DESIGN 2

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Introduction

The goal of this project is to design an easel that is adjustable and that is safe and easy to use within a community of cognitively impaired individuals. The easel is required by our sponsor NSF, specifically Brooke Hallowell, to be light-weight and easy to store when not in use, and be able to move in various directions. Some of the effects of cognitive impairment are that our client, Harry Grim, has limited dexterity and limited arm movement. We have designed an easel according to these specifications and are confident that Harry Grim will be pleased with the outcome of his new easel.

Design

Our easel is electrically controlled by two detachable joysticks which allow the operator to move the easel in multiple different planes. Each joystick moves the easel in four different directions. One of the joysticks will be responsible for joining the front to back and up and down motions. We decided to use two joysticks instead of one, because the devices have to be easy for Harry to use. If there are too many directions on one joystick it might be difficult to reach the desired positioning of the easel. The joysticks are controlled by relays and this allows for the desired motion of the easel. Once the user makes an input of which way they would like the easel to move, the easel will respond having the actuators and swing arm units make the requested movement. A small motor will be attached at the base of the unit which will be attached to a bevel gear to shift the easel left and right.

The first action taken to begin a well developed design for our adjustable easel involves a block diagram which states the basics as to what the project must do. This involves an easy set up, elementary styled controls for user input, dynamic movement of the easel, and a basic electrical flow diagram.

Figure 1 - Block Diagram for Easel Operation

![Diagram of easel operation]

- Put canvas on unit
- Turn on master switch
- Use joysticks to make easel move to desired position
- Easel moves to users desire
- Put easel away for storage
- Turn off master switch
- Paint
The design will essentially be a swing arm attached to a base unit which will be seated on the table. The motor will be light-weight and not too powerful so that it can control the motion of the easel and keep it safe for the user. The swing arm will be responsible for balancing most of the weight for the easel. The actuators will be attached to different parts of the swing arm so that it will be easily adjusted when the user asks for it to move. This design joins the up and down motions with the front to back motions making this design more compact and smoother to use. The tilt of the easel will be operated by a linear actuator from the canvas.

There are multiple safety features that our design includes. We are making sure that all the wires are safely attached and not exposed to anyone who might be tempted to tug or pull them out. We have also included a master on/off switch that lights up that will allow a supervising attendant to decide when the operator is done or in case of an emergency. This switch will be placed in the back of the easel so that it is not easily accessible to people who aren’t authorized to use it. We have also ensured that the movement of the easel itself is not too fast with the actuators or that it will overextend beyond its maximum range. This is done through the use of adjustable limiting switches which we will preset for the client.

In order to properly limit the speed at which the arm will rotate, bevel gears of specific ratios will help to slow down RPM values of the shaft. Obviously the easel cannot move at dangerous or uncontrollable speeds. Bevel gears will allow for circular motion to be transferred perpendicularly to a given axis. Thus, the motor can be properly situated within the base and perform efficiently. Diameters for the gears have been decided to be 12” and ½”, providing a sufficient ratio to slow the RPM values. This is discussed further in the mechanical analysis portion of the design. These gears will be fabricated at the UConn machine shop.

The easel frame for which the artist’s canvas will sit has been modified from the original design. Steering away from the classic “A” frame model of an easel stand, here, 1” x ¼” flat-stock aluminum will be used to construct a more “H” styled easel frame. The top clip will be adjustable ranging from 9” to 24”. The bottom lip will support the canvas securely, supporting a reasonable canvas width (no greater than 40”). ¾” diameter drill holes will provide one inch adjustments, allowing for a wide range of intricate canvas sizes. The supporting screws will be easy to tighten wing nuts. Again, since the type of canvas may differ from painting to painting, a diversely supportive easel frame must be able to accommodate all different types of canvas styles. Our design has accomplished this goal. A diagram of this new style is seen in Figure 2 on the next page:
As stated, this design differs greatly in the approach used to move the easel. After establishing the use of the “Flat Panel Monitor Positioning Arm” for the backbone of the easel, the process on how to electrically control and move the canvas became a complicated task. The positioning arm will remove most of the structural metal needed, as well as the need for drawer tracks. Ideally, installing actuators within the prefabricated arms would safely prevent anyone to tamper with dangerous moving parts. However it is hard to configure this arrangement due to the dimensions and sizes of actuators. The base of the easel will be made of sheet aluminum, and contain the gear motor, bevel gears, and all electrical circuitry needed for the project. Cubbies and drawers for painting supplies can also be added into the base. The basic design of this easel including actuators and a description of the alignment of gears and motor is seen on the next page.
Mechanical Analysis

Horizontal movement of the easel will be achieved by rotating the pivoting shaft of the arm’s base around our fabricated aluminum box. In order to achieve a reasonable tangential speed of the swing arm supporting the canvas, the RPM value of the gear motor and integration of bevel gears must be calculated. The advantage to using this gear motor hidden within the easel’s base is that now the artist can rotate the easel 360 degrees, never having to move the base to showcase his or her artwork to a classroom. Also, the table which the easel is mounted to can be rotated in any direction, moved anywhere in the room, and using our design, the easel face can always be adjusted to the front of the user. Again, the speed at which the easel’s arm rotates is a crucial limiting factor for the type of gear motor needed. Using a 12 VDC gear motor with high output torque, we can achieve the proper torque requirements for moving two bevel gears with a 24:1 ratio. This is attained by using two bevel gears, one being a .5 inch diameter attached to the shaft of the motor, and another 12 inch diameter gear welded to the shaft of the arm within the base. A gear motor running at 5.98 RPM with a torque stall at 65 in.-lbs has been determined to be a sufficient and affordable item for our project. To calculate the tangential speed of the easel, the arms projection range of 22 inches is needed.

\[
\frac{5.98}{60} = .1 \text{ rotations per second.} \quad .1 \times 2\pi = .628 \text{ radians per second}
\]

Using the 24:1 gear ratio:

\[
\frac{.628}{12} = .05236 \text{ radians per second. This is the rotational velocity of the shaft attached to the swing arm. Multiplying this value by the projection range, (the maximal excursion from the point of attachment to the base) we can get an accurate estimate of the tangential velocity of the easel face.}
\]

\[
.05236 \times 22 = 1.15 \text{ inches per second. We have decided that this value is an acceptable speed for controlling and responding for the horizontal motion of the easel.}
\]

The mechanical properties of the easel arm or stand needs to be statically analyzed as well. From the specifications of the positioning arm, its weight is assumed to be 7 lbs. We will assume that the easel frame and canvas will combine to have a weight around 2 lbs. The static analysis of the stand can be seen on the next page.

Another important feature to consider is the torque stall characteristics of the motor, and whether or not the selected gear motor will be able to contend with the applied forces. Moving in the horizontal direction, the centripetal force of the easel moving around its pivoting point will counter the drive of the motor. A 2 lb load, 22 inches from this point gives a torque of 44 in.-lbs. The center of gravity for the positioning arm is hard to evaluate, since weights for the individual parts are currently unattainable. Summing the weights of the two 1 lb. actuators and the 7 lb. stand, we will assume the center of gravity of this portion is roughly half the total distance of the maximum projection range. Thus, 9 (lbs) x 11” gives 99 in-lbs. Other factors to consider include friction of the stand. Using pivoting bearings or greasing the cylinders of the shaft will negate most to all of the frictional problems induced by the movement. All together the torque about the pivoting part of the arm will be 143 in-lbs. Using a 12”
diameter bevel gear in conjunction with a \( \frac{1}{2} \)" diameter gear attached to the drive of the motor, a required torque of 5.95 in-lbs is required. This value will be more than accommodated for with our high output torque motor with a stall quantity of 65 in-lbs.

The actuators in this design are also remarkably different in function than our first easel. Here, only two actuators will be used, where one will control tilting functions of the easel face attached at the top of the swing arm to the back of the newly design easel frame, and the second will control the tilting arm, adjusting forward to back and up and down functions simultaneously. As this actuator retracts, the swing arm will rotate down and out along a circular path in the side-view plane. Using a linear actuator with a 5 inch travel distance, a total tilt range of -23 degrees to 30 degrees from the vertical can be attained. This should be an acceptable range for Harry. These dimensions can be seen in figures 3 and 4 below.

The actuators under consideration are 115 VAC Linear Actuators. Actuator B will have a travel length of 5” as stated, while Actuator A (see Figure 5) will have a travel distance of 8”. Both actuators maintain the same constant speed of 14 in/min (0.2333 in/sec), which again are relatively slow speeds to allow for easy control.

**Figure 3 – Drawing Surface Tilted Downward**
Figure 4 – Drawing Surface Tilted Upward

Figure 5 – Easel Design with Actuators and Motor
Electrical System

The electrical system controlling the easel is a vital component in the overall functioning of the system. While it requires little mechanical design, the mechanism controlling current flow throughout the system must be efficient, practical, and reliable as it powers the both the actuators and the motor which are perhaps the most important modules in the design.

The easel itself will be powered by 120 VAC which will be supplied from a standard wall socket. The ground terminal of from the socket will be attached to the aluminum frame of the easel to protect against any electrical shocks in the event of an accident. The 120V line from the socket will feed into a single-pole-single-throw switch which will be mounted to the frame and serve as a master control for the easel. By turning the switch off, all current flow to the easel and its circuit is halted. The output leg of the switch and the neutral line of the socket will then be run into a transformer and the voltage will be stepped from 120VAC to 12VDC. The majority of the electrical system will run on the 12VDC power.

The actuators used in the system will run on 120 volts AC and at a full load will draw 1.6 amps. The motor being used is rated at 1.3 amps under full load and runs on 12 volts DC. Because a maximum of two actuators or one actuator and one motor can be run at any time the total current draw for the circuit should not exceed 3-4 amps. To protect against this, a fuse will be inserted into the +12 VDC leg from the transformer. Any circuit portion drawing more than 5 amps at any given time would indicate a malfunction with the unit. The +12VDC and ground legs from the transformer will then run to power a series of relays as well as the motor. Four relays will be used to control the current to the two actuators and an additional two relays will control the motor. The relays for the actuators will be double-pole-double-throw and rated for 5 amps at 120VAC. The main terminal of each pole will be connected to +120VAC and neutral respectively. The normally closed terminals will be left unwired, and the normally open terminals will be wired to the two legs of the actuator. Two relays are needed for each actuator; one to control extension and a second retraction. This is because the direction of the actuator is controlled by simply reversing the wire connections. Therefore each set of 2 relays will be wired oppositely. The relays for the 12 volt DC motor will be wired similarly, except that they will power the motor with the transformed 12VDC supply.

The joysticks used to control the movement of the easel consist of a 4 directional handle and 4 separate momentary micro switches – one switch for each direction. Because these switches are not capable of carrying the high amperage load of the actuators, each switch will be connected to a 12 VDC supply. The output of each switch will be wired to one end of the coil on one of the relays. The second end of the relay coils will be connected in parallel to ground. As a result, when one of the joysticks is moved in a certain direction, the micro switch will be activated. This will allow the 12VDC to power the coil in a particular relay. The relay mechanism will then engage the contacts on its poles and allow the actuator to be powered.

This design allows for more than one actuator to be active at a time by using the two joysticks. However, because of the mechanics of the joystick, only one direction of any actuator can ever be active at a time. A full circuit diagram can be found in Figure 6.
Budget:
Total = $750.00 allowed

(2) Actuators ....................... $34.95 ea.
(1) Surface mount Swing Arm ....................... $312.50
(2) Joysticks ....................... $15 ea.
(8) Relays ....................... $70 Magnecraft General Purpose
Part # 92S7D22D-12D
(1) Gear motor ....................... $11.95 Surplus Center
Part # 5-1552
(1) Lighted Push Button Switch ....................... $13.95 Surplus Center
Part # 11-2428
Miscellaneous ....................... $60 (bevel gear)
Aluminum ....................... $0 (donation)

$568.30 (All parts will require a shipping charge as well)

Timeline:
A timeline for the project can be found attached to this report.

Conclusion:
Designing the most efficient adjustable easel is a task that involves intricate evaluation of mechanical, material, and electrical principles of a device. After gathering a variety of information and doing a surplus of research, a well developed plan as to the fabrication and achievement of the easel has been derived. Specified dimensions, movements and safety features have all been incorporated and integrated within this design.

References
Surplus Center Catalog 278. Lincoln, NE. 2005. (402 474-5167)
Static Analysis of Stand

\[ M_{\text{stand}} = 7 \text{ lb.} \]
\[ M_{\text{surface}} = 2 \text{ lb.} \]

**Raised**
\[
\sum M_{\text{base}} = (-2)(20) - M
\]
\[ M = -40 \text{ in} - \text{lb} \]
\[ \uparrow \sum F_B = -7 - 2 = -9 \text{ lb} \]
\[ A_B = \pi(1)^2 = 3.14 \]
\[ \sigma_B = \frac{-9}{3.14} = 2.87 \text{ psi (compression)} \]

**Lowered**
\[
\sum M_{\text{base}} = (-2)(20) - M
\]
\[ M = -40 \text{ in} - \text{lb} \]
\[ \uparrow \sum F_B = -7 - 2 = -9 \text{ lb} \]
\[ A_B = \pi(1)^2 = 3.14 \]
\[ \sigma_B = \frac{-9}{3.14} = 2.87 \text{ psi (compression)} \]

**Extended**
\[
\sum M_{\text{base}} = (-2)(24) - M
\]
\[ M = -48 \text{ in} - \text{lb} \]
\[ \uparrow \sum F_B = -7 - 2 = -9 \text{ lb} \]
\[ A_B = \pi(1)^2 = 3.14 \]
\[ \sigma_B = \frac{-9}{3.14} = 2.87 \text{ psi (compression)} \]