

Project 3, Phase 2

Group 9
Design Methodology

November 5, 2009

1 Introduction

The objective of this combine will be to assess mechatronic football player performance in areas essential to successfully participating in a football game. The performance specifications defined in this plan will serve as design requirements in the development of the robots. This plan provides descriptions of each combine drill, the quantitative targets associated with each drill, and the rationale behind the procedures and quantities selected.

2 Basic Performance Testing

The Basic Performance Tests (or BPT's) will be given to every mechatronic football player. These tests will be given to the players in order to analyze how effective they will be at performing common maneuvers and tasks necessary during a game. There will be six BPT's, the first of which is an inspection to make sure that the players do not violate any rules for being on the playing surface. All tests will be scored out of ten and, ultimately, totaled out of sixty. The six BPT's are given below.

2.1 Pre-Game Inspection

As stated previously, this test is to ensure that the players meet all the specifications for playing in the game. Players must exhibit that they meet each of the following requirements in order to get a ten on this test. Failure to meet any one of them will result in a zero on this test and a temporary suspension from the combine until such time that all specifications for on-field play can be met.

- I. Kill switch is mounted directly to top-surface and cuts off main power
- II. Weight is 25 *lbs* or less
- III. Base is made of HDPE
- IV. Player fits in a 16 *in.* x 16 *in.* x 24 *in.* box

- V. Base is no thinner than 0.5 *in.* continuously and centerline of base is located 3 ± 0.1 *in.* above the playing surface
- VI. No more than 2 extensible arms
- VII. Arms cannot extend further than 18 *in.* in any direction and are made of only rotational joints
- VIII. Arms have no cross sections greater than 3 *in.* except on terminus (last 4 *in.* of arm) which may have cross sections of up to 5 *in.*
- IX. Four LED light holders are mounted around sides of player with centers at 8 ± 0.1 *in.* above the playing sensors
- X. Display that tackle sensor is operational (display green lights for two seconds and immobilize player for 2 *s*)
- XI. Display that “holding” the ball exposes at least 60% of the ball’s surface

2.2 94/3 *ft* Dash

In this test, the players will have to start from rest and move across a distance of 1/3 of the playing field (94/3 *ft*). This will gauge how fast players will be able to perform in-game tasks such as chasing down ball-carriers, rushing quarterbacks, or returning kicks. The maximum speed for a first generation robot was 14.7 *ft/s*. Using similar calculations to those in Appendix 1, a good time for this sprint is 3 *s*. Robots who can move across this distance in under 3 *s* will receive a ten. Every 0.25 *s* over the target that the robots times are will result in a one point deduction.

2.3 Force

The ability for a robot to reliably exert forces on it’s surroundings is an important performance criteria which needs to be addressed during the combine. In this test, a spring force gauge will be attached to a wall and the back of the robot. The robot will start at rest and move forward, pulling the force gauge. The force applied by the robot will then be read off the gauge at the point where movement ceases. This test is performed by an operator of the robot, who will end the test appropriately in order to reduce the risk of a motor burnout. An official will read and record the force displayed on the gauge. The force gauge will be borrowed from either the Learning Center or a Fitzpatrick lab, or purchased online by the class. A maximum of 10 points is awarded to a robot that exerts 50 *lbs* of force, and is scaled for any fraction under 50 *lbs* and rounded to the nearest integer. For example, an exertion of 30 *lbs* would result in a score of 6 points.

2.4 Straight Line

The ability for a robot to move reliably in a straight line is an important performance criteria which needs to be addressed during the combine. Starting from rest, the robot must

be automated to accelerate to its maximum speed and travel forward for 47 *ft*, or half the field. This allows sufficient distance for the robot to reach maximum speed and show the lateral deviation that could occur in a real game during a long play. Points will be awarded depending on the deviation of the robot. Ten points will be awarded for a deviation of under 3 *ft* in either direction. One point is deducted for each 1 *ft* exceeding 3 *ft* that the robot deviates. The sideline of an indoor basketball court found in either the JACC or Stepan Center will be used for the straight line. Students will mark off the proper distances, and this will be verified by Professor Schmiedeler.

2.5 Turn Rate Test

In this test each player will complete a full 360° circle in as little time as possible. An official will record the time elapsed using a stop watch, and the result will be expressed as a degree per second value. This will be calculated by dividing 360° by the time it takes the player to complete the test. The player will need to achieve a turn rate of at least 90°/s in order to receive a score of 10 for this test. Every five degrees per second under 90 that the player achieves will result in a one point deduction. For instance, a rate of 80°/s would result in a score of 8 points, as would all scores up to 76°/s.

As turning is clearly a common aspect of football, the results of this test are important for determining how effectively a player will be able to maneuver in a game. This test should be able to be performed autonomously using open-loop control which will correlate to design requirements such as motor speed, four-bar linkage geometry, etc.

2.6 Loose-Ball Recovery

This test will determine how effectively players can recover fumbled balls off of the playing surface and secure them. The ball will be rolled down a four foot ramp angled at 45°. The player will start from rest 15 *ft* from the ramp and start after the ball once it is released. If the player can touch the ball it will receive a score of five. If the player can take possession of the ball by securing it, it will receive a score of ten. Failure to do either of these will result in a score of 0.

3 Advanced Performance Criteria

3.1 Passing

In this test the quarterback will throw ten passes at rest to a target marked on the wall. This target, shown in Figure 1, will be 16 *in.* wide by 24 *in.* tall because these are the maximum dimensions of a robot. Four passes will be made with the quarterback and target 10 *ft* apart. These will be worth one point each if they contact the target. Three passes will be made with the quarterback and target 20 *ft* apart worth 2 points each. The maximum score possible on this test is 10. It is intended to judge how accurately the quarterback can make

short and long passes. Poor results will correlate to making new design decisions regarding the ball launching mechanism.

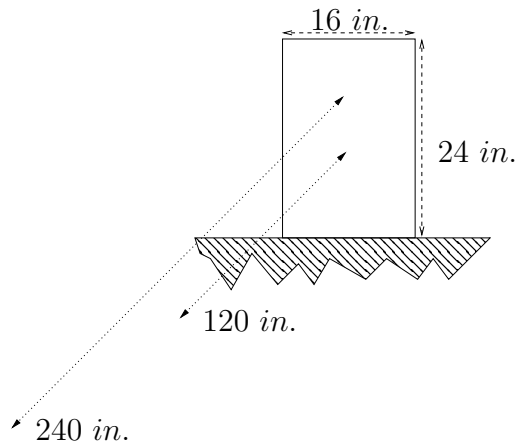


Figure 1: Throwing Test Setup

3.2 Kicking

Each team's kicker will attempt to demonstrate a successful field goal kick from the 1/3 and 2/3 field marks centered between the hash marks. This test implicitly includes kick off capabilities. The ball is to be placed on the tee, and the kicker attempts a field goal. The scoring criteria are that the ball must be kicked and travel across the goal line in the air adhering to the proposed second generation rules for a successful field goal. Three trials will be conducted, each consisting of a kick from the 1/3 and 2/3 field marks worth 4 and 6 points respectively. The 10 point totals from each trial will be averaged and rounded to the nearest whole number to calculate a final score out of 10. The test results will reward consistently good kicking designs.

3.3 Punting

In this test the player will be centered on the goal line, and the ball will initially be situated on the punter. The punter is to punt it as far as possible down field 3 times. The ball will be marked by an official where it first touches down out of the air. Balls that cross the sidelines in the air will be marked using the official's discretion. The punt scoring will go as follows: 3 points for 1/3 the field, 6 points for 2/3 the field, and 10 points for the entire field. The final score for the test will be the rounded average of the player's three scores out of 10. The results of this test will correlate to design decisions regarding a player's punting mechanism.

3.4 Snapping

This test will measure how effectively the quarterback can take the ball from the center without any additional help from the center or other robots. The ball will be placed on a stationary center, and the quarterback must remotely maneuver itself to the pre-snap

position and remove the ball from the center. There will be 10 snaps each worth 1 point, and the player's score at the end will equal how many successful snaps they performed. This test will gauge how effective the quarterback's snap-receiving mechanism is and may result in design changes for certain players such as switching from a clamping device to a scooping motion.

4 Scoring

When a player enters the combine, a human from their squad will have to declare what type of player they are so that they can be told which APT's the player is required to take in addition to all of the BPT's. They will be given a scoring card which will have all of the BPT's on it with a space to mark the score, as well as the APT's that are required. The scorecard will also have a space to total the scores of all the tests and give the player a letter grade for the combine. For BPT's, the number grade will be found by dividing the total score by 60 points. This will correspond to a letter grade shown on the scorecard. The same will be done for APT's, except the total score will be divided by the number of APT's the robot completed times 10. The proposed scorecard can be seen in Figure 2.

<p style="text-align: center;">Squad:</p> <p style="text-align: center;">BPTs</p> <p>Pre-game Inspection 94/3 ft Dash Force Test Straight Line Test Turn Rate Test Loose-Ball Recovery</p> <p style="text-align: center;">APTs</p> <p>(Required APTs are Written in here by a Combine official)</p>	<p style="text-align: center;">Player # : Player Position:</p> <p style="text-align: center;">Test Score</p> <table border="1" style="margin-left: auto; margin-right: auto; border-collapse: collapse;"> <thead> <tr> <th colspan="2" style="text-align: center;">Grade Scale</th> </tr> </thead> <tbody> <tr><td style="text-align: center;">>97</td><td style="text-align: center;">A+</td></tr> <tr><td style="text-align: center;">93-97</td><td style="text-align: center;">A</td></tr> <tr><td style="text-align: center;">90-92</td><td style="text-align: center;">A-</td></tr> <tr><td style="text-align: center;">88-89</td><td style="text-align: center;">B+</td></tr> <tr><td style="text-align: center;">83-87</td><td style="text-align: center;">B+</td></tr> <tr><td style="text-align: center;">80-82</td><td style="text-align: center;">B-</td></tr> <tr><td style="text-align: center;">78-79</td><td style="text-align: center;">C+</td></tr> <tr><td style="text-align: center;">73-77</td><td style="text-align: center;">C</td></tr> <tr><td style="text-align: center;">70-72</td><td style="text-align: center;">C-</td></tr> <tr><td style="text-align: center;">65-69</td><td style="text-align: center;">D</td></tr> <tr><td style="text-align: center;"><65</td><td style="text-align: center;">F</td></tr> </tbody> </table>	Grade Scale		>97	A+	93-97	A	90-92	A-	88-89	B+	83-87	B+	80-82	B-	78-79	C+	73-77	C	70-72	C-	65-69	D	<65	F
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Figure 2: Score Card

At the end of the combine every player will have a letter grade which is meant to help predict how valuable they will be in the mechatronic football game. A level players should be monitored and watched by opposing squads as they will clearly possess the highest skills, B or C level players will most likely be average, and D or F level players should be tracked and exploited by opposing squads if possible since their abilities are sub par.

5 Overall Organization

The combine will be organized to be a single-day, 3-hour event to test and evaluate systems on all robotic football players. The event will require a suitable venue for distance sprints and passing, and must have a surface with enough traction for evaluating robot performance. Suggested locations include Stepan Center or the north dome of the JACC. One hour prior to the combine, the location will be setup and organized for the testing. An hour after the event will be allotted for cleanup.

Prior to dynamic performance testing, the robots will be weighed and measured to demonstrate conformance with sizing rules. Once a robot has cleared the dimensioning check, it is put in the queue for the first event, minimizing the time impact of the dimensioning check on the duration of the combine. This dimensioning check is a pass/fail test.

Events will be organized so that BPT's take place before APT's. All robots will participate sequentially at each event. The first event will be the 94/3 *ft* sprint, and will be performed on 2 parallel test tracks one for each team. It is estimated to take approximately 15 minutes from the time the first robot begins the course, allowing each robot slightly more than 1 minute to be positioned, race, and exit the track. The second and third events will be force and steering tests. As before, two identical tracks will be established and each robot will be allowed slightly more than 1 minute for each test, totaling 15 minutes per event. The final 2 BPT's, turn rate test and loose-ball pickup, will be conducted in succession. They, too, will take 15 minutes apiece.

After the BPT's have been completed, skill position players are to be repositioned to prepare for the APT's. Each teams quarterback and center will gather at one end of the area for passing and snapping drills. The kicking and punting robots will gather at the other end. APT's can be conducted simultaneously to save time. Table 1 details all of the events in the combine.

Table 1: Combine Testing Summary

Section	Drill Name	What	Measurable	Duration	People
Basic	Pre-game	Weigh/Measure Robots	Weight/Dimensions	20 min	10
	Dash	Speed	Time	15 min	4
	Force	Measures force	Force in <i>lbs</i>	15 min	2
	Straight Line	Steering accuracy	Distance	15 min	2
	Turn Rate	Rate of turn	Angular velocity	15 min	2
	Loose Ball	Ability to pick up ball	Ability	15 min	1
Advanced	Passing	Throwing	Accuracy	15 min	3
	Kicking	Kicking	Accuracy/Dist.	10 min	3
	Punting	Kicking	Dist	10 min	3
	Snapping	Handoff	Ability	15 min	2

Appendix 1:

For the calculation of the maximum speed which will be used for the estimated highest allowable times for the sprint, cone drill, and shuttle run, several assumptions will be made which are key to the approximation. First, it will be assumed that the motor is running at its peak efficiency. The assumption is also made that all power is delivered to the wheels at once and that it takes the robot almost no time to speed up. This assumption also neglects wheel slip.

One of the drive motors used last year was made by Bane Bots(www.banebots.com). This motor was a RS-545 with a 16:1 gear ratio. With the assumption that the motor is running at its peak efficiency, the output of the gear train is rotating at 861 *rpm*, according to the website. The speed of the robot can be found with the knowledge that the wheels have a diameter, d , equal to about 5 *in*.

$$\begin{aligned} speed &= \left(\frac{861rev}{1min}\right) \left(\frac{5\pi in.}{1rev}\right) \left(\frac{1ft}{12in.}\right) \left(\frac{1min}{60s}\right), \\ speed &= 18.8\frac{ft}{s}. \end{aligned}$$

This can be further simplified to

$$\begin{aligned} speed &= \left(\frac{18.8ft}{s}\right) \left(\frac{3600s}{1hr}\right) \left(\frac{1mi}{5280ft}\right), \\ speed &= 12.8mph. \end{aligned}$$

This final value, given in units that almost everyone is accustomed to, does not seem too outrageous given that many actual football players can run at speeds in excess of 20 *mph*. However, lets assume a small factor of safety and say that the maximum speed of a robot is 10 *mph*, or 14.7 *ft/s*, and that it takes the robot 10 *ft* to get up to this speed. Therefore, the time it should take the average robot to go 47 *ft* will be about

$$\begin{aligned} t_{sprint} &= \left(\frac{s \cdot 10ft}{.5(14.7ft)}\right) + \left(\frac{s \cdot 37ft}{14.7ft}\right), \\ t_{sprint} &= 3.9s. \end{aligned}$$

Because all of the approximations have been rough, it can just be assumed that the time it takes for a 47 *ft* sprint will be 4 *s*. The cone drill, which is 75 *ft* in total length, would take about 6 *s* to complete if it was a straight away. However, because of the turns, it should take about 7.5 *s* to complete. The shuttle run, at 45 *ft*, would take about 4 *s* if it were a straight away. However, because of the turn, it should take closer to 5.5 *s*.

Appendix 2:

To find the maximum weight of the sled at which the robot can no longer push it from rest,

two main assumptions are made. First, it is assumed that the maximum torque of the robot is its stall torque, $592\text{ oz} \cdot \text{in.}$ (www.banebots.com), and that the wheels of the robot do not slip. Also, it is assumed that the coefficient of friction of the sled is the same as that of steel on concrete, $\mu_s = 0.45$ (<http://www.supercivilcd.com/FRICTION.htm>). To find the force of the robot, it must first be realized that there are two motors and that the radius, r , is 2.5 in.

$$F_{robot} = (2 \cdot 592\text{oz} \cdot \text{in.}) \left(\frac{1}{2.5\text{in.}} \right) \left(\frac{1\text{lb}}{16\text{oz}} \right),$$

$$F_{robot} = 29.6\text{lbs.}$$

Therefore,

$$F_{robot} = \mu_s \cdot W_{sled},$$

$$W_{sled} = \left(\frac{29.6\text{lbs}}{0.45} \right),$$

$$W_{sled} = 65.8\text{lbs.}$$

Accounting for some error in the assumptions made, this number can be rounded down so that the maximum sled weight the robot can push must be at least 60 lbs.