Concept Development

EML 4551C – Senior Design– Fall 2012 Deliverable

Team 10 – CISCOR Autonomous Ground Vehicle

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Introduction

The focus in this deliverable will be to introduce the concepts and designs for the multiple locomotion components of the Center for Intelligent Systems, Controls and Robotics (CISCOR) Autonomous Ground Vehicle (AGV). Under the direction and sponsorship of CISCOR, this group was tasked with modifying an existing all terrain vehicle (ATV) to be capable of full autonomous movement. This goal is to be achieved by designing, researching and manufacturing components to allow full-unmanned locomotion control. Currently there is no off road vehicle platform for autonomous research and development in CISCOR's inventory. Thus, this group was instructed to retrofit such ATV to accommodate such research platform. The ATV platform for this project is the 2012 Polaris 550 Sportsman ESP.

Multiple private research organization as well as higher education institutes have used all terrain vehicles for autonomous design, research and development. This deliverable will also briefly introduce the more notable AGVs that have already been designed and used for such purposes as listed above.

Locomotion control will be the focus of the concept generation and design illustration. The concepts and designs proposed in this deliverable will be divided into four different subcategories that include: Steering, Braking, Gear Shifting, and Throttle. Within each subcategory, the respective component's objectives will be stated as well as the corresponding measureable components.

Previous Designs

Carnegie Mellon University - The Robotics Institute

Figure 1: CMU’s Autonomous Ground Vehicle

At the Robotics Institute at Carnegie Mellon University, the following AGV was produced as a platform for military surveillance. This project features the same locomotion controls as this group’s design however, this design only allows for autonomous computer driven locomotion.

University of North Carolina – Chapel Hill

Figures 2: UNC’s Autonomous Ground Vehicle

At the University of North Carolina – Chapel Hill, the following was produced for the purpose of autonomous research and development; much like the purpose for which CISCOR’s AGV will be used. The vehicle platform is a single cylinder Honda all terrain vehicle. This design, much like the CNU’s design is only intended for unmanned locomotion.

Stanford University – DARPA Grand Challenge Project

Figure 3: Stanford University 2004 DARPA G.C. Winner (Project name Stanley)

This project came from Stanford University DARPA Grand Challenge Project. This is a full sized off road vehicle retrofitted with the same locomotion control mechanism as this project. This project however is much more elaborate, costly, and advanced compared to retrofitting an ATV with locomotion controls. This project was entered in the 2004 Defense Advanced Research Projects Agency (DARPA) Grand Challenge. This challenge involves a lengthy and treacherous off road race where vehicle must start and finish the race solely on autonomous locomotion. In 2004 Stanley, the vehicles name won the race.

Locomotion Concept Generation

Steering Locomotion

The process of actuating the steering system has three main objectives. The first objective is that the ATV will operate with full range of motion. The objective will be accomplished in two steps. The first step will be to measure the turning angle in degrees of the steering column. This will help us greatly with the second step of designing a system that allows for the amount of travel required. The second objective is that the steering system will be able to withstand feedback from the terrain. The necessity of this objective is mainly to protect and preserve the equipment used. This objective can be accomplished in one of two ways. First, the system inherently can block the feedback by only being forward driven motors. The second way is to design a system with components that can compensate for the feedback received. Determining the amount of feedback will be difficult and the data acquired will most likely be from trial and error type experimentation. The third objective is to used a motor for any design that will provide enough output to steer the ATV on any terrain at any speed. This will be accomplished by measuring the force in Newtons required to turn the steering column on various surfaces.

Design I

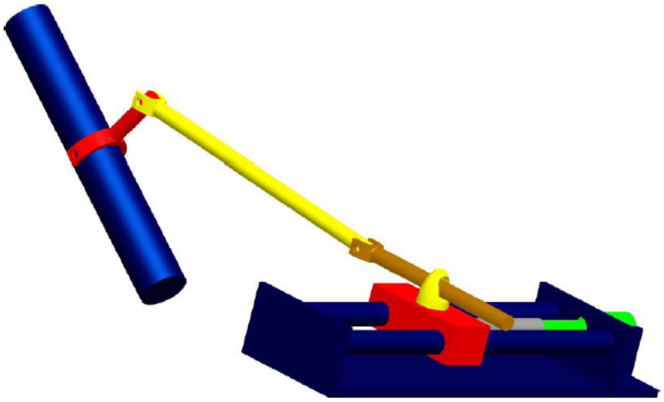


Figure 4: Design 1 (Steering)

The first design for the locomotion control of the steering system is presented in Figure 4. The system works by moving a sliding joint with one or two linear actuators along a rigidly mounted slide. The sliding joint will be connected to pin jointed "arms" that connect to the steering column. The "arms" will act as a third handlebar coming off the front of the steering column. The pin joints are used for two reasons. First, since the steering column is at an angle, the joints allow for vertical travel in the system. Second, the pins will be removable so that the system can easily put into user mode.

Pros:

- Long moment arm allows for less powerful actuators
- Having two actuators compensates for failure with one
- Pin-jointed shafts allow for system to conform to body shape with no unsightly protrusions
- Pin joints allow for easy disconnect

Cons:

- Multitude of parts yield higher possibility of failure
- Higher cost than other designs
- Pin joints can fail due to debris
- Programming two actuators to work together can be difficult
- Full range of motion is hard to achieve

Design II

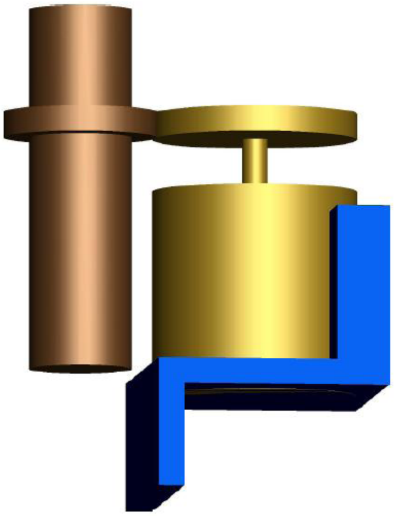


Figure 5: Design 2 (Steering)

The second design for the automation of the steering system is presented in Figure 5. This design is extremely simple using only a gearing system, a DC motor, and a fabricated mount. The mount will be rigidly attached to the frame of the ATV. Attached to the mount will be the DC motor geared to the steering column. This design will allow us to use one of a number of gear ratios to provide us the chance to choose from a larger number of motors. Using a DC motor will also allow the system to be user friendly as soon as power is cut to the motor.

Pros:

- Least amount of space required
- Least amount of parts required
- Lowest cost
- Simplest mounting requirements
- Allows for full range of motion

Cons:

- Small moment arm requires more powerful motor
- Debris can get caught in gear teeth
- Difficult to disconnect

Design III

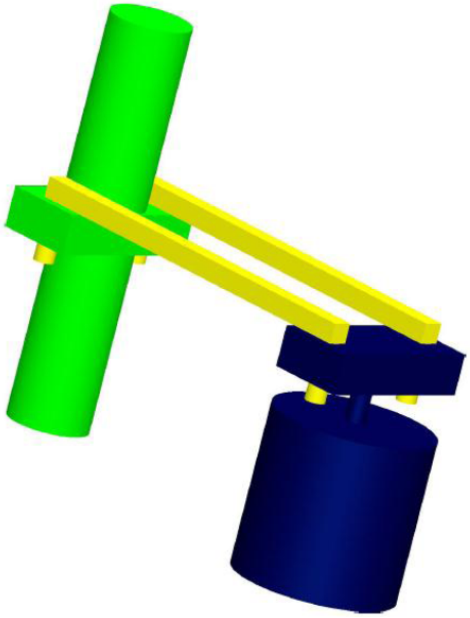


Figure 6: Design 3 (Steering)

The third design for the automation of the steering system is presented in Figure 6. This design works similarly to the steering system on a remote controlled car. The motor will turn a fabricated block with two "arms" attached similarly to revolute joints. The other end of the "arms" will attach to another fabricated block rigidly attached to the steering column. As the motor turns, the steering column will turn the same angle with the same angular velocity.

Pros:

- Larger moment arm requires less powerful motor
- Low cost
- Pin joints allow for easy disconnect

Cons:

- Full range of motion is hard to achieve
- Pin joints may fail due to debris
- Long shafts may deflect when encountering feedback from terrain

Braking Locomotion

For braking locomotion, a manner in which the vehicle can safely be brought to a halt must be devised. It was decided that devising an entirely new braking system was inefficient and possibly would lead to unsafe or unstable operation. Thus, to accomplish this task, the new braking mechanism will tap into the existing braking system with a computer controlled input component. After studying the existing braking system and its operation, three concepts were devised to achieve the goal of autonomy.

The existing braking system uses a lever to convert the riders gripping force into translational motion onto a small piston (shown in Figure 7). The depression of this piston cause the master handbrake cylinder to translate as well, which allows brake fluid to flow from the reservoir into the braking system. This fluid pressurizes the system, which causes the brake calipers to engage, bringing the vehicle to a stop. Force required to brake measured in Newtons and brake fluid pressure measured in Pascals will be required for design selection.

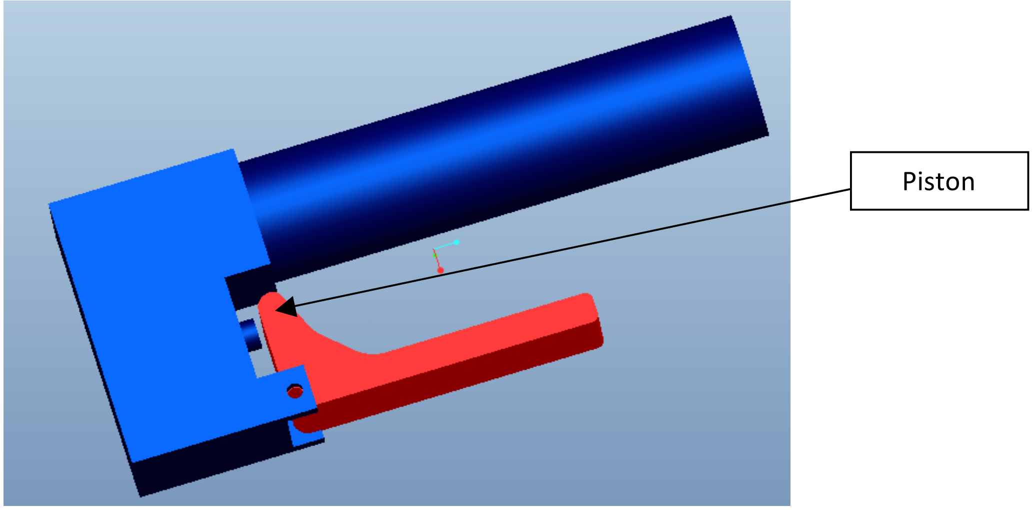


Figure 7: Current Braking System

Design I

The location, accessibility, and the easily reproduced linear motion allowed for the implementation of a simple, autonomous system that would act directly on the piston, thus operating the brakes. To access the piston, a hole must be drilled through the braking lever. Then, a linear actuator would be aligned with this hole, brought into contact with the braking piston in its at rest position, and locked into place. The motor would be mounted into place with a clamp that would be mounted in turn on the handlebar of the vehicle. See Figure 8 below for the configuration.

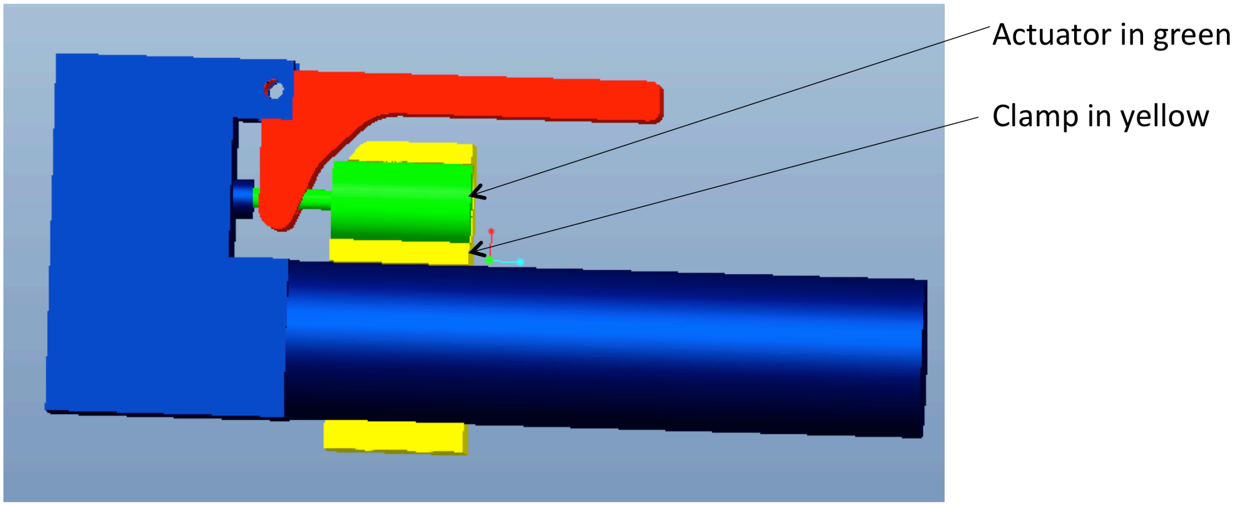


Figure 8: Design 1 (Braking)

This concept would require very little modification of the existing braking system, eliminating potential sources of failure in the system itself. It would also be a responsive system as the actuator could quickly achieve the small amount of translation necessary to fully depress the piston. The system accuracy would be high due to the direct action of the actuator upon the braking system. Unfortunately, due to the location of the piston, this automated system would have to be removed from the vehicle before a rider could operate the vehicle, as the brake lever could no longer be depressed. Removing the clamp attachments to the handlebar and removing the automated system to be placed in storage would accomplish this.

Pros:

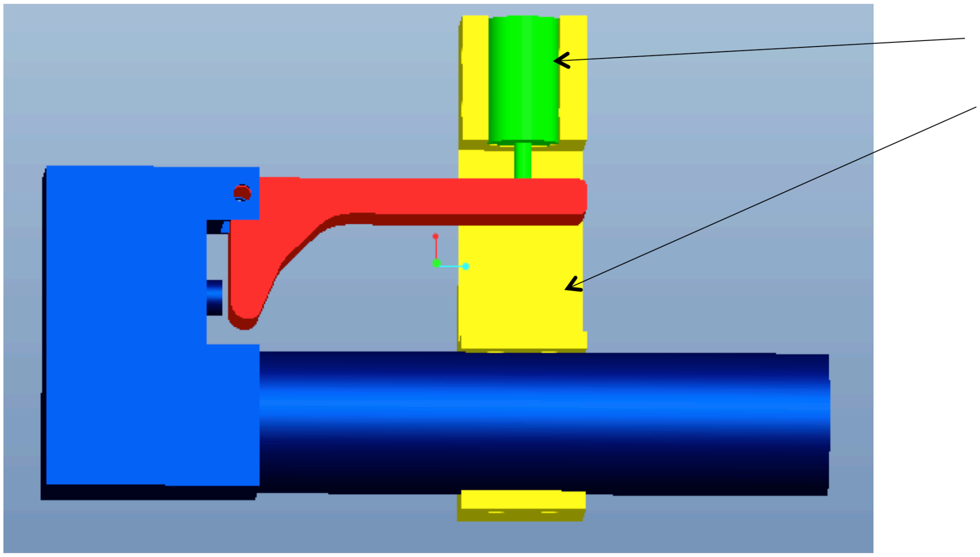
- Small modification
- Easy to mount and implement

Cons:

- Requires removal for user operation
- Slow reaction time

Design II

The second concept used a linear actuator to give the closest approximation of the input received by the existing system from a rider operator. To do this, the lever must be depressed back towards the handle so that the piston will be depressed. Mounting a linear actuator in front of the lever, and allowing the actuator motion to depress the lever would accomplish this. The configuration is shown below in Figure 9.



Actuator in green

Clamp in yellow

Figure 9: Design 2 (Braking)

This system would require no modification of the existing braking system, eliminating potential sources of failure in the system itself. This system would require a larger range of translational motion to adequately brake the vehicle, which would reduce responsiveness and accuracy. This systems location in front of the lever would necessitate its removal before rider operation so that the lever can be accessed. Removing the clamp attachments to the handlebar and removing the automated system to be placed in storage would accomplish this. This system is least aesthetically pleasing concept as well.

Pros:

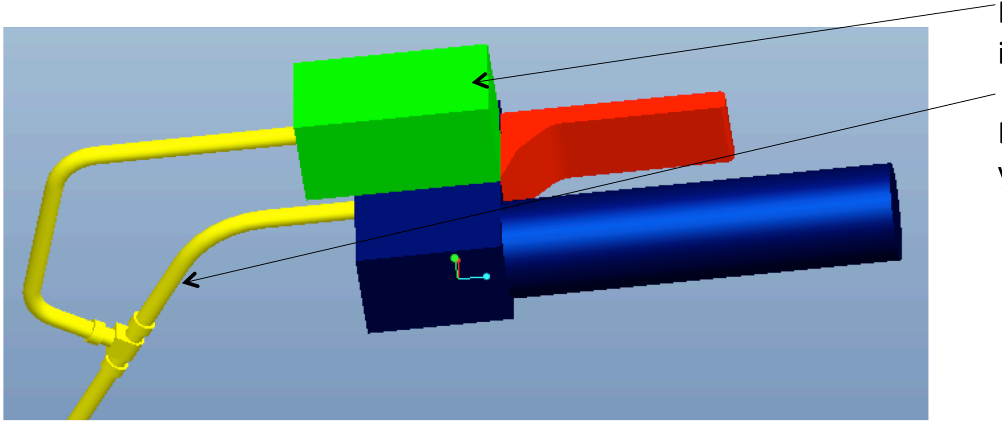
- No modification
- Easy to mount and implement

Cons:

- Requires removal for user operation

Design III

The third concept was to use an electrically controlled master cylinder to mimic the actions of the existing master cylinder, thus bypassing the need for an actuator to operate on the existing braking system. To do this, the new master cylinder would be mounted somewhere on the vehicle. A line would be run from the new cylinder and spliced into the existing brake line. The configuration of this design is shown in Figure 410 below.



Master Cylinder in green

Brake lines in yellow

Figure 10: Design 3 (Braking)

When the new master cylinder is not in operation, it has effect upon the braking system. This system would not have to be removed from the vehicle to allow rider operation. It would also allow the highest degree of accuracy for the control of the braking system. This concept was the most aesthetically pleasing concept.

Pros:

- Small modification
- Easy to mount
- Does not require removal for manual operation
- Most accurate control

Cons:

- Modification to brake line
- Costly

Gear Shifting Locomotion

In order to accomplish the overall project scope, the phase of automating the shifting must be completed. Several goals must be set in order to make sure this process is completed. First and most obvious is moving the shift arm back and forth between drive selections. The actuator will need to also accomplish the full range of motion. In order to move the shift arm a lateral force will need to be overcome and the distances of each drive select to be able to locate the five different possibilities. The actuator will need to be able to be back driven in case there is a power loss to the computer. In order to make the process be both automatic and manual a Graphical User Interface (GUI) will be installed in between the handle bars to allow the user to manually override the computer and select whatever drive select is necessary.

The measurable objectives will be fully completed by overcoming certain tasks. Upon completion a specific actuator and mounting system will be defined allowing the order process to take place on time. One of the most important tasks is to measure the maximum distance the shift arm can travel and the respective location for each drive option. After the locations are determined the amount of force required to move the arm between locations will need to be determined. This can be accomplished by using a spring or scale with a known stiffness. By attaching the spring to the shift arm and measuring the displacement of the spring required to move the arm, the total force can be calculated. It will be necessary for the actuator to be able to overcome this force in both the push and pull directions. In addition, the shift arm still needs to be able to receive user input in the instance that there is power loss to the system that results in the actuator to be back drivable. Mounting brackets to minimize resulting forces need to be designed for the actuators and the GUI interface.

Design I

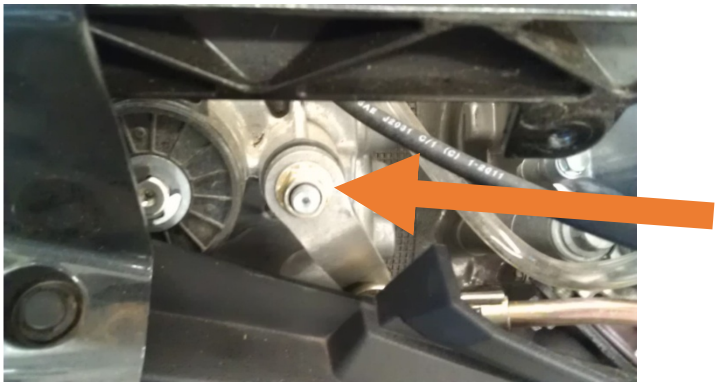


Figure 11: Design I (Gear Select) utilizing a servomotor mounted directly to input of drive select on motor block illustrated by the arrow.

A servomotor will be used to rotate the drive select input directly. The shift arm and mechanism would need to be completely removed so servo could be attached. By rotating the servo the motor would shift between drive select options.

Pros:

Design one is a very simple and direct idea. This would allow for basic programming and input from the computer. By directly mounting the servo to the drive input, extra moving parts are eliminated completely.

Cons:

The biggest con in this design is eliminating the mechanical advantage of the shift arm. The servo would need to overcome a high amount of torque and be accurate over a small angle. Second, mounting the servomotor would be extremely complicated as there is little mounting space and mounting brackets. Also, this design concept doesn’t accomplish all of the necessary tasks. It wouldn’t be able to have user input if power was lost to the system.

Design II

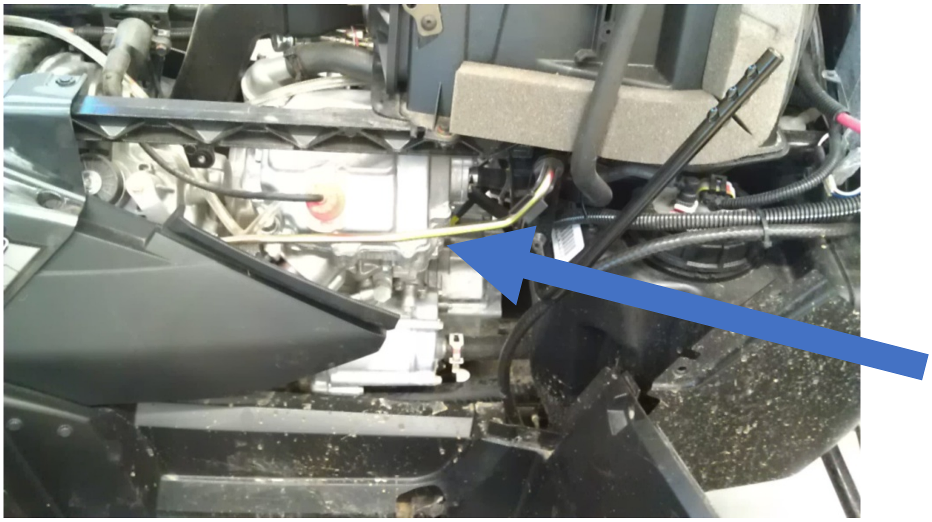


Figure 12: Design II (Gear Select) with an arrow illustrating the translation four bar mechanism that functions as the shifting arm.

The second design concept approached was removing the shift arm and installing a linear actuator to the translating arm connecting the shift arm to the drive select input. Linear motion from the actuator would move the translating arm resulting in the ability move between the five different drive options.

Pros:

One of the best qualities of this design was the use of a linear actuator. This would allow for a fair amount of lateral force with an accurate and repeatable motion. Programming would be reduced due to the ease of linear actuators. Overcoming the force required for drive selection would be easier than the Design one due to the increased distance traveled and the same force.

Cons:

Again, like Design one, the biggest problem lays in the mounting configuration. Because one of our measurable objectives is for the ATV to have to option to be user driven, this design is not feasible. It would limit the ability for the user to select the proper drive select option if the system were to lose power. Also, by locating the linear actuator on the translating arm, access the emergency brake would be limited.

Design III

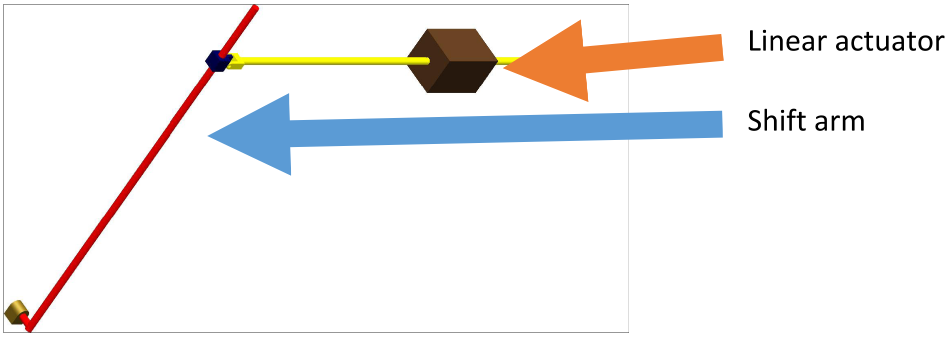


Figure 13: Design III (Gear Select) with corresponding shift arm and linear actuator labels

What turned out to be the best option for automating the shifting was utilizing a linear actuator and the mounting support plates located on the front of the ATV. The linear actuator will be directly mounted to the front support plate. A small hole will be drilled through the plastic body of the ATV allowing the arm of the actuator to be coupled to the shift arm. The linear actuator will be able to overcome the force required to locate the shift arm in all the drive select options. Due to the internal bearing of the actuator, it has the ability to be back driven. This allows full control by the user if power loss to the system. In order to make the AGV more modernized, a GUI (graphical user interface) will be installed in between the handlebars. This will allow the user to switch between autonomous and manual, in addition to the individual drive select options.

Pros:

When compared to the other two designs, Design II has the optimal mounting capabilities. By using a linear actuator, the ability to locate the shift arm becomes very accurate with great repeatability. Just like Designs I and II, programming the actuator and integrating into the system will come with ease. Also, the ability for the actuator to be back driven eliminates the need for a disconnecting mechanism reducing the number of parts required.

Cons:

One of the main problems with this design is that the shift arm pivots about a point located lower than the axis of the actuator. This imposes to effects that have to be considered. The first is the shift arm moves through an arc motion. Second, due to the arc motion, lateral forces will be induced on the actuator. In order to overcome this situation, two options will be discussed; option one, making the mounting mechanism slightly flexible in the vertical direction only, option two, making the coupling mechanism able to slide up and down the shift arm.

Throttle Locomotion

In order to accomplish the overall project scope, the phase of automating the throttle must be completed. Several goals must be set in order to make sure this process is completed. First and most obvious is moving the throttle lever between the zero position and the forward acceleration position. A servomotor will be utilized to also accomplish the full range of motion. In order to rotate the throttle lever a lateral force will need to be overcome and the distances of the full range of throttle will need to be calculated. The force will be calculated and measured in Newtons and the distance of the full throttle range will be measured in degrees. For calculating the force, springs with a known spring constant will be utilized and displaced. For measuring the displacement of the throttle, simple measuring devices will be used such as digital protractors. Note that the designs in this subcategory are very simple and cheap.

Design I

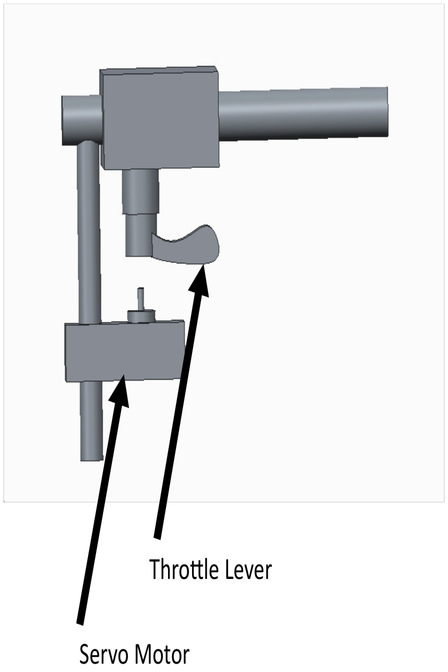


Figure 14: Design 1 (Throttle)

Design II that is illustrate in Figure 14 utilized a simple waterproof servomotor mounted on a rail. The height of the servomotor can be adjusted according to which operation the ATV will run at (human/autonomous). In autonomous mode, the servo will slide up into the fabricated pinhole on the bottom of the throttle arm. It will them be able to turn the throttle arm without human interaction. In human mode, the servo will just slide down allowing access to the throttle lever.

Pros:

- Cheap
- Easy to mount and implement

Cons:

- Requires adjustment for user interaction
- Not enclosed

Design II

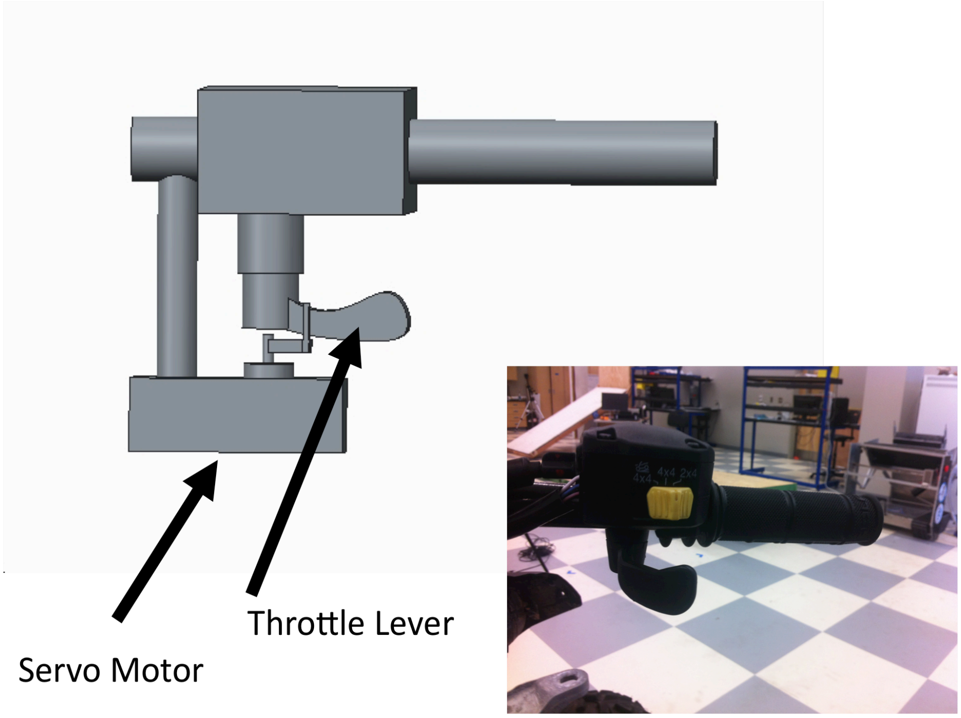


Figure 15: Design II (Throttle) with actual throttle picture from ATV

Design II that is illustrated in Figure 15 is comprised of a fixed height servomotor and a turning arm. Since the throttle lever is spring loaded it will return to the zero position without the need of an additional input. Therefore, this design will allow for both autonomous and human interaction at any point without the need for adjustments. If in autonomous mode, the turning arm attached to the servomotor will be activated and turned. This will cause the throttle arm to turn and accelerate the ATV. Once the servomotor returns to the zero position, the throttle level will as well return to the zero position.

Pros:

- Cheap
- Easy to mount and implement
- Enclosed
- No adjustments for user interaction

Cons:

- More complex design
- More difficult to service

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