Project 3, Group 8: Phase II

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Design Methodology

November 5, 2009

1 Introduction

This report discusses a mechatronic combine to analyze the performance of the robot players. Players are rated through various stations and given a total weighted score. The event is 3 hours and will take place in Stepan Center.

2 Basic Perfomance Criteria

2.1 Steering Test

2.1.1 Event Drivers

The purpose of the turning test is to help determine the agility of a robot. This test will accomplish this by measuring how long it takes the robot to complete one full revolution. The speed is determined in the following calculation from the Banebots website (www.banebots.com):

$$s = \left(861\frac{rev}{min}\right)\left(\frac{3.5*\pi}{rev}\right)\left(\frac{1ft}{12in}\right)\left(\frac{1min}{60s}\right) \quad (1)$$

$$s = 13.15\frac{ft}{s}. \quad (2)$$

This maximum speed is not quite realistic for how fast the robot should turn, so the maximum speed for turning was taken to be 50% of the maximum actual speed. The allowed dimensions of the square robot are 16 in. Realistically, the wheels will not be on the outmost edge of the robot. A turn radius of 7 in. was chosen, and the maximum turning speed, ω, can then be determined in the following calculation:

$$\omega = \left(\frac{13.15}{2}\frac{ft}{s}\right)*\left(\frac{1rev}{2*\pi*7in}\right)*\left(\frac{12in}{ft}\right)*\left(360\frac{degrees}{revolution}\right)$$

$$\omega = 645.75\frac{degrees}{s}.$$

From this a graded scale was calculated and this scale can be found in Table (1).

Table 1: Rating System for Turn Test

Percentage of Maximum Turn Speed (%)	Actual Turn Speed Range (degrees/s)	Rating
>75	>486	4–Outstanding
51-75	330-485	3–Good
31-50	201-329	2–Acceptable
16-30	104-200	1–Poor
0-15	<103	0–Unacceptable

2.1.2 Test Conduct

To begin the turn test the robot must be placed with its front edge parallel to a line of masking tape on the ground. One official will be needed to measure the time. On the officials mark the player would then start turning in a counter-clockwise direction. In order to minimize error in measuring, the robot would then complete five revolutions. The end of a revolution would be observed by the official as when the right corner of the robot crosses the line. The official will record the time of the five total rotations and this time, t, will be converted to degrees per seconds with the following calculation:

$$\omega_{measured} = \left(\frac{5}{t}\frac{rev}{s}\right) * \left(360\frac{degrees}{rev}\right).$$

The calculated turning speed can then be compared to the rating system seen in Table (1) in order to assess the robots performance.

2.2 Speed Test

This test will measure the ability of robot players to set and maintain a speed for three different target speeds. For each target speed, the player will be set to run 15 yards in a straight line at a constant speed. The robot's time will be recorded at four checkpoints: 0–, 5–, 10–, and 15–yardlines. Four students with stopwatches will be placed at each of the checkpoints. They will start their stopwatches when the robot reaches the 0–yardline and stop them when it reaches their checkpoint. In order to allow the robot to accelerate to the specified speed, the player will start 5 yards prior to the 0–yard checkpoint. A person with a stopwatch capable of measuring hundredths of seconds will be placed at each checkpoint to clock the robot when it reaches that mark.

The target speeds for this test are percentages of the robots theoretical maximum speed which is calculated using data from the BaneBots Robot Parts website for the RS-545 motor with a 16:1 gear ratio. The wheel diameter of 3.5 in is taken from Group 4 Project 2 data. Assuming the motor is running at peak efficiency, there is no slip on the wheels, and no power is lost to the gearbox, the speed, s, is found with Equation (1) to be:

$$s = 13.15\frac{ft}{s}$$

The robot would undergo three tests that require it to hold speeds of 25%, 50%, and 75% of the theoretical maximum speed, 13.15 ft/s. Target speeds for each test are shown in Table (2). The

Table 2: Target Speeds for Speed Test

	Percentage of Theoretical Speed	Target Speeds in ft/s	Target Speed in mph
Ideal	100%	13.15 ft/s	8.97 mph
Test 1	75%	9.86 ft/s	6.72 mph
Test 2	50%	5.58 ft/s	4.49 mph
Test 3	25%	3.29 ft/s	2.24 mph

speeds in Table (2) correspond to the target times for each distance in Table (3).

2.2.1 Rating

Recorded times for these four checkpoints will be used to calculate the average speed. A player's rating will be determined by the percent deviation of its average speed from the specified hold speed according to Table (4) located in Appendix 1. The method of calculation for the percent deviation of the robot's actual speed is shown below.

$$\frac{\text{Target Speed - Averaged Actual Speed}}{\text{Target Speed}} * 100\% = \text{Percent Deviation.}$$

Table 3: Target Times for Speed Test

Distance (yards)	Ideal Time for a Target Speed of 3.29 ft/s (s)	Ideal Time for a Target Speed of 5.58 ft/s (s)	Ideal Time for a Target Speed of 9.86 ft/s (s)
0	0	0	0
5	4.56	2.69	1.52
10	9.12	5.38	3.04
15	13.68	8.06	4.56

2.3 Traction Test

The traction test will determine the ability of the robots wheels to grip the playing surface. This is an important factor in the ability to precisely control the movement of the robot during gameplay. The test will be done by placing the robot on an inclined plane and varying the angle of the incline in increments of 5 degrees. Based on the angle at which the robot begins to slide down the plane, the performance of the robot will be graded. One judge would be needed to ensure that the robot was not moving backward down the slope, and as long as this was the case, the judge could then increase the slope by five degrees. The motor would need to be engaged in order to prevent the wheels from spinning and thus rolling down the slope; otherwise, the test would not accurately depict the effectiveness of the wheels traction. In order for the robot to hold its position on the incline, the friction force F_f (Equation 3) has to be greater than the force F_x (Equation 4), as shown in Figure (1).

$$F_f = \mu * m * g * cos(\theta) \quad (3)$$
$$F_x = m * g * sin(\theta). \quad (4)$$

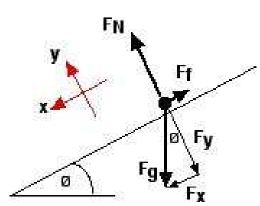

Figure 1: Traction Test

2.3.1 Rating

The scoring will then be determined by Table (5) located in Appendix 1. Each robot will start with a base score of 50. If the robot is successful at the given angle, then the points from the second column (Success) will be added to the score, and if it slips, the points from the second column (Failure) would be subtracted from the score. The maximum and minimum scores are shown for each angle in the last column of Table (5).

2.4 Power Test

2.4.1 Event Drivers

This test will examine each players ability to perform a block and push opposing players. The design of the Power Test was driven in part by the data for the motors provided by the Bane Bots website($http://banebots.com$) and the dimensions of the wheels. Calculating the theoretical force produced by the two motors:

$$
\begin{aligned}
F &= \frac{2Torque}{radius} \\
F &= \left(2\right)\left(\frac{592oz-in}{1}\right)\left(\frac{1lb}{16oz}\right)\left(\frac{1}{1.75in}\right) \\
F &= 42.3lb.
\end{aligned}
$$

This theoretical force exceeds the maximum possible friction force by more than 50% based on a coefficient of friction of 0.8 between the concrete and rubber tire surface. This is illustrated in Figure (2).

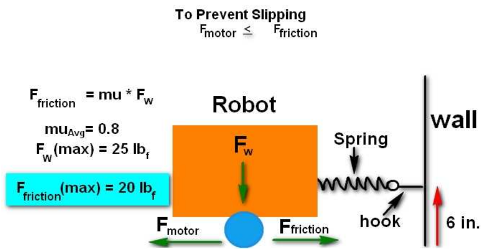

Figure 2: Power Test

2.4.2 Test Conduct

Each player must enter the test with a $\frac{1}{4}$ in. diameter hole drilled at the center of the robot, 6 in. above the ground. A 6 inch spring will be attached to the wall of the testing facility 6 in. above ground level via a hook protruding 2 in. from the wall. The player will drive forward in an attempt to elongate the spring as far as possible during a 10 second period. The final distance will be recorded and translated into a maximum force rating for the player. The players performance will be evaluated by two officials. Official One will operate a stopwatch to measure the 10 second period. Official Two will follow the robot and mark the final back end location of the robot with a washable chalk line at the conclusion of the testing period. The final distance from the wall to the chalk line will be measured with a tape measure and recorded.

2.4.3 Rating System

The steel spring coefficient ($http://www.mcmaster.com/94135k38/=4cy7bo$) of 5.29 $\frac{lb_f}{in}$ was used in conjunction with the theoretical maximum value presented in Figure (2) to determine ratings for the players, summarized in Table (6) in Appendix 1.

3 Advanced Performance Criteria

3.1 The Quarterback

3.1.1 Accuracy Test

The quarterback will be tested on how accurate the throwing mechanism is at various distances. This test will be more of an evaluation than a requirement compliance. It will aid both teams by showing each teams quarterbacks capabilities, which will be useful during the Mechatronic Football Game.

The quarterback will be placed at the back of the end zone in the middle of the field and the robot will throw to a wide receiver placed at different distances straight ahead. The distances will be the shortest short pass, (5') the longest "short" pass (15'), and then two longer passes (25' and 50'). The 50-foot pass was chosen since this was the longest pass completed in practice by one of the teams last year. The 25 foot pass was picked because this is a mid range long pass. The distances will be measured using a measuring tape and by placing the middle of the receiver robot at that distance. The quarterback will get 5 attempts from each distance to hit the receiver robot, simulating a catch. An official will stand with the robot to judge where the ball has landed. The judge will record the distance away from the center of the receiver for each attempt and average it at each distance. If the quarterback hits the receiver this will be recorded as zero feet. These averages will then be taken and scaled based on the scoring system for each distance as seen in Table (10) in Appendix 2.

These numbers will be added together to get the distance away from the receiver based on the rating system in Table (10). This number will then be graded based on the grading scale shown in Figure (3). Since there were no completed passes in last years game there was little information to use to judge the accuracy of the throwing mechanism.

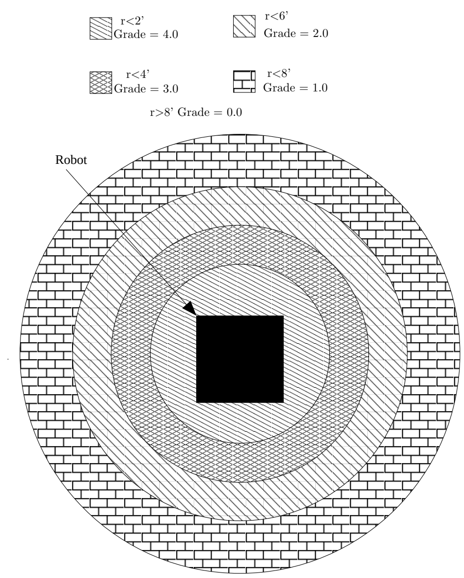

Figure 3: QB Accuracy Grading

3.1.2 Grasp Test

Rule 5.3 of the Second Generation Collegiate Mechatronic Football Rules states that a team"s quarterback must be able to take the ball from the center or the team forfeits the game. This test is designed to measure the quarterbacks ability to take the ball from the center and both place it in its throwing apparatus and complete a hand-off to the running back. Each of these tasks will be performed five times and be evaluated based on the number of balls successfully transferred. This can be seen in Table (7) located in Appendix 1. The combined evaluations will require the presence of the center, the quarterback, and a running back and will be performed in a 5' by 5' area as it will require minimum space.

3.2 The Kicker/The Punter

The punter and kicker will be put through an accuracy test for the kicking mechanism. As with the quarterback test, this is more of an evaluation than a requirement compliance. These events will be weighted less than the other events as well.

3.2.1 The Kicker

The Kicker will be put through a repeatability test for field goal kicking. This test will be done to show how accurate the kickers are at various distances. This will aid teams in deciding whether or not to kick a field goal on fourth down. The kicker will kick 5 field goals from the one-third mark (PAT), mideld, and the opposite one-third mark. The number of hits will be recorded by a judge and scored in Table (11) seen in Appendix 2. These numbers are based on intuition since there was no kicking in last years game. A rating system will be employed to determine a grade for each kicker. The grading system can be seen in Table (8) in Appendix 1.

3.2.2 The Punter

The Punter will be put through a test to illustrate directional punting. Field position is important in the football game so the punter needs to be able to pin the opposing team deep within their territory. The punter will also be put through a repeatability test to show teams the capabilities of their punter. The punter will kick 5 punts from mideld, the one-third mark, and the end zone and will attempt to get the ball to land and stop between the opposite one-third mark and the opposite end zone. The number of successes will be recorded by a judge and rated in Table (12) in Appendix 2. The same grading system as kicking, Table (8), will be used for the punter.

3.3 The Running Back

The purpose of this drill is to test the ball holding apparatus of the running back while being hit. The running back will be hit with a pendulum that swings from horizontal. Data from Project 5 indicated an average tackle would be approximately 4g of force so the pendulum should hit with a force of about 4g. Ten tests will be conducted on the robot. Each test will hit the robot at approximately 36 degrees from the previous test for a full rotation. This is shown in Table (9) in Appendix 1. The goal is for the running back to avoid fumbles. Scores will be distributed per the number of fumbles.

4 Framework of the Combine

Schedule	
Location: Stepan Center	
Check-In and Field Setup	30 minutes
Session I - Basic Performance	60 minutes
Break - Battery Change and Repairs	30 minutes
Session II - Advanced Performance	40 minutes
Final Scores Tally / Cleanup	15 minutes
Results / Awards	5 minutes

4.1 Check-In

- 3 Check-In Tables: One table each will be provided for the gold squad, the blue squad, and the officials. Squad tables will be equipped with a 50 lb scale, voltmeter, laptop, and printer.

Unique ID numbers and score sheets will be distributed to each player. The officials table will be connected to a projection screen to display results.

- Player Restrictions: Failure to comply with restrictions will result in instant disqualification: Max Weight = 25 lbs; Max Size = 16" x 16" base with 24" height; Kill switch required; DC battery - Maximum of 24 Volts

4.2 Field Setup

Four students will be given masking tape and 20 foot tape measures to prepare the field. Four other students will prepare the other stations. During the break, these students will update the field for Session II.

4.3 Sessions

During the sessions, robots will rotate from station to station. There are 4 basic stations and 4 advanced stations. A human controller will accompany each robot throughout the combine. The human will be responsible for reporting scores to the Players Combine Report, which is Table (13) in Appendix 2. In addition, a student will be stationed at each test. Results will also be recorded on the Station Report, which is Table (14) in Appendix 2. Runners will report scores to the officials for updating and display. At the end of the combine, final scores will be posted online.

4.4 Necessary Components

The following components will be required for an effective combine:

- Combine Report Spreadsheets
- Station Report Spreadsheets
- Score Updater Sheet
- Pens/Pencils/Clipboards
- Miniature Footballs (5)
- 20-Foot Tape Measure Ruler (4)
- 50-lb Scale (2)
- 12-in Ruler (2)
- Stopwatch (5)
- Masking Tape (4 rolls)
- Pendulum Mechanism
- Traction Ramp
- Power-Spring Mechanism Test

5 Appendix 1: Scoring Systems for Each Event

Table 4: Rating System for Speed Test

Percent Deviation	Rating
<1%	4–Outstanding
< 5%	3–Good
<10%	2–Acceptable
<15%	1–Poor
<20%	0–Unacceptable

Table 5: Rating System for Traction Test

Angle (Degrees)	Success	Failure	Total	Grade
5	+5	-20	(55/30)	0 - Unacceptable
10	+10	-15	(65/40)	1 - Poor
15	+10	-5	(75/60)	2 - Acceptable
20	+10	-5	(85/70)	3 - Good
30	+5	0	(95/90)	4 - Outstanding

Table 6: Rating System for Power Test

Distance	Force Rating	Rating
$>$ 12 in.	21.16 lb_f	4.0
$>$ 11 in.	15.87 lb_f	3.0
$>$ 10 in.	10.58 lb_f	2.0
$<$ 10 in.	0-10.58 lb_f	1.0

Table 7: Rating System for Grasp Test

Balls Transferred to Throwing Arm	Rating	Weight (%)	Score
5	4	60	2.4
4	3	60	1.8
3	2	60	1.2
2	1	60	0.6
≤1	0	60	0.0
Balls Handed Off to Running Back	Rating	Weight (%)	Score
5	4	40	1.6
4	3	40	1.2
3	2	40	0.8
2	1	40	0.4
≤1	0	40	0.0

Table 8: Kicker/Punter Rating System

Weighted Total (out of 5)	Grade (out of 4.0)
>4.0	4.0
$3.0 < x \leq 4.0$	3.0
$2.0 < x \leq 3.0$	2.0
$1.0 < x \leq 2.0$	1.0
< 1.0	0.0

Table 9: Rating System for Running Test

Balls Fumbled	Rating
0	4–Outstanding
1-2	3–Good
2-4	2–Acceptable
5-6	1–Poor
>6 (or less than 60% of the ball showing)	0–Unacceptable

6 Appendix 2: Scoring Sheets

Table 10: Quarterback Scoring System

Pass Length	Avg. Distance Away	Weight	Total
5’		45%	
15’		35%	
25’		15%	
50’		5%	
Total		100%	

Table 11: Kicker Scoring System

Position	Successes	Weight	Total
1/3		60%	
1/2		30%	
Opp. 1/3		10%	
Total		100%	

Table 12: Punter Scoring System

Position	Successes	Weight	Total
1/2		60%	
Opp. 1/3		30%	
Opp. End Zone		10%	
Total		100%	

Table 13: Player’s Combine Report

Robot ID:		Team:	
Robot Type:		Student:	
Station	Reported Score	Station Weight	Weighted Score
Steering Test		0.3	
Speed Test		0.3	
Traction Test		0.15	
Power Test		0.25	
Basic Total		1.0	
Quarterback			
Accuracy Test		0.2	
Grasping Test		0.8	
Advanced Total		1.0	
Punter/Kicker			
Punt Test		0.5	
Kick Test		0.5	
Advanced Total		1.0	
Running Back			
RB Test		1.0	
Advanced Total		1.0	

Table 14: Station Report

Station:			Official:	
	Robot ID	Team Color	Student Controller	Reported Score
1				
2				
3				
4				
5				
6				
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