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EASTMAN MUSEUM DIGITIZATION PROCESS IMPROVEMENT

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ABSTRACT

The Eastman Museum Digitization Process Improvement project is the continuation of an effort to partially automate the digitization process at the Eastman Museum in Rochester, NY. This digitization effort involves the preservation of the Eastman Museum's current physical collection of artifacts which numbers in the tens of thousands. The goal of this project is to make the digitization process easier for the customer by automating the placement of the artifact and the color test strip under the camera, which will ensure the operator can remain stationary, and improving the speed of the photo processing that happens after each artifact is digitized. In meeting these goals, we will deliver the supporting documentation for another team to finish our prototype by the end of MSD II. The resulting prototype design will utilize as much of the existing design as possible to reduce the cost to the stakeholders, as well as maintain the quality of all artifacts that are digitized.

NOMENCLATUREN X

Color test strip/color bar - A bar used in photography applications to "white balance" photos. Some cameras have trouble reproducing white objects in photos and often tint them with other colors. This produces an image that does not correctly reproduce the white objects in the original photo [1]. The color bar is required to be in the same frame as the artifacts in the museum's process.

FADGI Guidelines - FADGI is a collaborative effort started in 2007 by federal agencies to articulate common sustainable practices and guidelines for digitized and born digital historical, archival and cultural content. The Eastman Museum adheres to these guidelines.

BACKGROUND

The Eastman Museum is in the process of digitizing their physical collection of photos. This process involves rephotographing each artifact in the collection individually on a copy stand. This process is slow and menial for the person digitizing these artifacts. This project was motivated by a desire to improve this process, making it faster and less tiring for the operator. Last year's MSD team came up with a design that involved a conveyor belt that would pass the artifacts underneath the camera and a sensor that would stop the artifact beneath the camera. The camera was placed on a tower, with its height being adjustable by a motor controlled by the operator. Last year's team also developed an auto-cropping script designed to save the operator time in post-processing. Coming into the project this year, our team decided to keep the camera height adjustment apparatus as-is and try to improve the auto-cropping script from last year's team. The conveyor belt subsystem of the digitization process was also discovered to be clunky to use and actually added time and effort to the process of digitization. With this in mind we decided to determine a new way, with the customer feedback in mind, to set-up and move artifacts so that they are more quickly and easily digitized.

Description of Design

Our system consists of a motor driven circular table, a mechanical arm that changes the position of the calibrating color bar, and AppleScript software that automatically crops the images taken. These subsystems were determined by discussing the requirements for the system with our customer, and turning these requirements into engineering requirements that define aspects of our system that we need to achieve.

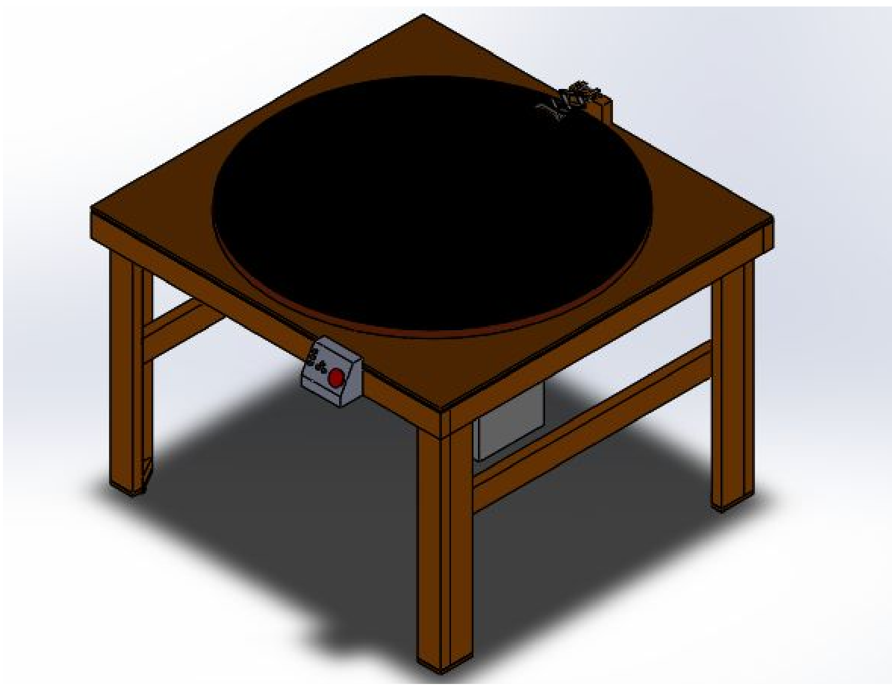

Figure 1: Complete Design Model

The mechanical arm is powered by a stepper motor. A stepper motor moves in "steps", which are portions of a full revolution of the motor shaft [2]. Since the artifacts tend to come in three sizes (5x7, 8x10, and 11x14 inches), presetarm positions can be determined for each artifact size. The team figured out how many steps would cause the color bar to be in the same frame as each photo size. The user selects their desired position by pressing a button, and the motor rotates accordingly. There are two buttons hooked up to the arm; one extends the arm forward, and one retracts it backwards. The motor is connected to a driver that tells the motor which direction to turn in and how far to go, and this information is fed to the buttons [3]. The rotating shaft on the stepper motor connects to the mechanical assembly using a coupling, which is in turn connected to a lead screw, which was machined to mate with the stepper motor coupling. The arm is constructed of strips of acrylic that are connected similar to a scissor lift; they can extend and retract as the bottom of the arm is compressed and extended. These strips are then connected to a lead screw via machined coupling that will move along the lead screw in such a way as to extend and retract the strips.

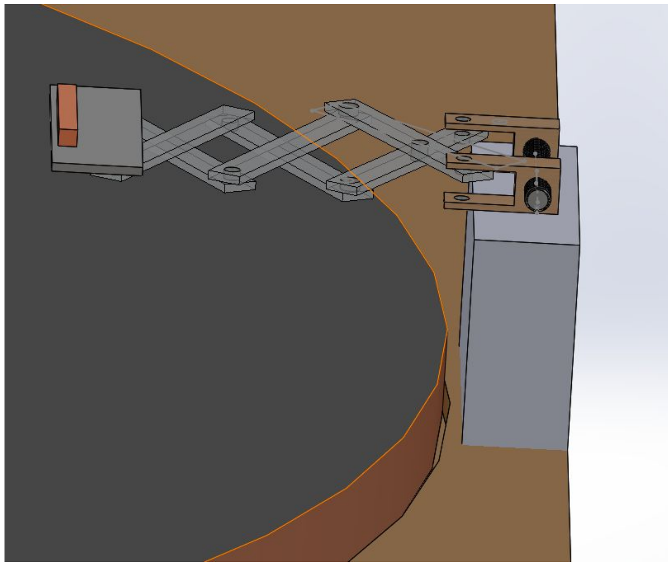

Figure 2: SolidWorks model of the mechanical arm system.

The rotating table is powered by a DC motor with a servo encoder. The tabletop itself and the servo encoder are connected through the use of a bearing. Using the servo's known position and desired position, a PWM signal is generated with PID control in order to move the table in the desired direction. The use of the PID controller introduced a gradual acceleration when the table initially begins to turn and when it is slowing down as it approaches its desired position. This gradual acceleration was necessary as opposed to a sudden start or sudden stop in order to maintain the static friction to keep any artifacts on the table from unnecessarily shifting. There are two buttons hooked up to the arm, one indicating clockwise and one indicating counter clockwise. Pressing and releasing the button would turn in the desired direction by 90 degrees, and pressing and holding the button for more than three seconds would turn in the desired direction by one degree per additional second.

The whole system is powered by a power supply that takes a 115VAC input(common wall power) and steps it down to 12VDC. This 12VDC output is fed to the stepper motor driver and the table motor driver from the electrical enclosure on the table. The system is controlled by a Teensy 4.0 microcontroller that will be mounted to a proto-board inside the electrical enclosure along with the stepper motor driver and table motor driver. The Teensy 4.0 microcontroller requires 5VDC to operate which will be provided via a buck converter that steps down the 12VDC output from the power supply to the 5VDC the Teensy requires. The Teensy will receive input via several push-buttons mounted in a way that makes them easily accessible to the user that will control the stepper and table motor functions as well as the previous team's camera motor.

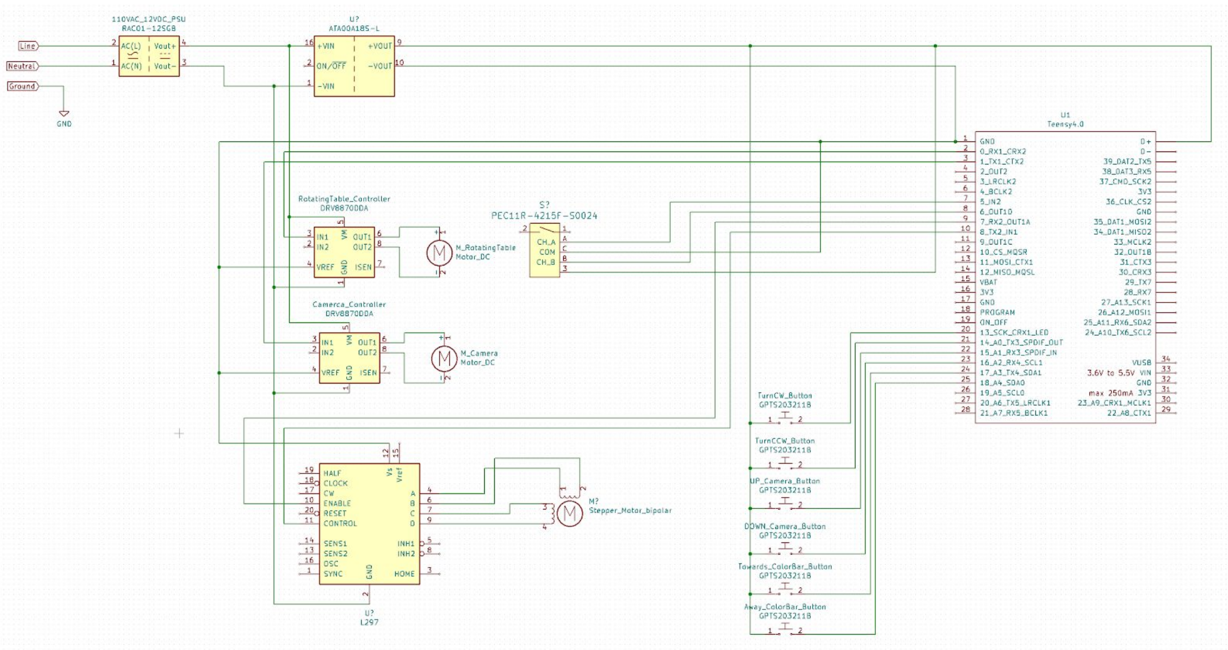

Figure 3: Electrical Schematic

The modified autocrop script was updated in order to reduce the performance time, particularly the time used by the compiled executable that returned the crop dimensions to the Applescript. The goal of this executable is to, given an image, return the pixel dimensions of the bounding box containing the artifact. This bounding box must contain the entirety of the artifact but also must remove the color bar that is placed adjacent to the artifact itself. In the updated algorithm, a raycast is performed from the center of each side of the image in the direction normal to that side of the image. Alongside each raycast trace, the color values at each pixel as a single-byte grayscale color is recorded alongside the trace, and a difference filter is applied alongside all four traces. This filter will update each value along the trace such that the resulting value will indicate the difference in color between the current pixel location and that of the pixel location five steps ahead. Due to the images having a black border per the FADGI guidelines, this can be used to detect the border of the image. When five consecutive pixels have been detected to have a difference that exceeds a provided threshold, this pixel is determined to be the edge of the image. The color bar can be detected by reperforming the raycast in each direction starting at each corner moving out until a raycast is found to have no difference exceeding a provided threshold across the entirety of the raycast. This line can be determined to be the gap between the color bar and the artifact.

The design was shaped from the requirements provided by the customer, as well as the engineering requirements determined by the team. The customer gave three requirements: the layout must be streamlined to allow a single operator to remain stationary, the placement of the artifact under the camera must be fully automated, and the color bar must be placed adjacent to the artifacts automatically. The team built off of these requirements to come up with engineering requirements. As stated before, the prototype should be operable by one stationary person and should re-use as much of the previous design as possible. The goal is to keep the operator's required movement within a 3x3 ft. area. Remaining within the $500 budget and adhering to OSHA standards were given chief importance. Specifically, OSHA standards 1910.212(a)(1) and 1910.3039(b)(1) were consulted to develop safe machine guards and electrical wiring methods. Since this will be used in a museum, the product must be operable without requiring any comprehensive or extensive training. Artifacts will occasionally differ from the sizes the system is programmed for, so the prototype must support manual control or override of placement of the artifact under the camera and the positioning and focusing of the camera. Outside of these uncommon cases, the system automates both of those processes and should place the color bar within 1 inch of the photograph. The artifact location shall be within 5 millimeters from the defined position on the tabletop. The prototype must accommodate the placement of the operator's lights. The software should automate the location and cropping of the artifact while also identifying the color bar. It should crop the image within a distance of 100 pixels from the image border. The naming and parameters of each artifact should be automatic. The operator should only have to click once to use the software. Maintaining the safety of the artifacts according to the FADGI guidelines is incredibly important, and was accomplished by designing the subsystems such that they do not touch the artifacts. This requires choosing a material for the arm that won't bend under pressures lower than 5 lbs./sq. in. and should be able to withstand extending and retracting repeatedly. The process should also be as quick as possible to increase output. A realistic goal for this is 60 seconds per artifact, from being placed under the camera to being named and saved to the operator's computer. This process should improve the overall quality of the digitization process. In case of failure, the parts must be easy to repair or replace.

Feasibility Evidence

To determine if the motor we obtained would be able to rotate our tabletop, we had to determine if the motor could overcome the static friction exerted. Once the supporting table was constructed and the bearing was attached, the rotating tabletop was placed on the bearing and the torque required to rotate the tabletop was measured. This was done by taking a hanging spring scale and clamping it, via c-clamp, to the very edge of the table (thin pieces of plywood were used to protect the table from the clamp). We then exerted on the spring scale until the point that the table begins to move, which would give us the force required to overcome the inertia of the table. This was repeated a few times till we had a value we felt was accurate enough for our purpose. This value was multiplied by the radius to give us the required torque to rotate the table. Our motor can supply 1.96 Nm of torque, much more than the 1.34 Nm we found to be required to turn the table.

The modified autocrop script was tested against the original script using two sample images. Each was run for several iterations in order to measure the performance of each individual script. Using a test image where the artifact was an empty, white square, the original autocrop script averaged 0.947 seconds over 100 iterations whereas the updated script averaged 0.000031 seconds over 100 thousand iterations and again over one million iterations. Using a test image where the artifact was also a rectangular image, the original autocrop script averaged 1.168 seconds over 100 iterations whereas the updated script averaged 0.000040 seconds over 100 thousand iterations and averaged 0.000034 seconds over one million iterations. In these specific test cases, both the original and the updated autocrop script were successfully able to isolate the artifact from the color bar, and the returned bounding box contained the entirety of the artifact.

The arm was able to move when we left, but will need some adjustments. We measured how many steps would cause the arm to move one inch through a trial-and-error process. The arm moved the expected distance in the forward direction. However, the arm did not move a full inch when retracted backwards. After some analysis, it was determined that this is most likely due to backlash on the lead screw. Due to the threading on the screw, the number of steps required for forward motion does not directly translate to the amount needed for backwards motion. Unfortunately we were not able to calculate the difference, but we know that more steps are required to move the same distance backwards than forwards.

Results, Conclusions, and Recommendations

Due to difficulties arising from the COVID-19 outbreak, the team was not able to complete the project as planned. As of the date in-person work times stopped the rotating table was in the process of being built and both the arm motor and table motor were in the process of being run through further testing to verify proper functionality. The results of this testing would have led to tweeks to the design where necessary. Because of the timing of this series of events, the team was not able to run through most of the test plans that had been developed. As such, it is hard for the team to come to any conclusions without any test data to base them off of. Several informal tests were run to verify that the arm motor worked with the PCB the team had made to be used in the electrical enclosure. These tests were successful and led the team to believe that this concept is sound and would have worked with both the table motor and the arm motor being run at the same time from the Teensy mounted on the PCB.

A follow-on team will need to finish constructing the rotating table and figure out a way for the mechanical arm to hold the color test strip and then finish mounting the mechanical arm to the table. Once this is done, the follow-on team will need to finish putting together the electrical enclosure which should amount to attaching the PCB, table motor driver, and power supply inside the enclosure and running wires from the enclosure to the components driven by it. The push-buttons controlling table functionality don't have a final place in the current team's design, and the placement of those can be left to the discretion of the follow-on team and the customer. Once the location of those is figured out, those will also need to be wired to the electrical enclosure. Once this is all sorted out, the follow-on team should be able to follow through with the test plans developed by the current MSD team. Adjustments to the design may be necessary depending on the outcome of the planned tests and on the discretion of the follow-on team.

One of our major failures was in the lack of thought into the actual construction of the tabletop and how we were going to rotate it. We thought it would have been best to directly mate the motor to the tabletop and rotate it that way, but it took an intervention from Dr. Wellin for us to realize that we would have to purchase or machine some kind of coupling to make sure that any disturbance on the table would not directly affect the motor and potentially damage it. This was a failure on our part because we did not take the initiative in communicating with any experts in this subject area and incorrectly assumed that we would have the necessary knowledge to construct it. This could have been a catastrophic failure that could have damaged the motor and put us in a position where we would not have had the funds to complete the project at all.

Another failure that our team encountered was the lack of budget that we had as the project wore on. This was due to mistakes in tracking the total cost of orders. The team was allotted a budget of $500 at the start of MSD 1. Each purchase the team made was tracked in a bill of materials listing the link to the vendor's page for the item, quantity, and cost of the item before tax. This bill of materials did not account for any taxes paid on the items nor the shipping cost of the items. This resulted in the team unknowingly going over budget. This problem was resolved by requesting a $100 budget increase to cover the budget overrun and leave extra money to cover the cost of any last minute purchases that may have been needed in the closing weeks of MSD 2. This turned out to be unnecessary due to in-person work being cancelled.

The team did very well with communicating with the client and determining whether or not our designs would be useful to her when the system is actually used. Through constant communication with our client, we have been able to adjust our design in a way that will make the system more useful to her, as well as to more easily integrate with the system that she already has in place.

References

[1] 2005, "Tutorials: White Balance," *Cambridge in Colour*. https://www.cambridgeincolour.com/tutorials/white-balance.htm

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[3] Romer, Charlie, 2016 , "How To Wire It! Stepper Motors," *Youtube.* https://www.youtube.com/watch?v=GgfgWU0bpHk

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