Project 1 Report

Team 42

Section 3

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Executive Summary

The project's purpose was to build a mousetrap vehicle system for which the only input energy device was a mousetrap. The objective was to minimize the mass of the car, maximize its velocity and maximize the distance the car could travel. The mousetrap car was also required to pull a soda can sled weighing 200 grams for a minimum distance of 4 inches.

Unique aspects of the finalized design included two front wheels made by 4.7-inch diameter CDs and two rear wheels made by 1.5-inch diameter bottle caps, which were all covered by two layers of rubber balloons. Attached to each of the larger front wheels were two additional bottle caps, which were super glued on the CDs' sides for supplemental support. A tape roll was taped onto two wooden dowels at the front of the vehicle system, and this additional mass was balanced by two screw eye hooks hanging on the rear axle. The mass of this mousetrap vehicle system was centered at the front, driven, wheels.

The mousetrap rested its weight on two wooden dowels, which were connected to the front and rear axles by screw eye hooks. Wooden dowels were also used as axles for the vehicle, wherein each dowel was positioned through straws. The ends of the dowels were inserted through the bottle caps. For maximum support of the wheels, the straws were inserted through the eye hooks attached to the wooden dowels and super glued underneath the body of the mousetrap. This allowed the axles to turn freely without sacrificing any stability of movement. Finally, a ribbon string, attached 1 inch down the lever arm of the mousetrap, was used to aid the propelling mechanism.

The finalized design successfully met 75% of the technical requirements. The mousetrap car pulled the soda can sled a distance of 9 inches at 5.06 inches per second, which surpassed the required distance of 4 inches and average speed of 5 inches per second and met the required mass the car can pull of 200 grams.

Our design, however, failed to accelerate as quickly as required by the technical requirement. The vehicle system was too slow to accelerate after the trigger was pulled, and this resulted in the car remaining immobile and losing the tug-of-war competition against other teams' vehicles.

Design Considerations

The mousetrap car was required to pull a 200g load as quickly as possible while minimizing mass, using only one loaded mousetrap for input energy. In addition, the total worth of the materials of the car could not exceed $8.00. Before any work began, the team organized itself and set a timeline for the project. Then, the team quantified the customers requirements to generate technical needs. From this, two main functions were derived: transforming the potential energy of the mousetrap's spring into kinetic energy for the mousetrap vehicle, and then transferring the kinetic energy of the vehicle to the can. These components of the robot were then evaluated based on how well they completed these functions.

The first thing that the team did was set a project timeline, as seen in the Gantt chart in figure 1. Because the whole of the project only ran for 2 weeks, it was important to keep a strict schedule in order to avoid scope creep, as a 2-day delay spent pursuing unnecessary goals represented more than 10% of the total project time wasted. Next, customer requirements were analyzed and broken down so that they could be systematically solved. Table 1 contains the technical requirements that the components of the vehicle were constantly checked against, in order to ensure that all of the customer's needs were accounted for. Finally, a chart of potential vehicular components, figure 2 in the appendix, was generated in order to prevent the team from sticking with the first ideas that meet requirements, so that better performing and less obvious components would be considered.

The first function, turning the potential spring energy of the mousetrap into kinetic energy of the vehicle, was accomplished by wrapping a string around a wheel and axle, and then attaching the other end of the string to the lever arm of the mousetrap. Therefore, the parameters of interest that could be modified were whether the wheels would be large or small, whether the car would be front or rear-wheel driven, the material that contacts the ground, and the length of the lever arm that would pull the string.

The size of the wheel had a large impact on the speed of the car and the distance the car could travel, as seen in table 2 in the appendix. When small, 1.5" diameter wheels were used, the wheels would spin very quickly and with a lot of force, but often slipped, and barely managed to move 2 inches. The large, 4.7" diameter wheels, spun more slowly, but managed to travel far meet the distance requirement without severely lengthening the lever arm. The larger wheels were therefore chosen to drive the vehicle.

Next, it was tested whether the car would drive faster and straighter as a front or rear wheel drive car. The results would help determine how to efficiently keep the kinetic energy pointed in one direction and not generate any wasted side-to-side movement, as recorded in table 2. Because the front-wheel drive design resulted in 80% less lateral drift on average and travelled further, it was decided to make the car front-wheel-drive.

Third, various materials were tested to determine which would give the greatest traction. As table 3 demonstrates, a double-layered rubber padding allowed the vehicle to keep traction in all except the most extreme conditions. As a loss of traction meant a loss of potential energy to heat, the double layer of balloon rubber was chosen to provide tread for the wheels. Because the double layer of rubber managed to maintain traction longer than the single layer of rubber without decreasing performance, it was chosen as the material to contact the ground.

Finally, the length of the lever arm had to be determined in order to set the final force to multiplier from the spring to the wheels. The lever arm had to be set so that the car could travel at least 16" (4" for the can and 12" of slack in the connecting tether) while keeping as high a force as possible. A shorter lever arm meant more force was applied to the wheels, but the car travelled a shorter overall distance. As the 1" lever arm was the shortest lever arm tested that met distance requirements, as demonstrated in table 4, it was chosen for the final design.

The second function of transferring the vehicle's kinetic energy to the can was accomplished through the utilization of a hook and tether system. In this system, a paperclip acting as a tether was attached to the body and the back axle of the mousetrap, and the string used as a tether was connected to both the paperclip and the can. One modifiable parameter included the length of slack of the string, which could be at full slack, medium slack, or no slack at all. More slack meant that the car could build up more momentum before having to pull the load of the can, but it would also pull at less force when the slack ran out. The second parameter was the mass of the mousetrap car. A more massive mousetrap car could build up more momentum before running out of slack, but it would also move more slowly. Finally, the balance of the car could be modified to move the center of mass between the front and rear wheels, which could allow the car a higher acceleration before slipping if positioned well.

Observations from testing the various methods revealed that with a maximum amount of slack at 12 inches, the vehicle moved forward until running out of slack and then jerked the can forward 12.5 inches in 1.75 seconds; the mousetrap sprung through 50% of its full 180 degree range. With 6 inches of slack, the car moved forward and pulled the can a total of 4 inches before coming to a stop after 1.5 seconds. In this case, the mousetrap rotated through 33% of its full range. When the vehicle was tested with almost no slack, only 0.5 inches worth, it moved the can forward 0.25 inches in 0.5 seconds before stopping, and the mousetrap rotated through only 10% of its range. Based on these observations, it was concluded that utilizing the maximum amount of slack in the tether was the best option.

With the can at full slack and nearly touching the rear end of the vehicle, another parameter had to be analyzed: pulling with a car of high or low mass. When 60 grams was added to the base design, it was observed that the can jerked a total distance forward of 12 inches. However, with no additional mass added to the vehicle, the can was pulled a mere 5 inches. The difference between the time traveled between the two is negligible. These tests revealed that using a high amount of mass was more effective at transferring energy to the can.

The third and final parameter was the location of the additional mass on the vehicle. When positioned in the middle of the body with no can attached, the vehicle traveled 14 feet at 4 feet per second. With the weight balanced near the front wheels, the car moved a total of 16 feet at 3.5 feet per second. Based on these observation, it was concluded that positioning the weight at the front of the car was the better option.

The final car implemented the best component from each test, and can be seen in figure 3. It was front wheel driven, with large, 4.7” wheels covered in a layer of rubber, and small, 1.5” rear wheels for support. A large, 60g counterbalance extended past the front wheels of the vehicle so that almost the entirety of the mass balanced on the two wheels. A small, “u” shaped hook extended past the rear axle to provide a hitch for the load to be attached to. The swinging 1” lever arm of the mousetrap was attached to a string which drove the vehicle, the other end of the string being wrapped around the center of the front axle. Based on each test, the vehicle was expected to be able to pull the can a minimum of 8” for a net speed of 1.3 feet per second.

Results and Discussion

In order to assess the mousetrap car's successes and failures, values from the final demonstration were compared with technical requirements. Table 6 shows the results. During the final demonstration, the mousetrap car successfully pulled a soda can sled of 200 grams for a distance of 9 inches with an average speed of 5.056 inches / second and lost in both rounds of the tug of wars competition. Overall, the mousetrap car met 3 out of 4 technical requirements.

The car's failure in the tug of war could be due to the following reasons. First, the mousetrap car had a low acceleration when triggered. In order to get a better performance in the soda can task, the car was designed to have two big CDs as the driven wheels, which provided a stronger force compared to small wheels in pulling a still object. However, in the tug of war competition, the object to be pulled was a moving mousetrap car. The big wheels lowered the car's acceleration, so with the other team's car starting at a higher speed, the mousetrap car did not get to move very far from the middle line. It was not able to move towards the opposite direction while being pulled by the other car.

Another factor that may have contributed to the failure was the slow trigger. The mousetrap car could only be set off by successfully hitting a small, spring-loaded trigger without hitting anything else. Because of the difficulty in triggering the car, the person triggering it had to be slower and more deliberate, and the vehicle could not be started instantaneously, causing some latency between when the car was supposed to go off and when it actually started moving.

The mousetrap car met the technical requirement of travelling a distance of at least 4 inches, at a speed of at least 5 inches per second, while pulling a can with a mass of around 200 grams. There are three major reasons for its successes.

First of all, the vehicle was designed to have as light a weight as possible, which reduced the energy wasted on carrying unnecessary weight. During testing, it was decided that an additional mass was to be placed at the front of the car to provide more momentum and increase the distance the car can travel while pulling the soda can sled.

Secondly, by having the larger wheels at the front as driven wheels and small wheels in the back, the car was able to pull the can further and stay balanced at the same time. Lastly, the mousetrap car is very stable in terms of construction. All parts were super glued and taped together, which made the vehicle sturdy.

Conclusions and Recommendations

The completed prototype adequately met three out of the four technical requirements. In the final demonstration, the vehicle traveled a total distance of nine inches at a speed of 5.06 inches per second while pulling a 200 gram can. The only function of the design that failed to meet the designated technical requirement was its "fast trigger" ability; that is, maximizing the trigger arm's speed. According to the technical requirement, it was desired for the trigger to operate through the entirety of its functionality in less than 0.5 seconds. In the run, the design took exactly 0.5 seconds. Overall, the design performed successfully in the task of pulling the can but failed in the tug-of-war competitions against other prototypes.

One modification that could have been made to improve overall functionality was utilizing the Artisan and Fabrication Lab. By using this resource, the design possibilities would not have been as limited. Specific designs with modifiable dimensions could have been created for maximizing the different abilities of the vehicle, which was more efficient than creating designs in accordance to the purchased resources with fixed dimensions. Another benefit of using the Artisan and Fabrication Lab would be weight. The different types of materials available would have provided a wider range of options for the consideration of vehicular weight.

Another modification that could have been made was experimenting with different materials for traction. In the final design, balloon rubber was used over the top of the CDs, but no other tests were done to confirm this material was the most efficient. By testing the traction of the car with a wider variety of supplies, traction could have been drastically improved, which in turn would have benefited the driving stability and speed of the prototype.

References

Video link:

https://www.youtube.com/watch?v=yUtd4F6EuRI&feature=share

Appendix

Table 1: Engineering Specifications

Customer Needs	**Technical Needs**	**Technical Requirements**	**Target Values**
Travel far while pulling the can	Distance traveled	>= 4 inches	6 inches
Travel fast	Speed	5 inches/second	6 inches/ second
Able to pull soda can	Minimum mass the car can pull	>= 200 grams	>=200 grams
Fast trigger	Time it takes for car to start moving after trigger is pulled	< 0.5 s	0.5

Table 2: Effect of Wheel size on Speed and Distance Travelled (2” lever arm, no load)

Wheel Size	Speed (ft/s)	Distance (ft)
1.5”	7	0.25
4.7”	3.5	16

Table 3: Effect of Front vs. Rear Wheel Drive on Lateral Motion (2” lever arm, no load)

	Distance travelled (ft)	Distance drifted left/right per 10ft travelled (ft/ft)

Front Wheel	16	0.5
Rear Wheel	13	3

Table 4: Effect of tread on traction under various loads and forces

	Low Load, low force multiplier	Low load, high force multiplier	High load, low force multiplier	High load, high force multiplier
Cd Edge	No Slip	Slip	Slip	Slip
Single Layer Balloon	No Slip	No Slip	Slip	Slip
Double Layer Balloon	No Slip	No Slip	No Slip	Slip

Table 5: Effect of lever arm on Speed and Distance Travelled (no load, 4.7" wheels)

	Speed (ft/s)	Distance Travelled (ft)
2"	3.5	16
1"	4.5	10
0.5"	8	0.25

Table 6: Performance vs. Technical Requirements

Technical Needs	Technical Requirements	Performance
distance traveled	>= 4inches	9inches
speed	5 inches / second	5.056 inches / second
minimum mass the car can pull	>= 200 grams	200 grams
fast trigger	<0.5 s	1s

Name	Begin date	End date
Brainstorm/Plan Design	1/20/16	1/21/16
Finalize design	1/21/16	1/22/16
Purchase additional resources	1/21/16	1/21/16
Build design (rough draft)	1/22/16	1/26/16
Test design	1/25/16	1/25/16
Modify design (finalize)	1/25/16	1/27/16
Final Demonstration	1/27/16	1/27/16
Record design process	1/20/16	1/28/16
Executive Summary	1/27/16	1/28/16

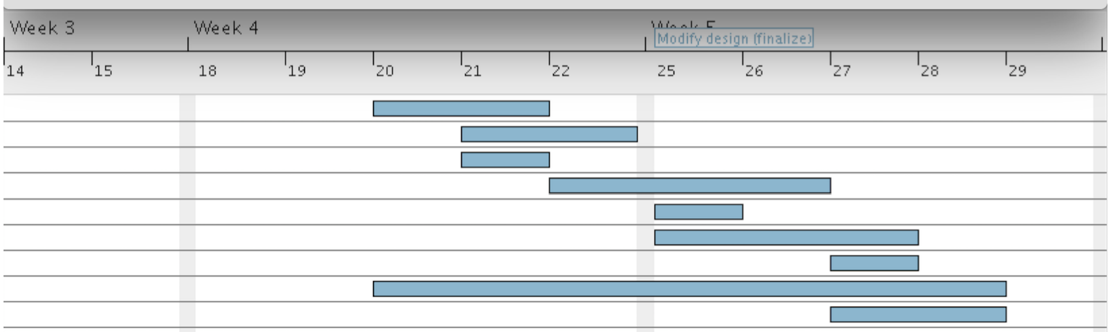

Figure 1: Gantt Project

MOVEMENT	CDs	Chopsticks (Legs)	Tape Roll	No Wheels	Bottle Caps	Coins
AXLE	Pens	Chopsticks	Pencils	Metal Rods	Round Dowels	
METHOD OF PULLING	String	Ribbon	Wire			
BRAKING POWER/TRACTION	Cardboard	Balloons	Skids	Thin Metal		
BASE (BODY)	Cardboard	No Base	Metal			

Figure 2: Morphological Chart

Figure 3: Image of Final Design