Sustainable Design of a lawn care robot

Our robot is general purpose lawn care machinery. The robot is powered by motors and rechargeable NiMH batteries for zero carbon emission. The robot consists of three modules - drive chassis, elevation subsystem and application module. The application module carries out tasks such as weed control or fertilizer application. Our prototype showcases precision weed control using herbicides for targeted treatment. The drive chassis and elevation subsystem provide a vehicle that carry payload of tool(s) to perform specific lawn care operation. The modular approach of our design ensures that future upgrade of tools can reuse the same vehicle with a modest amount of effort.

The robot has a wireless color camera mounted on each side of the robot to search for weeds. The wireless camera relays real time image back to the control room and allows an operator to run the robot remotely. An ultrasonic range finder mounted on the robotic arm measures the distance from the target weed and controls the elevation of the robotic arm that carries a can of herbicide to an optimal boom height and spray out the least amount of chemical for targeted treatment on weeds. To reduce spray drift, shields are installed around the nozzle to create a spray chamber to minimize damaging wind so that the herbicide is on the target! Our design is simple, efficient and sustainable.

We began this project with a review of videos and tutorials from the Autodesk Sustainability Workshop. The Workshop raised our awareness that a designer can change a product the way it works that lead to a sustainable world. By understanding the Whole System and Lifecycle Thinking from the Workshop, we identified ways to minimize environmental impact of herbicide treatment and improved energy efficiency in our design. After brainstorming, we started putting our ideas on drawing in paper. Then, we used Autodesk Inventor to assemble VEX parts for accurate and true representation of our prototype. We find out that using Autodesk Inventor in the design phase to make changes rather than modifying the physical prototype later save us substantial time and effort.

We had two more iterations of design process for improvements.

Iteration 2 – Improve Product lifecycle

We realized a sturdy robot frame could not guarantee long durability unless we run safety test to prevent rollover on uneven terrain. We analyzed the reaction forces on wheels in Autodesk ForceEffect to help us adjust the ground clearance, and the position of wheels and payload in version 2 of our design. The prototype was tilted 35 degree downward to test if the stationary robot would roll over at down slope or not. The test results led us to change our digital prototype to a six wheel configuration to prevent the risk ahead of time. Plus the modular design for change, the robot frame is made to last and adapt.

Iteration 3 – Energy efficient

We selected lightweight Aluminum instead of stainless steel to reduce soil compaction, soil erosion and save energy. To cut down energy consumption by the robot, we employed Whole Systems and Lifecycle Thinking. The main energy consumers are the four drive motors and reducing travel distance will improve efficiency. In version 3 of our design, we extended our treatment coverage from 18 inches to 36 inches wide, therefore travel distance was effectively halved. We installed a linear slide that allowed lateral movement of the spray module so that it could provide additional nine inches of coverage on each side of the robot.

Our design also chooses to use renewable energy source of solar panel to power up the camera receivers during robot operation. At other daylight time, the solar panel recharges batteries at the service station.

Software

We appreciate the capability of Autodesk Inventor for digital prototyping. Using Eco Materials Adviser in Inventor, we learn that Aluminum has 24% less CO_2 footprint than stainless steel. At the end of design process, we generated a list of Vex parts for purchase from 'Bill of Materials' (BOM) in Inventor to avoid any surplus inventory. The total weight of robot can be estimated if the weight of individual parts is known. We can also calculate how much weight has been saved by replacing stainless steel C-channels with Aluminum counterparts.

Autodesk ForceEffect empowers us to analyze reaction forces on wheels associated with weight distribution for various wheel and payload configurations in our early design before building an actual prototype. We also use Autodesk Showcase to render images of our design for appealing presentation.