Smart Garage Goor - Mechanics

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0. Abstract

This project is a new approach at the functionality of a garage door by integrating some additional electronic components to it in order to make its mechanical functionality smart, more efficient, and more suitable to the current demand of the market. It is designed in order to create a better garage door that is able to function autonomously by including several different components including sensors, actuators and microcontrollers.

1. Introduction

The necessity for doors is somewhat obvious and requires little discussion. Creating a space that is secluded from the climate, the weather, animals and other people is a basic requirement for every individual and their possessions. Naturally it is necessary to occasionally enter or leave such a place, but still have it sealed and thus doors exist. Since the beginning of the 20^{th} century automobile ownership has risen exponentially, and so has the impact they have on our lives. Cars have increased in complexity, reliability, security and efficiency. They have changed the way we communicate, the way we move around and they way we preform even the most basic tasks in our lives. They have significantly changed the choices we make in architecture in both a macro and a micro scale; excellent examples of this are the suburban sprawl that is so ubiquitous in the USA, and the garage.

Cars are not constantly in use and with the skyrocketing rate of automobile ownership, the need arises to park them somewhere. Curb side parking is a viable solution, but cars are expensive and parking them on the curb exposes them to many of the environmental factors that cause us to build buildings in the first place. Of course parking a car on the curb also exposes them to the most dangerous thing of all, a menace that is ever lurking in the streets, other drivers. The obvious solution is to bring them off the street into a safe place where they are not exposed to the environment.

2. Purpose and Scope of Work

Many people would like to bring their cars inside their home or a purpose built structure. This presents yet another problem however: you can't drive most cars through a standard size doorframe. The initial solution is to scale up the door. This is heavy and unwieldy; double doors are closer to the ideal but the need to close them after backing the car out is not ideal as it has to be done manually. A sliding door can be powered very simply with a motor, but it needs to go somewhere. More than likely there is not enough space to accommodate it going up or left and right; if it were to be going into the ground it would definitely look cool, but it would require the digging of a deep hole to accommodate the door, this is expensive.

This leads to the criteria for the design of a garage door:

- large enough to fit most standard size vehicles,
- secure against the elements,
- secure against uninvited persons,
- reliable
- inexpensive
- compact and unobtrusive
- simple to implement in standard family homes or garages.

3. Overview of Existing Solutions

There are many types of garage doors of varying complexity, one of the more ubiquitous is the articulated spring assisted garage door. Quite obviously our design took significant inspiration from this. Figure 1.

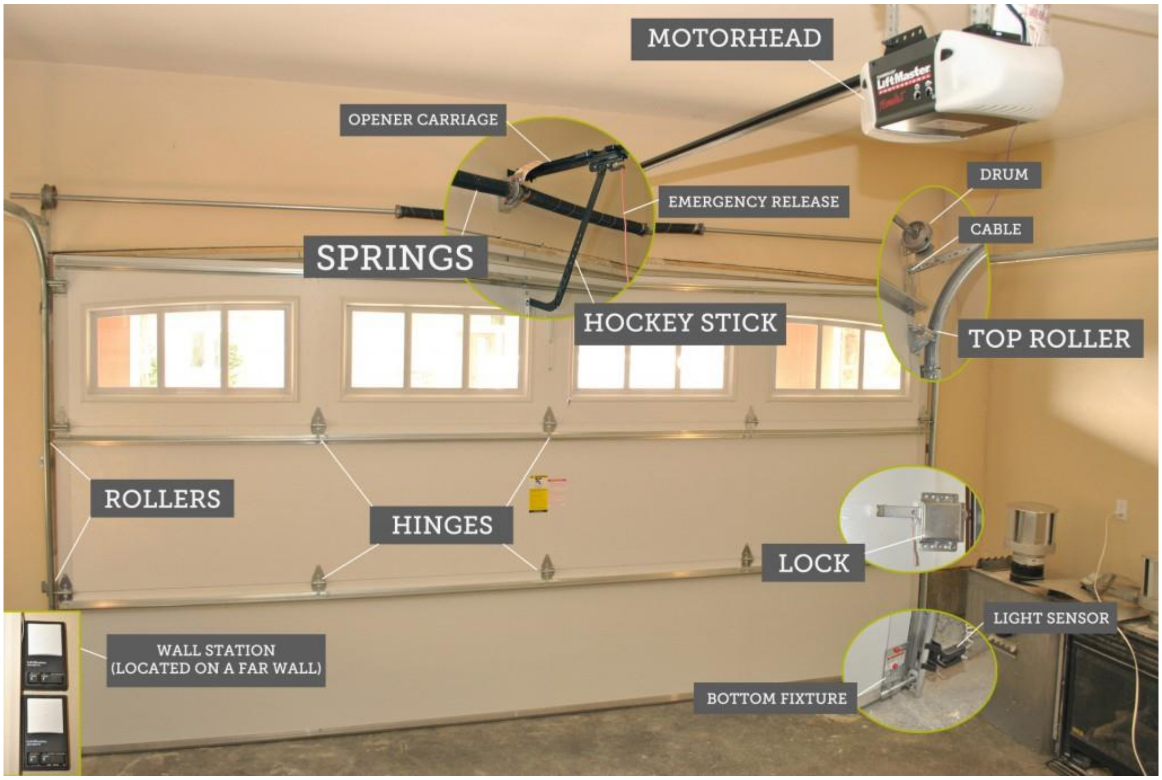


Figure 1 shows the real mechanical design of a garage door.

These doors fill the criteria defined above quite well. They are inexpensive and simple to implement into a basic garage. When they are opened, they hang above the area where the car is usually parked, thus they do not get into the way, and they make use of otherwise unused space. They are simple to operate. The design is simple and reliable, and it is easy to diagnose an issue and replace the necessary parts. A further bonus of this design that it can be easily scaled for different sized doorframes; different door sections can be produced for different widths and vertically. The height of the door is only limited by how much horizontal space you have to roll up the door and the strength of the motor in the lifting mechanism and the spring.

Author’s remark: *I have had significant experience with this design of garage door, they are rather robust even when exposed to sub-optimal conditions. I once repaired a door of this type by hitting it with a hammer when a roller jumped out of the track at a point where this track had been dented. From personal experience I can also attest to the simplicity of the design from the angle of installation. An individual with no experience with these devices can easily install them into a doorframe with only the most basic tools.*

Another example is the single piece garage door, which is similar in principle, however it suffers in execution. This image demonstrates the problem clearly:

The single piece garage door traces a suboptimal path, the door swings out quite far into the street. This is not always a problem, but when a garage is situated next to a sidewalk the opening door poses a danger to unsuspecting pedestrians. Furthermore, it is surprisingly a more complex design incorporating several pivot points, some of which are in motion. This simplifies the door itself but complicates the various components that make it move, this is demonstrated in the second picture. Unlike the articulated door, this scales poorly as well, a larger single piece door makes a greater arc. Shown in Figure 2.

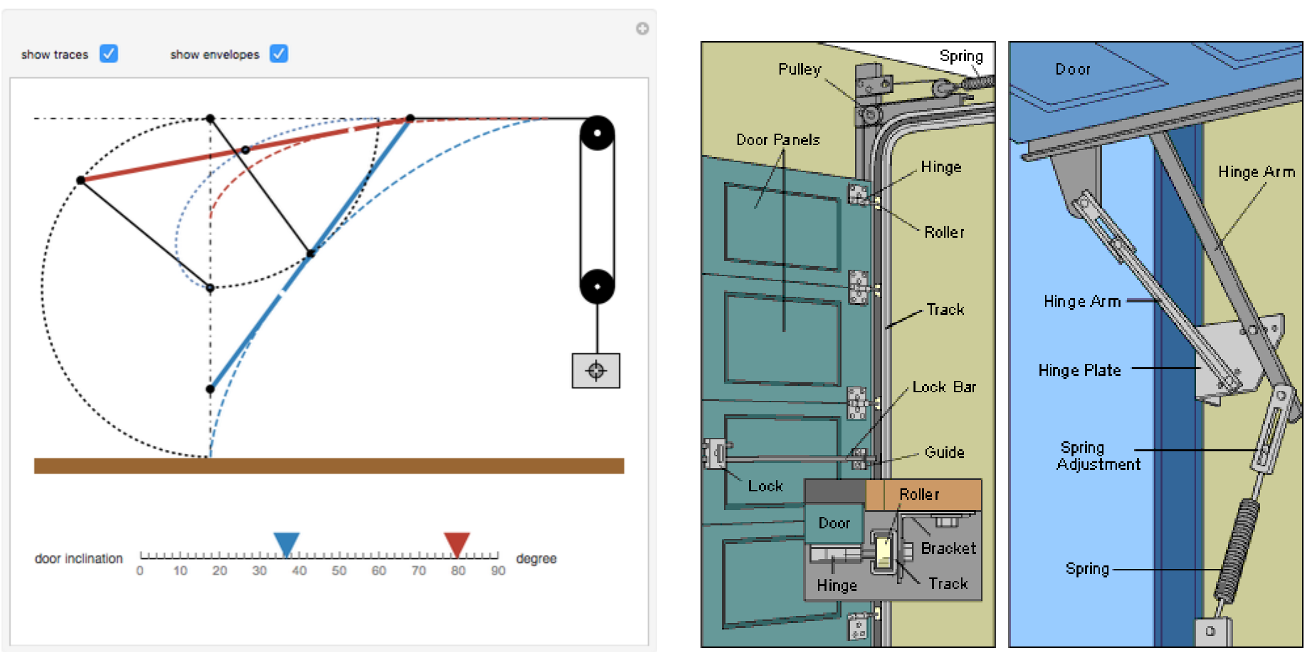


Figure 2 shows a schematic of a real prototype

4. Morphological Chart

1	Garage Door Movement	Belt & Gear Multiplier	Chain & Gear Multiplier		
	reliability	unsatisfactory	relieable		
	number of parts	very low	somewhat low		
	availability of parts	common	uncommon		
	jamming and snagging	almost impossible	somewhat common		
	rigid when not moving	no	somewhat		
2	Stopping the garage door	Proximity Sensor	Touch Sensor	Programming Control	
	simple mechanical solution	yes	yes	no mechanics involved	
	availability of parts	yes	yes	yes	
	faliure proof design	yes	yes	no	
	ease of implementation	difficult	easy	somewhat difficult	
3	Controlling the door from a distance	Proximity Sensor	button	only bluetooth control	
	simplicity	somewhat	yes	easy to make, hard to code	
	availability	not enough	yes	yes	
	price	$$	$	free	
4	Pulling Mechanism	Nylon String	Steel Wire	regular string	
	price	$$	$$$	$	
	availability	yes	no	yes	
	strength	high	highest	weak	
5	Gear Arrangment	Gear Multiplier	Gear Reducer	Belt Gear	worm and gear
	angular velocity (compared to motor)	higher	lower	equal	low
	torque (comopared to motor)	lower	higher	equal	extemely high
	availability of parts	yes	yes	yes	no
6	door design	multiple piece articulated	single piece	horizontally sliding	
	simple design of individual pieces	yes	no	yes	
	simple overall design	somewhat	no	yes	
	smooth operation	somewhat	yes	yes	
	compact overall size	yes	yes	no	

5. Prototype and Testing

The basic premise of the design is very basic: the door is a set of articulated sections riding in a track. The top link is pulled horizontally onto an angled ramp, as it is pulled it also imparts this force onto the link below it, due to the angle, this piece is pulled up and over the angled surface while all the other sections of the door follow. This can be done with as many or as few sections of door as desired. The door does not move far outside of the region that is defined by the track meaning that it is easy to predict and does not take up much space.

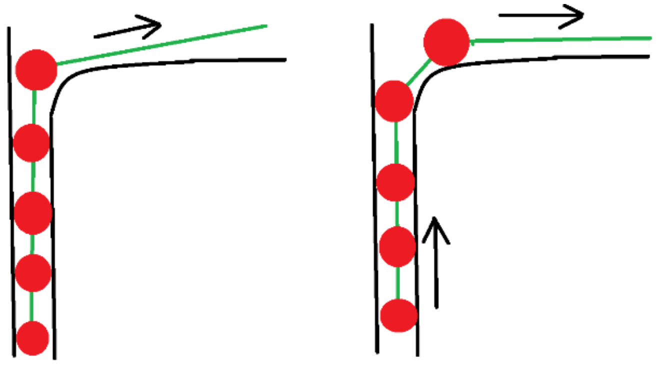


Figure 3 drawing of how the roller slide

This simple drawing, shown in Figure 3,demonstrates how horizontal linear force is translated into the vertical motion of the garage door. It depicts the rollers in red, the connection between them in green and the track in black. The first image shows how the first section of the door must move over the angled surface and slide onto the horizontal track in order to pull the rest of the door behind it and over the angle.

For this design it is also necessary that the last piece of the track to hang over the edge of angle when the door reaches its uppermost position. The force to close the door is imparted by the weight of the last section which pulls the rest of the door behind it when the string holding it in place is unravelled. The design has no way of imparting force to push the door down if it over-travels, this is regulated by having a maximum height to which the last door section can be raised. Building a working prototype is complicated by the nature of the materials used, the rails are made from several sections of lego technix beam, which have rounded corners, the rollers would occasionally get jammed in them at the points where two beams met, especially near the angle, this was solved by taping over the joint with highly adhesive duct tape.

The pulling force on the doors is provided by a string attached to a spindle. This spindle was originally turned by another spindle which was connected to a motor on the bottom of the structure with a rubber band. The motor had to be placed in this position because of the way the test stand was constructed, the construction would have been significantly imbalanced if large weight of the motor was placed near the spindles, thus the need to transfer the force to the appropriate height. It soon became clear that the rubber bands being used were too weak, they were stretched out very quickly. Furthermore, the weight of the door increased as initially only a partially complete door was used to determine the reliability of the system. The method of force transfer changed to a chain and a gear reducer. The gear reducer was introduced because there was not enough chain to reach the upper axel available and we concluded that an increase in torque at the top was desirable. Shown in Figure 4.

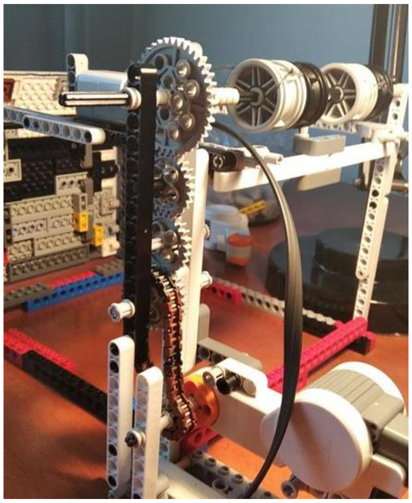


Figure 4 Gear arrangement of our prototype

Another major mechanical solution that had to be dealt with was the hinges of the door. Each would have to have at minimum two one on each side so as to stop it from bending overly. They had to be constructed so that when at rest vertically they would line up well and transfer force linearly, but they had to also be able to bend when force was imparted on them in a certain way. Since we did not have any complex pieces available it was necessary to come up with a clever solution. The edges of the door would not allow the hinge to over rotate outwards. The hinge was connected by a bar that allowed one piece to rotate 180 degrees around the other hinge. This was repeated over all five of the pieces. Unfortunately, due to the shape of some of the pieces, the hinge can get stuck as it is in the second image, this happens because the corner of the rectangular piece into which the connecting bar is attached is sitting proud and the corner of the flat section occasionally interferes with it while the door is closing. This is rare however and with greater availability of better parts, this would be eliminated. Shown in Figure 5.

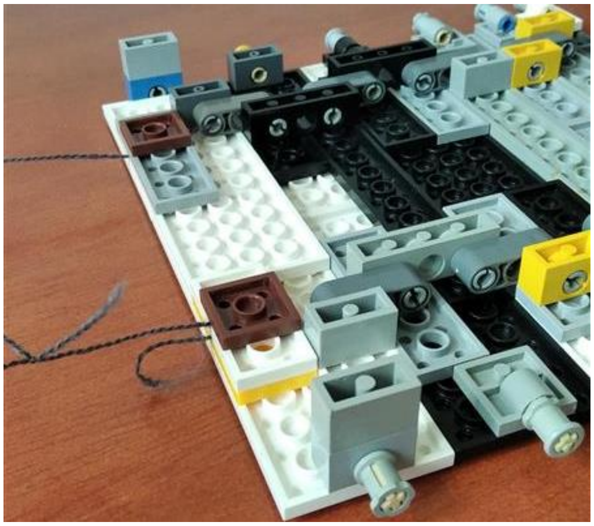
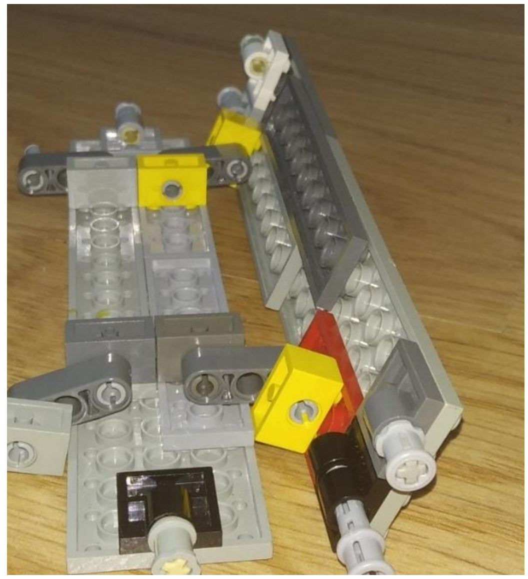


Figure 5 Door assembly and design components



6. Conclusion

From a mechanical perspective, this project has met all the major requirements that we set out to achieve at the beginning, the main changes that could be implemented are replacement of suboptimal elements with different ones that would fit better (eg. The elements in the door hinges could be replaced with ones that have smaller less pronounced corners.) Another design change would be to develop mounting brackets and a mock-up garage so that we could simulate mounting this or another motor to the ceiling of a garage, thereby eliminating most of the support structure and the chain. A spring that rebounds the door could be implemented so the door could be raised higher and more reliably lowered without relying on gravity. Another quality-of-life improvement would be a physical lock that would prevent the door being opened manually as this is currently an issue. Such a mechanical lock would require a sensor that would prevent the motor from operating while it is engaged as it would damage either the motor, or some other element of the system. This project was made with great haste, due to improper coordination and planning, many of the difficulties were due to, bad communication, lack of parts and difficulties with electronic components. The communication problems would more than likely be resolved by making physical meetings more possible and allowing more time to finish the project (as our group started work rather late in the semester). It is our opinion that this very possible and desirable.

7. Bibliography.

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[3] “elektrodoor” -online- (http://www.elektrodoor.co.za/garage-door-basics.html) accessed [06-06-21]

[4] Full project code on GitHub: https://github.com/khaldounfayad/Garage-Door-BoM