illumination-Applications.aspx. [Accessed: 16-Sep-2019]

[14] "Motion/Position Control Motors, Controls and Feedback Devices." [Online]. Available: https://www.nema.org/Standards/Pages/Motion-Position-Control-Motors-Controls-and-Feedback-Devices.aspx. [Accessed: 16-Sep-2019]

[15] "About NEMA Enclosure Types," Integra Enclosures. [Online]. Available: https://www.integraenclosures.com/resources/about-nema-enclosure-types/. [Accessed: 16-Sep-2019]

[16] "NEMA 5-15 receptacle description." [Online]. Available: https://www.schneider-electric.us/en/faqs/FA156527/?viewlocale=en_US. [Accessed: 16-Sep-2019]

[17] "Chapter 1 - Basics of Machine Safeguarding." [Online]. Available: https://www.osha.gov/Publications/Mach_SafeGuard/chapt1.html. [Accessed: 26-Sep-2019]

[18] "290-028 Digilent, Inc. | Motors, Solenoids, Driver Boards/Modules | DigiKey." [Online]. Available: https://www.digikey.com/products/en?mpart=290-028&v=1286. [Accessed: 19-Sep-2019]

STS Prospectus

Motivation

My motivation for picking this topic came from the recent college admissions scandal. While UVA wasn't directly involved, my sister's school, Georgetown University, was one of the schools impacted. In the Georgetown case specifically, four students were admitted with a combination of essay fraud, falsified athletics records, and a special proctor for their SAT (Li & Mandell, 2019). The SAT was a common factor in many of the other college admissions cases as well. I became interested how the SAT was so commonly used to fraudulently admit students to elite colleges, and what purpose the SAT served in admissions.

This topic is also relevant to science, technology, engineering, and math (STEM). Entering those fields often requires a college degree in a STEM area. Due to factors like increased awareness of sexual harassment and microaggressions, diversity in STEM is a popular topic of discussion. Since SAT scores can be influenced by things like socioeconomic status, it is a potential barrier to college for people of diverse backgrounds, thus preventing them from entering the STEM workforce.

Background

Standardized tests in college admissions date back to 1900 with the establishment of the College Entrance Examination Board (Beatty et al., 1999). This organization would later become known as the College Board, which gives the SAT and Advanced Placement examinations to thousands of students each year (Lemann, 2000). The original intent of these examinations was to determine whether students were prepared for the rigor of college work (Beatty et al., 1999). Elite colleges and universities were receiving applications from students who had completed

secondary school, but their skills and abilities were not always reflected in their secondary grades (Ibid). Since then, more and more institutions have required the SAT or other standardized testing results for college admissions.

There are arguments for and against the use of standardized testing in college admissions. Some assert that qualified students will assuredly be accepted into some university, and the only purpose of the SAT is to restrict admission to highly competitive universities (Beatty et al., 1999). In other words, for most non-exclusive schools, standardized testing serves no purpose. An argument against that is that testing scores provide a common metric for students from different states, schools, and backgrounds, which is essential for determining a student's success at university (Strauss, 2019).

Despite this argument for standardized testing, many schools are shifting to make test scores optional for applicants. About 40% of accredited colleges and universities in the United States have made SAT and ACT scores optional (Strauss, 2019). The argument is that the schools have found no difference in academic achievement. Additionally, some schools noted an increase in student body diversity when test scores were made optional. At Wake Forest, ethnic diversity increased by 90% when the requirement of test scores was removed (Ibid). At the University of Chicago, they saw a 20% increase in first generation, low income, rural, and veteran students (Ibid).

Approach

I plan to apply Actor Network Theory (ANT) and utilitarian ethics to this issue. ANT can be used to analyze the relationships between different actors in the network. When the network has been characterized, utilitarianism can then be applied to determine who is benefited and who

is harmed by the existing standardized testing system, with an emphasis on minorities and disadvantaged groups. I plan to explore alternative suggestions to the current system and analyze those using utilitarianism. In addition to using ANT as a method to explore utilitarian ethics, I plan to consider an individual's right to higher education. Since standardized testing can be a barrier to entry into elite schools, I will consider whether those tests inhibit individuals from exercising their right to education.

Key Definitions

- Actor Network Theory: a framework that emphasizes individual actors in a network as well as the relationships between different actors (Rodger, Moore, & Newsome, 2009). This was chosen because it allows for focus on inter-actor relationships. In this specific network, the interactions between actors are extremely valuable for analysis.
- Utilitarianism: a form of ethics that determines whether an action is right or wrong by judging how much happiness or harm it causes (Gorman, Mehalik, & Werhane, 2000). When applied to society, it can be generalized to judging how much benefit or harm an action causes to society. It is in contrast to other ethical framework that emphasize an individual's happiness. This ethics framework was chosen because in the United States, college admissions has an impact on a wide range of people, from businesses to families. In order to consider the impact of standardized testing on this large network, utilitarianism was chosen for its emphasis on society as a whole over individuals.
- Right to higher education: the extent to which individuals can make a claim on post-secondary education, including both undergraduate and graduate studies (McCowan, 2012). Unlike utilitarian ethics, the human rights approach emphasizes individuals

instead of society as a whole. This framework was chosen for its emphasis on individuals and can be contrasted with utilitarianism.

Actors

The most obvious actors are the College Board and the ACT. These are the organizations that administer college standardized testing. Both organizations are registered tax-exempt nonprofits (ProPublica, n.d.-a; ProPublica, n.d.-b). The stake they hold in standardized testing is financial. According to ProPublica, which collects data from the Federal Audit Cleaninghouse, in 2017, the College Board had a total revenue of around $1.1 billion and a net income of $140 million (ProPublica, n.d.-b). About 94% of their revenue comes from their "program services" which includes administration of the SAT and AP exams (Ibid). In the same year, ACT Inc., which provides the ACT exam as an alternative to the SAT, had a total revenue of $353 million and a net loss of $3 million (ProPublica, n.d.-a). Like the College Board, 94.1% of their revenue comes from "program services" or test administration (Ibid). Based on these numbers, both nonprofits rely heavily on revenue from standardized testing. Thus, they have a vested interest in maintaining or expanding the existing standardized testing industry.

The stated mission of the College Board nonprofit is to "expand access to higher education" and "[promote] excellence and equity in education" (The College Board, 2018). The organization also "serves the education community through research and advocacy on behalf of students, educators, and schools" (Ibid). The ACT has a similar mission statement: the organization is "dedicated to helping people achieve education and workplace success" (ACT, n.d.). With respect to standardized testing, the ACT holds the view that:

> "ACT scores are the only admission decision factor that provide a common, standardized metric allowing colleges to compare students from different schools, states and countries on a level playing field. No other factor used in admission decisions can do that." (Strauss, 2019)

Another actor in the network is university admissions departments. Around 60% of universities in the United States require the SAT or ACT for admission. For example, UVA requires either the SAT or ACT, but states that "standardized testing is a useful but imprecise instrument" and does not have a minimum SAT score requirement (University of Virginia, n.d.). This makes the rationale behind the requirement unclear. For the 40% of universities who do not require the SAT/ACT, the reasoning is typically that they do not find the scores valuable for assessing the academic capabilities of students. The university admissions departments are a split group of actors, some of who support standardized testing and some who do not. Only some admissions departments directly benefit from standardized testing as a measurement of academic potential, where ideally they are able to pick students who will be successful at their schools. This gives them an advantage over schools who do not use standardized testing. Those schools lack a quick and easy way to filter through applicants, which increases the time they need to spend on each application and the manpower involved in admitting students.

Some individuals and companies have built careers around helping students prepare for SAT and ACT testing. The test preparation industry will earn a revenue of $1.1 billion in 2019, a 2.4% increase from the year prior (IBISWorld, n.d.). Preparation for the SAT can range between $10 for a book, and $1,000 for an instructor-led class ("How much does SAT prep cost?," n.d.). In 2018, about 2 million students took the SAT, and another 1.9 million took the ACT (Emma &

Wermund, 2018). These students are an excellent market for the test preparation industry. These actors obviously benefit financially from the continued use of standardized tests: if the SAT and ACT were removed from university admissions requirements, it is unlikely that as many people would take these exams, and the industry would shrink.

The final actor considered here is high school students and their families. These students are the ones who take the exams and are applying for college admissions. They are impacted by standardized exams because of the belief that a high score will help their admission, and conversely that a low score will prevent them from going to a good school. The College Board recommends that a student take the SAT at least two times (College Board, 2018b). Students who wish to improve their scores may take the exam multiple times. However, each SAT exam costs a minimum of $49.50 (College Board, 2018a). That means that the SAT may place a financial burden on students and their families.

Relationships

More expansion and research on these relationships is needed, but here are the ones I plan to focus on.

- The College Board/ACT and high school students: students pay the College Board/ACT to take their exams. Students who wish to improve their score may take the same test multiple times, or take a different test. The College Board benefits financially from this, and there is a commonly held perception that a better score may benefit a student by helping them get into an elite school. Some elite schools may use scores to screen out applicants, so a high score can help students proceed beyond an initial survey of

applications. These standardized tests may be a financial burden on students and their families, so both companies offer fee waivers for qualifying students.

- University admissions and the College Board/ACT: admissions departments may consider standardized testing scores when admitting applicants. Many departments also superscore applicants, which means that their highest scores from each section are taken, even across different test sessions (College Board, 2018b). For example, a student who excels in the SAT Reading section on one exam and the SAT Math section on another version of the exam would have their two good scores combined and submitted as their final score. This practice means that both the College Board/ACT and admissions departments benefit from students taking the exam multiple times. The College Board/ACT benefit financially, and admissions departments get to see the best academic performance for some students.
- University admissions and high school students: students must submit their standardized testing scores to some universities to apply and be accepted. Universities may use these scores to separate qualified and unqualified applicants, so students are incentivized to do as well as they can on their exams. Due to the practice of superscoring, students are also incentivized to take their exams multiple times to maximize their score for university admissions departments.
- Test preparation industry and high school students: students who wish to do well on their exams may hire a tutor, attend classes, or buy practice exams, all of which are sold by the test preparation industry. Due to the high importance placed on the results of these exams, these services come in a wide range of prices, from a few dollars for a book to

thousands of dollars for an in-depth class, which can be inaccessible to people of low socioeconomic status.

College Admissions Scandal

I plan to analyze the relationships the recent Varsity Blues scandal arose from, focusing on the relationships between students and their families, university admissions, and the test preparation industry. While this requires more research, I expect that the practice of family intervention to ensure admission to a university comes from the relationship between families and test preparation professionals, and the relationship between university admissions and test preparation.

Application of Utilitarianism

More research on proposed solutions to standardized testing is needed. I plan to analyze the current system as well as proposed systems through a utilitarian lens. Some proposed systems I have seen in my research are making exams completely optional, removing them altogether, or restricting the exam so it can only be taken once. I plan to analyze these and other proposed systems to determine which benefits the most people while causing the least amount of harm.

Human Rights Analysis

The question I want to address is the following: Is higher education a human right, and if so, are standardized tests an obstacle to fulfilling that human right? McCowan (2012) explores whether higher education is a human right or privilege by using conceptual legal and moral arguments. Article 26 of the Universal Declaration of Human Rights (1948) states that higher

education should be accessible to all but can be restricted by merit. Restriction based on merit and academic preparation ensures that all students will be able to engage meaningfully in their education. Article 4 of the Convention against Discrimination in Education (1960) similarly states that education should be accessible to all but can be restricted only based on "individual capacity", or the academic potential of students. This accounts for students that come from low-resource areas and may not have opportunities for achievement available to them. Both of these state that higher education is a right similar to elementary education, but can be restricted. Neither declaration addresses the relative quality of the education. Thus, international law generally sees higher education as a human right, but as independent of the quality of instruction.

McCowan (2012) also justifies the right to higher education by characterizing it not only as classroom learning, but a learning experience and period of intellectual development that should be accessible to all. By considering higher education in terms of international law as well as a developmental experience, McCowan concludes that higher education is a human right that can be restricted based only on merit.

It can also be argued that higher education is not a right but a privilege, and still benefits society. McCowan (2012) notes an argument that while higher education is restricted, it benefits society economically by taxing those individuals and generally by using their expertise. Hashi (2012) asserts that while higher education is a privilege, it is accessible to all through online courses and scholarships. While these are valid arguments, they fail to address the idea that higher education is a developmental experience that everyone should have easy access to, in the same way that they have access to elementary education.

If higher education is a human right, does the SAT restrict access to it? The role of the SAT is to restrict admission to highly competitive universities by giving preference to students

with high scores (Beatty et al., 1999). However, for universities outside of the elite, high scores do not serve much purpose in admission aside from a basic academic assessment. Some schools do not require the SAT at all. While other barriers may exist outside of standardized test scores, such as inadequate academic preparation or economic status, the SAT itself does not inhibit students from accessing general higher education. It does prevent some students from attending elite institutions and receiving a higher quality education. However, this is not addressed in international law, and it is certainly possible to develop intellectually at a non-elite institution. Thus, the SAT does not prevent people from achieving their human right to higher education.

Future Work

I received some fantastic suggestions for work from feedback on my forum post and presentation, but I won't be able to include it all in my thesis. Some opportunities for future work are studying the impact of standardized testing on college athletes, focusing on disadvantaged groups, comparing the role of standardized tests for graduate school with undergraduate schools, and focusing more on the specific case of the college admissions scandal. With respect to the human rights discussion, there is an opportunity for work in comparing the quality of an online and in-person degree, and whether an online degree fulfills the human rights requirements for higher education. Finally, I suggest that future work focuses on not only the current role of standardized testing in higher education admissions, but also analyzes trends and potential future developments in that industry, with the end goal of analyzing what standardized testing should be allowed to become.

References

ACT. (n.d.). About ACT. Retrieved November 1, 2019, from ACT website: https://www.act.org/content/act/en/about-act.html

Beatty, A., Greenwood, M. R. C., Linn, R. L., Steering Committee for the Workshop on Higher Education Admissions, Board on Testing and Assessment, Commission on Behavioral and Social Sciences and Education, … National Research Council. (1999). *Myths and Tradeoffs: The Role of Tests in Undergraduate Admissions*. Retrieved from https://www.nap.edu/catalog/9632/myths-and-tradeoffs-the-role-of-tests-in-undergraduate-admissions

College Board. (2018a, May 18). How much do the SAT and SAT subject tests cost? Retrieved November 1, 2019, from The College Board Blog website: https://blog.collegeboard.org/how-much-does-sat-and-sat-subject-test-cost

College Board. (2018b, June 6). How many times can a student take the SAT, and when should they take it? Retrieved November 1, 2019, from For Parents & Guardians website: https://parents.collegeboard.org/faq/how-many-times-can-student-take-sat-when-should-take

Convention Against Discrimination in Education. (1960). Retrieved December 2, 2019, from Records of the General Conference, 11th session, Paris, 1960: Resolutions website: https://unesdoc.unesco.org/ark:/48223/pf0000114583.locale=en

Emma, C., & Wermund, B. (2018, October 25). SAT scores rise, as do the numbers of test-takers. *Politico*. Retrieved from https://www.politico.com/newsletters/morning-education/2018/10/25/sat-scores-rise-as-do-the-numbers-of-test-takers-388387

Gorman, M. E., Mehalik, M. M., & Werhane, P. H. (2000). *Ethical and environmental*

challenges to engineering. Upper Saddle River, N.J: Prentice Hall.

Hashi, S. (2012, September 19). Is higher education a right or privilege? Retrieved November 28, 2019, from The Sheaf website: https://thesheaf.com/2012/09/19/is-higher-education-a-right-or-privilege/

How much does SAT prep cost? - Costhelper. Com. (n.d.). Retrieved November 1, 2019, from CostHelper website: https://education.costhelper.com/sat-prep.html

IBISWorld. (n.d.). Key Statistics. Retrieved from Tutoring & Test Preparation Franchises website: https://clients1.ibisworld.com/reports/us/industry/keystatistics.aspx?entid=5609

Lemann, N. (2000). *The Big Test: The Secret History of the American Meritocracy*. New York: Farrar, Straus and Giroux.

Li, A., & Mandell, M. (2019, March 12). Georgetown Parents, Former Coach Face Bribery Charges. *The Hoya*. Retrieved from https://thehoya.com/georgetown-parents-former-coach-face-bribery-charges-admissions-cases/

McCowan, T. (2012). Is there a universal right to higher education? *British Journal of Educational Studies*, *60*(2), 111–128. https://doi.org/10.1080/00071005.2011.648605

ProPublica. (n.d.-a). ACT Inc. Retrieved from Nonprofit Explorer: Research Tax-Exempt Organizations website: https://projects.propublica.org/nonprofits/organizations/420841485

ProPublica. (n.d.-b). College Board. Retrieved from Nonprofit Explorer: Research Tax-Exempt Organizations website: https://projects.propublica.org/nonprofits/organizations/131623965

Rodger, K., Moore, S. A., & Newsome, D. (2009). Wildlife tourism, science and actor network theory. *Annals of Tourism Research*, *36*(4), 645–666.

https://doi.org/10.1016/j.annals.2009.06.001

Strauss, V. (2019, October 18). A record number of colleges drop SAT/ACT admissions requirement amid growing disenchantment with standardized tests. *The Washington Post*. Retrieved from https://www.washingtonpost.com/education/2019/10/18/record-number-colleges-drop-satact-admissions-requirement-amid-growing-disenchantment-with-standardized-tests/

The College Board. (2018, December 6). About Us. Retrieved November 1, 2019, from College Board website: https://about.collegeboard.org/overview

Universal Declaration of Human Rights. (1948). Retrieved December 2, 2019, from https://www.un.org/en/universal-declaration-human-rights/index.html

University of Virginia. (n.d.). FAQ. Retrieved November 1, 2019, from Office of Undergraduate Admission website: https://admission.virginia.edu/faq

Potential Further Reading

Buckley, J., Letukas, L., & Wildavsky, B. (Eds.). (2018). *Measuring success: Testing, grades, and the future of college admissions*. Baltimore: Johns Hopkins University Press.

Cole, M. (Ed.). (2006). *Education, equality and human rights: Issues of gender, "race", sexuality, disability and social class* (2nd ed). London: New York : Routledge.

Geiser, S., & Studley, R. (n.d.). *UC and the SAT: UC and the SAT: Predictive Validity and Differential Impact of the SAT I and SAT II at the University of California*. Retrieved from http://web.stanford.edu/~rag/ed351B/sat_study.pdf

National Center for Education Statistics. (2011). Higher education: Gaps in access and persistence study. Retrieved November 1, 2019, from

https://nces.ed.gov/pubs2012/2012046/figures/figure_24-2.asp

Rincon, R. (2018, September 11). SWE research update: Women in engineering by the numbers. Retrieved November 1, 2019, from All Together website: https://alltogether.swe.org/2018/09/swe-research-update-women-in-engineering-by-the-numbers/

Saxena, J. (2019, March 28). The SAT and ACT can be prohibitively expensive for some students. Retrieved November 1, 2019, from Vox website: https://www.vox.com/the-goods/2019/3/28/18282453/sat-act-college-admission-testing-cost-price

Stemler, S. E. (2012). What should university admissions tests predict? *Educational Psychologist*, *47*(1), 5–17. https://doi.org/10.1080/00461520.2011.611444