P11217 Golf Robot

Test and Assembly Plan

Name	Discipline
Jeff Cosimano	ME
Marcus Grant	EE
Cory Gregory	EE
John Gutmann	CE
Derek Hugo	CE
Tenzin Seldon	ME
Karikalan Thirumavalavan	EE
Jason Thrush	EE/CE

1. MSD I: WKS 8-10 AND MSD II: WKS 1-2 TEST AND ASSEMBLY PLAN

Major Sub-Systems/Features/Functions	
1.1	Chassis Development
1.2	Chassis Testing
1.3	Sensor Development
1.4	Sensor Testing
1.5	Camera Development
1.6	Camera Testing
1.7	Communication System Development
1.8	Communication System Testing
1.9	Ultrasonic Beacon Development
1.10	Ultrasonic Beacon Testing Testing
1.11	Ball Placement Mechanism Development
1.12	Ball Placement Mechanism Testing
1.13	Laser Positioning Development
1.14	Laser Positioning Testing

1.1 Chassis Development

1.1.1 Assemble Chassis [Jeff/John]
1.1.2 Assemble Motor Mountings (Motors, Gearboxes, Wheels, etc.) [Jeff/John]
1.1.3 Mounting Sensors [Jeff/John]
1.1.4 Build Integrated Power Supply [Jason]
1.1.5 Write/Debug Navigation Software [John]
1.1.6 Write/Debug Manual Navigation Software [Derek]

1.2 Chassis Testing

1.2.1 Battery [John]
1.2.2 Durability [Jeff]
1.2.3 Motors [Jeff/John]

1.3 Sensor Development

1.3.1 Write/Debug Object Avoidance Sensor Software [Marcus/Kari]
1.3.2 Write/Debug Compass Software [Marcus/Kari]
1.3.3 Write/Debug Temperature Sensor Software [Marcus/Kari]
1.3.4 Write/Debug Encoder Software [John]
1.3.5 Combine Sensor Software [Marcus/Kari]
1.3.6 Combine Sensor Software and Chassis Software [Marcus/Kari]

1.4 Sensor Testing (Object Avoidance Sensors, Compass, Temperature Sensor)

1.4.1 Functional Testing on Sensors [Marcus/Kari]
1.4.2 Accuracy Testing on Sensors [Marcus/Kari]
1.4.3 Integration Testing [Marcus/Kari/Derek]

1.5 Camera Development

1.5.1 Mount Pan/Tilt Mechanism [Cory/Marcus]
1.5.2 Calibration [Cory/Marcus]
1.5.3 Write/Debug Recognition Software [Cory/Marcus]
1.5.4 Combine Camera Software and Chassis Software [Cory/Marcus]

1.6 Camera Testing

1.6.1 Target Tracking/Servo Control [Cory/Marcus]
1.6.2 Camera Overhead [Cory/Marcus]
1.6.3 Accuracy Testing [Cory/Marcus]
1.6.4 Determine Optimal Flags [Cory/Marcus]
1.6.5 Light Sensitivity Testing [Cory/Marcus]

1.7 Communication System Development

1.7.1 Write/Debug Graphical User Interface [Derek]
1.7.2 Write/Debug Communication Software [Derek]
1.7.3 Combine GUI and Communication Software [Derek]
1.7.4 Combine Communication System Software and Chassis Software [Derek]

1.8 Communication System Testing

1.8.1 Server to Laptop [Derek]
1.8.2 Laptop to Microcontroller [Derek]

1.9 Ultrasonic Beacon Development

1.9.1 Design Robot-side and Beacon-side Circuitry [Jason]
1.9.2 Write/Debug Ultrasonic Beacon Software [Jason]
1.9.3 Design Beacon Housing [Jeff/Tenzin]
1.9.4 Design Omni-directional Transducer Cones [Jeff/Tenzin]

1.10 Ultrasonic Beacon Testing

1.10.1 Range Testing [Jason]
1.10.2 Accuracy Testing [Jason]

1.11 Ball-Placement Mechanism Development

1.11.1 Assemble Ball-Placement Mechanism [Tenzin]
1.11.2 Mount Ball-Placement Mechanism [Tenzin]
1.11.3 Write/Debug Servo Software [Cory]
1.11.4 Write/Debug Emitter and Phototransistor Software [Cory]
1.11.5 Combine Servo Software with Emitter and Phototransistor Software [Cory]
1.11.6 Combine Ball-Placement Mechanism Software and Chassis Software [Cory]

1.12 Ball-Placement Mechanism Testing

1.12.1 Functional Testing [Cory/Tenzin]

1.12.2 Accuracy of Emitter and Phototransistor [Cory/Tenzin]

1.12.3 Usability of Ball-Placement Servo [Cory/Tenzin]

1.13 Laser Positioning Development

1.13.1 Design Circuitry [Jason]

1.13.2 Write/Debug Software [Jason]

1.14 Laser Positioning Testing

1.14.1 Range Testing [Jason]

1.14.2 Accuracy Testing [Jason]

1.1 Subsystem/ Function/ Feature Name: Chassis Development

Date Completed: 04/22/11

Performed By: Jeff, John, Jason, Derek

Engr. Spec. #	Specification (description)	Unit of Measure	Marginal Value	Test Equipment Needed
ES6	Smooth treads on wheels	N/A	N/A	N/A
- Manually navigate robot on different grass surfaces to make sure the treads on the wheels are smooth. - If not, amend wheels and retest.				
ES7	Solid outer shell	N/A	N/A	N/A
ES8	Clearance from ground	in	1.5	Tape Measure
ES9	Weight of robot	lbs	50	Scale

1.2 Subsystem/ Function/ Feature Name: Chassis Testing

Date Completed: 05/02/11

Tested By: John, Jeff

Engr. Spec. #	Specification (description)	Unit of Measure	Marginal Value	Test Equipment Needed
ES1	Robot speed	Ball deliveries/hr	10	Timer
- Test coordinates will be sent to the robot. - The number of ball deliveries will be recorded during a one hour time period.				
ES3	Distance robot should move	ft	30	Tape Measure
ES10	Battery life	hr	1	Timer/Multimeter
- A 12 V battery will be fully charged and then attached to the robot and used until the battery is drained. - The full voltage and no voltage times will be recorded to determine the battery life.				

Since there wasn't enough time to develop a novel navigation method, encoders became the fallback navigation method. The major caveat to wheel spin is that it can't account for systemic error introduced by the robot chassis and is highly sensitive to workspace errors (or in this case wheel slippage). To combat this, the robot is manually navigated to the center of the green to reset odometer error and is then given coordinates for the ball placement there. This allows the robot to be more accurate near the hole, where accuracy is more noticeable. The error in linear distance, using odometry came out to be approximately 5%. So if the robot is asked to drive one meter to place the ball, it has a potential linear offset of +/- 25mm. Attempting to turn with any practical accuracy is very troublesome using encoders. Since turning the robot requires that the wheels skid, and as such the attempt to develop an automated turn algorithm using the odometer didn't give reliable results indoors or outdoors.

1.3 Subsystem/ Function/ Feature Name: Sensor Development

Date Completed: 04/08/11

Performed By: Marcus, Kari, John, Cory

Engr. Spec. #	Specification (description)	Unit of Measure	Marginal Value	Test Equipment Needed
ES12	Sensor to detect ball is returned to robot	N/A	N/A	N/A
- An emitter and phototransistor will be placed across ball placement mechanism to detect if ball is present.				

1.4 Subsystem/ Function/ Feature Name: Sensor Testing

Date Completed: 04/15/11

Tested By: Marcus, Kari, Derek, Cory

Engr. Spec. #	Specification (description)	Unit of Measure	Marginal Value	Test Equipment Needed
ES3	Distance robot should move	ft	30	Tape Measure
ES4	Navigational margin of error	%	0.4	Tape Measure
- The radial error between the provided (x,y) and the actual (x,y) will be calculated. - The radial error should be less than or equal to 0.4 % of the radius of the putting green.				
ES10	Battery life	hr	1	Timer/Multimeter
- A 12 V battery will be fully charged and then attached to the robot and used until the battery is drained. - The full voltage and no voltage times will be recorded to determine the battery life.				
ES11	Distance kept from user	ft	1	Tape Measure

1.5 Subsystem/ Function/ Feature Name: Camera Development

Date Completed: N/A

Performed By: Cory, Marcus

Engr. Spec. #	Specification (description)	Unit of Measure	Marginal Value	Test Equipment Needed
N/A	N/A	N/A	N/A	N/A

1.6 Subsystem/ Function/ Feature Name: Camera Testing

Date Completed: 04/22/11

Tested By: Cory, Marcus

Engr. Spec. #	Specification (description)	Unit of Measure	Marginal Value	Test Equipment Needed
ES2	Ball must be within radius of coordinates	In	2	Tape Measure
ES4	Navigational margin of error	%	.4	N/A
- The radial error between the provided (x,y) and the actual (x,y) will be calculated. - The radial error should be less than or equal to 0.4 % of the radius of the putting green.				
ES10	Battery life	hr	1	Timer/Multimeter
- A 12 V battery will be fully charged and then attached to the robot and used until the battery is drained. - The full voltage and no voltage times will be recorded to determine the battery life.				

1.7 Subsystem/ Function/ Feature Name: Communication System Development

Date Completed: N/A

Performed By: Derek

Engr. Spec. #	Specification (description)	Unit of Measure	Marginal Value	Test Equipment Needed
N/A	N/A	N/A	N/A	N/A

1.8 Subsystem/ Function/ Feature Name: Communication System Testing

Date Completed: 04/15/11

Tested By: Derek

<table>
<tr><th>Engr. Spec. #</th><th>Specification (description)</th><th>Unit of Measure</th><th>Marginal Value</th><th>Test Equipment Needed</th></tr>
<tr><td>ES5</td><td>Wireless communication range</td><td>ft</td><td>40</td><td>N/A</td></tr>
<tr><td colspan="5">- The XBEE transmitter and receiver will be distanced until the signal is lost.</td></tr>
<tr><td>ES10</td><td>Battery life</td><td>hr</td><td>1</td><td>Timer/Multimeter</td></tr>
<tr><td colspan="5">- A 12 V battery will be fully charged and then attached to the robot and used until the battery is drained.
- The full voltage and no voltage times will be recorded to determine the battery life.</td></tr>
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For the demonstration, the laptop running the Golf Robot control program was placed inside a tent approximately 10 feet from the golf green and 100 feet from the Gordon Field House, the nearest building. Unfortunately, the wireless network in this location was not strong enough to establish and maintain a connection. Therefore, the robot simply relied on either manual control or coordinates generated by the operator. In earlier tests, the control program was able to connect to the AR Golf database and successfully retrieve coordinates at a rate of one pair every 30 seconds, so the software itself requires no major changes. Possible solutions to this issue include running a wired network connection out to the tent or setting up a wireless repeater near the doors of the Field House.

The Golf Robot GUI (graphical user interface) worked well throughout the demonstration. Many of the features were unavailable because of the lack of connection to the data server and the lack of implementation on the Golf Robot's side (sonars, battery, compass, etc.). The GUI layout could certainly be improved to simplify manual controls; however, no major issues were reported by the operators.

Fortunately, the XBee antennas maintained an excellent wireless connection with the Golf Robot throughout the entire day. The connection was broken once or twice but was immediately re-established. Range is not believed to be the issue that caused this temporary connection loss. Interference is likely the main factor. One improvement would be to place the Golf Robot's XBee antenna in a more prominent location; ensure that it is not covered in wires or blocked by any large components. More importantly, ensure that the Golf Robot handles a dropped connection properly. If the connection was lost while the Golf Robot was moving, it continued to move until the connection was re-established. This issue must be handled by the engineer responsible for the Golf Robot's programming.

1.9 Subsystem/ Function/ Feature Name: Ultrasonic Beacon Development

Date Completed: N/A

Performed By: Jason, Jeff, Tenzin

Engr. Spec. #	Specification (description)	Unit of Measure	Marginal Value	Test Equipment Needed
N/A	N/A	N/A	N/A	N/A

1.10 Subsystem/ Function/ Feature Name: Ultrasonic Beacon Testing

Date Completed: 04/15/11

Tested By: Jason

Engr. Spec. #	Specification (description)	Unit of Measure	Marginal Value	Test Equipment Needed
ES2	Ball must be within radius of coordinates	In	2	Tape Measure
ES4	Navigational margin of error	%	.4	N/A
- The radial error between the provided (x,y) and the actual (x,y) will be calculated. - The radial error should be less than or equal to 0.4 % of the radius of the putting green.				
ES10	Battery life	hr	1	Timer/Multimeter
- A 12 V battery will be fully charged and then attached to the robot and used until the battery is drained. - The full voltage and no voltage times will be recorded to determine the battery life.				

The ultrasonic positioning method uses two ultrasonic beacons placed on the outside of the green to help the robot find its position. Each of these beacons emits and receives on different frequencies. In order for the robot to find its position, it first emits a quick ultrasonic pulse at one of the beacon's frequencies, and then starts a timer. When the beacon corresponding to that frequency hears the pulse, it will send back another pulse to the robot at a different frequency. When the robot hears that return pulse, it stops the timer. The measured time represents the time-of-flight of the ultrasonic pulses, and therefore can be used to determine the robot's distance away from that beacon. This process is repeated again for the other beacon so that its distance from that beacon is also known. From then, trigonometry can be done to obtain the robots position on the golf green in relation to the beacons.

In testing the ultrasonic positioning method, it was found that it was difficult to measure accurate time-of-flight times. The times measured never seemed to be consistent and varied greatly. This could have been caused by a number of factors. For example, it is hard to guarantee that when the robot sends out a pulse that the beacon will immediately recognize it and send one back. If there is any delay because of this, the time-of-flight time is invalid. Positioning using this method is definitely achievable, but more development time was needed than was available.

1.11 Subsystem/ Function/ Feature Name: Ball Placement Mechanism Development

Date Completed: N/A

Performed By: Cory, Tenzin

Engr. Spec. #	Specification (description)	Unit of Measure	Marginal Value	Test Equipment Needed
N/A	N/A	N/A	N/A	N/A

1.12 Subsystem/ Function/ Feature Name: Ball Placement Mechanism Testing

Date Completed: 04/08/11

Tested By: Cory, Tenzin

Engr. Spec. #	Specification (description)	Unit of Measure	Marginal Value	Test Equipment Needed
ES10	Battery life	hr	1	Timer/Multimeter
- A 12 V battery will be fully charged and then attached to the robot and used until the battery is drained. - The full voltage and no voltage times will be recorded to determine the battery life.				
ES12	Sensor to detect ball is returned to robot	N/A	N/A	N/A
- An emitter and phototransistor will be placed across ball placement mechanism to detect if ball is present.				

1.13 Subsystem/ Function/ Feature Name: Laser Positioning Development

Date Completed: N/A

Performed By: Jason

Engr. Spec. #	Specification (description)	Unit of Measure	Marginal Value	Test Equipment Needed
N/A	N/A	N/A	N/A	N/A

1.14 Subsystem/ Function/ Feature Name: Laser Positioning Testing

Date Completed: 05/02/11

Tested By: Jason

Engr. Spec. #	Specification (description)	Unit of Measure	Marginal Value	Test Equipment Needed
ES2	Ball must be within radius of coordinates	In	2	Tape Measure
ES4	Navigational margin of error	%	.4	N/A
- The radial error between the provided (x,y) and the actual (x,y) will be calculated. - The radial error should be less than or equal to 0.4 % of the radius of the putting green.				
ES10	Battery life	hr	1	Timer/Multimeter
- A 12 V battery will be fully charged and then attached to the robot and used until the battery is drained. - The full voltage and no voltage times will be recorded to determine the battery life.				

The laser positioning system uses a laser and reflectors to determine the robot's position on the golf green. A laser is mounted horizontally on a stepper motor, which spins around so that the laser scans around outwards. Two retroreflectors are placed around the green with their separation distance known. As the laser spins around, when it hits one of the reflectors, the laser beam is reflected back to the laser. Photocell sensors detect this reflection. Since a stepper motor is used to spin the laser, the angle at which it is at is known and recorded. Once reflections from both of the reflectors are found, their corresponding angles are used to calculate the robot's position on the golf green using triangulation.

Tests with the laser positioning system showed that it functioned perfectly up to distances of about 25-30ft. It proved to be a very reliable and usable system for determining the robot's position. Testing could only be done indoors, although it is assumed that it would function properly outdoors, as well.

Instead of using basic mirrors, retroreflectors were used. This eliminated the need for the laser to hit the reflector perfectly perpendicular in order to get a reflection straight back to the robot. Retroreflectors always reflect light back parallel to the incident light, regardless of the incident angle. This is a requirement for this application, as the golf green terrain is not perfectly flat.