

Combine Concept Design Proposal

AME30362 - Design Methodology

Ben Fotsch
Tyler Jaramillo
Michael W. Koehler
Kenneth Minogue
Ryan Peterson
Damian Sharratt
Scott Vitter

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Abstract

The purpose of this project was to create a combine of quantitative performance characteristics that should be implemented in the second-generation Mechatronic football players. In other words the goal was to quantify the qualitative “whats” or desired characteristics of the robots. The combine was to include desired attributes for both basic and skilled positions and it was to be complimented by benchmark values. The benchmark values from this combine are to be used as design specifications for building the second-generation robots. Lastly, a framework for executing the combine was formulated to efficiently test the Mechatronic football players within the three-hour time constraint. ¹

1 Basic Performance Criteria

1.1 Size

Each player will be measured according to the rules for play. The measurement will be performed by placing each robot in a 16 *in.* square 24 *in.* high box. In order for the robot to pass it must be able to fit in the box because that is a requirement in the rules for the robot to play.

1.2 Weight

Each player will be weighed with a digital scale to know the exact weight; the units will be pounds. In order for the robot to pass it must weigh less than 25 *lbs* because that is a requirement in the rules.

1.3 Speed

This test is designed to find the top sustained speed of the robot. The robot can start anywhere behind the starting line (to get up to speed) and run through the start to the finish. The time will start when the robot crosses the start and end when it crosses the finish line. Enabling the robot to start behind the line ensures that the test find the maximum sustained speed without considering acceleration. The units of the test will be in $\frac{ft}{s}$ and found by dividing the distance (50 *ft*) by the time it took to complete the test. For linemen, a satisfactory performance would have a minimum average speed of $4\frac{ft}{s}$ and an excellent robot would have an average speed of $8\frac{ft}{s}$ or greater. Skill position players would be considered satisfactory if their average speed at least $6\frac{ft}{s}$ and excellent if their speed is greater than or equal to $12\frac{ft}{s}$.

1.4 Straight Line Deviation

Previous generations of Mechatronic football players frequently incorporated two separate motors that drove one wheel each. This would allow robots to be steered by rotating one

¹Batill, Stephen M. P3 - Product Requirements Project. [Online] Available http://www.nd.edu/~batill/www.ame30362f09/P3_Product_Requirements.pdf, September 16, 2009.

wheel faster than the other. However, this design presents the problem of motors not being adequately synchronized and causing deviations from an intended path. Stronger designs would minimize this hazard either by using a single motor for power or by tightly controlling synchronization.

This test would require autonomous control by the robot to ensure that any deviations are not the result of controller error. In the test, a straight line of 40 feet would be taped out, and a robot placed with its centerline directly over the line. Using the on-board processor, the motor(s) would be set at 80% of full scale output and the deviation measured in terms of $\frac{\text{feet of deviation}}{40 \text{ feet}}$. The design target for excellent robots would be 1 foot of deviation, and the target for satisfactory performance would be 3 feet.

1.5 Turning Resolution

All robots will undergo an automated turning resolution test once. This test will quantify the mechanical ability of a robot to turn 90°. The robot will be placed on the game surface, or equivalent, and centered on a line, and the command to turn the robot will be activated. Once the robot has stopped moving, the turn angle will be measured in relation to the center line on which it was placed. An excellent robot will turn an angle between 85° and 95°. A satisfactory robot will turn an angle between 80° and 100°.

Table 1: Summary of the Basic Performance Criteria

Base Tests	Weight (<i>lbs</i>)	Size (<i>in.</i>)	Speed Lineman $\frac{ft}{s}$	Speed Skill Position $\frac{ft}{s}$	Straight Line Deviation (<i>ft</i>)	Turning Resolution
Satisfactory	< 25	< 16x16x24	4	6	3	±10°
Excellent			8	12	1	±5°

2 Advanced Performance Criteria

2.1 Eight Yard Shuttle

The shuttle run measures acceleration over short distances, and is crucial for players who need to change direction quickly in order to have success (RB's, WR's, LB's, DB's). For

Mechatronic football players, maximum acceleration obtainable relates to the tractive effort of the robot. The tractive effort provided by the robot depends on two criteria:

1. Motor selection, which is a design choice.
2. The maximum tractive effort cannot exceed robot weight multiplied by coefficient of friction. Wheel spin results if this condition is violated.

The weight limit for Robots is $25 lb_f$. Stepan floor is approximated with a coefficient of friction of 0.8 [†]. Thus, the maximum tractive effort possible is $F_{tractive} = 20 lb_f$, and a max acceleration, $a = 25.6 \frac{ft}{s^2}$. This value is unlikely to be obtained by Mechatronic football players. Applying 33% of the max tractive effort, in 1 second the robot can be accelerated to $8 \frac{ft}{s}$ ($a = 8.5 \frac{ft}{s^2}$), which will approach the top speed of many of the robots. In fact, for skill positions, a top speed of $8 \frac{ft}{s}$ is considered satisfactory, and $12 \frac{ft}{s}$ is considered excellent (see previous section). Acceleration of $a = 8.5 \frac{ft}{s^2}$ will correlate to the excellent standard, outlined below.

Robots will be tested individually, and will complete a sequence of movement as illustrated below on the command “GO”. The event is illustrated in Figure 1: From rest, a robot

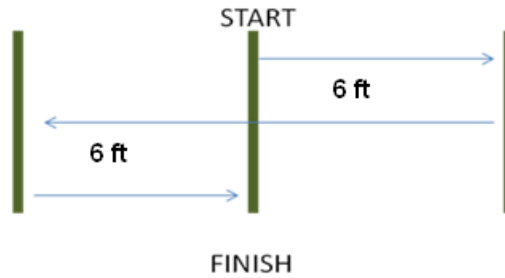


Figure 1: Visual Depiction of the 8-Yard Dash Setup

accelerating at $a = 8.5 \frac{ft}{s^2}$ will traverse $6 ft$ in $1.2 s$ and $12 ft$ in $1.7 s$. Robots will be afforded 25% extra time for deceleration. Thus, to obtain the excellent standard, a robot must complete the shuttle run in less than 5.1 seconds. The satisfactory standard is 6.6 seconds, meaning the robot supplies only 20% of the maximum possible tractive effort, $a = 5 \frac{ft}{s^2}$, and includes the same 25% time cushion for deceleration. A robot performing at this satisfactory level should expect no competitive edge based on performance.

2.2 Linemen Strength

All linemen will perform a pull test. This test will gauge their ability to gain traction and move an external load. The linemen will be attached to a $25 lb$ wheeled cart (a robot may be used instead of fabricating a cart) with a taught line, and they will pull the cart $5 ft$ (from the front edge of the robot). The desired time for this pull is $2 s$ which gives an average acceleration of $6.6 \frac{ft}{s^2}$. From this acceleration, tractive effort and tractive torque can

[†]The value for the coefficient was found using engineertoolbox.com

be calculated (assuming a total normal load of 50 *lb*—a 25 *lb* robot and a 25 *lb* cart, a wheel radius of 3 *in.* and a 10% error):

$$\begin{aligned} TE &= F \cdot error = a \cdot N \cdot 1.1 = 11.18lb \\ T &= TE \cdot r_w = 2.8ft - lb \end{aligned}$$

The error factor is included to account for rolling resistance and energy lost due to friction and slip. These torque values are within the same range as the torque produced by the first generation robots' motors. An excellent robot will have a pull time less than or equal to 2 s while a satisfactory robot will have a pull time of over 2 s.

2.3 Passing Ability

The Passing Test will measure the accuracy of the QB robot by rate of completion. The test will be set up where the QB is stationary and will be aimed at a target, both of which will be positioned in the middle of the field (25 *ft* from edge of field). The target will consist of the Wide Receiver Robot of the same team. The QB will have five throws at the target. This test will contain two rounds. The first round will measure the accuracy of the short pass with distances at either 5 *ft*, 10 *ft*, or 15 *ft* (user preference). The second round will measure the accuracy of the long pass with distances 15 *ft* or greater in increments of 5 *ft*. It is important to note that there is a 5 *ft* mandatory difference between the short pass and long pass. A pass will be deemed accurate if the ball strikes the target. These distances were chosen in large part due to the scoring system in place. A short pass is 5 *ft* - 15 *ft* and worth 7 points upon completion and a long pass is greater than 15 *ft*, worth 10 points upon completion. The QB robot must have a completion rate of at least 30% (three completions) in order to be satisfactory and a completion rate of at least 60% (6 completions) to be rated excellent. The completion rate includes short and long pass results.

2.4 Handoffs QB / RB / C

The running game is a very significant aspect of Mechatronic football, and a clean handoff from the quarterback to the running back is a highly important aspect. In actual football, it is almost assumed that players can hand the football off well, but for robots it is not a given. Due to this importance, a handoff drill must be part of the combine. In this drill, both the QB and center would be positioned as they would be for a snap, and the quarterback would take the ball off the center. After this, the QB would rotate 90° and hand the ball to a running back. Failures of both the handoff from the center to quarterback and the quarterback to running back would be noted. Excellent performance would entail 1 dropped ball out of 5 attempts, and satisfactory performance would have 2 failures.

2.5 Kicking

Place-kick and punt testing will be combined into a single test. The kickers for both squads will be given 5 tries at a "Point After Attempt" (PAT). The kicker will line up 376 *in.* ($\frac{94}{3}$ *ft*) from an "end zone" line and try to kick the football between a 200 *in.* wide target. The kick is considered successful if the ball passes within the target before touching the ground. This

test will directly reflect each kicker’s ability to kick PATs as well as field goals. It is also indicative of punting and kickoff abilities. A success rate of at least 4 out of 5 tries will be considered excellent; at least 2 out of 5 will be deemed satisfactory.

Table 2: Summary of the Advanced Performance Criteria

Advanced Tests	Shuttle Run (s)	Lineman Pull (s)	Overall QB Accuracy	Handoffs (Drops)	Kicking Test (Made PATs)
Satisfactory	6.6	> 2	30%	≤ 2	2
Excellent	5.1	≤ 2	60%	≤ 1	4

3 Performance Criteria Overview

Due to the number of criteria and their varying levels of importance to each position, the following table was created to address the relative importance of each test for the specific positions:

Test Weighting Method	Weight	Size	Speed	Straight Line Deviation	Turning Resolution	Shuttle Run	Lineman Pull	Kicking Test	Handoff	QB Accuracy
Lineman	15	15	10	5	5		50			
Skill Position	15	15	20	10	10	30				
Quarterback	15	15	5	5	10				25	25
Kicker	15	15	5	5	5			55		
Running Back	15	15	15	5	5	25			20	
Center	15	15	5	5			30		30	

Additionally, in order to streamline the process of testing each of the players within the 3-hour time constraint, it was necessary to design a process through which each player would be tested. The outcome (Figure 2) was a flowchart shown below:

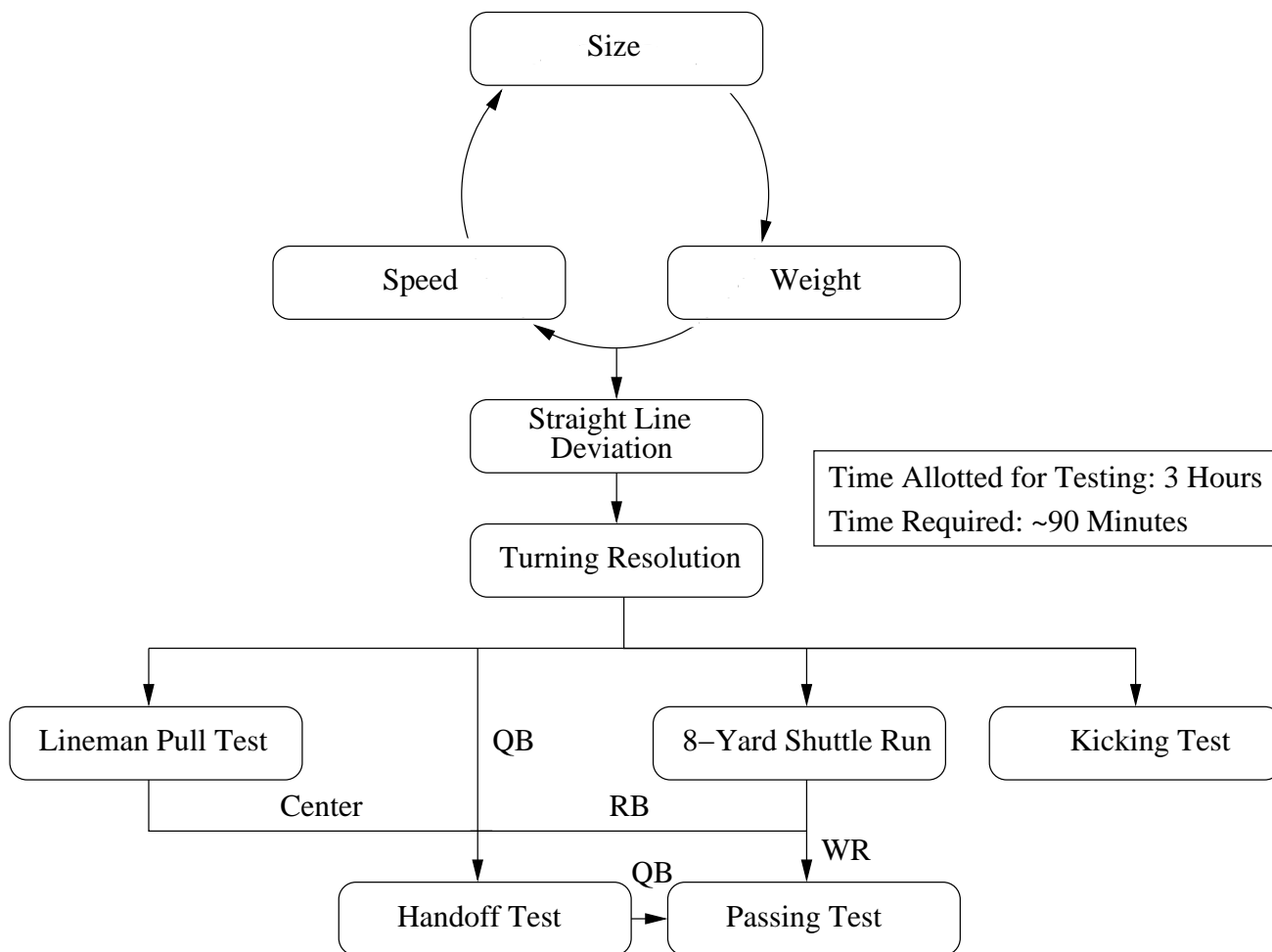


Figure 2: Flowchart Depicting Combine Execution