Case Study

Robotics

intel REALSENSE™

Robotic Automation for Smart Agriculture and Renewable Energy

Intel© RealSense™ technology enables autonomous outdoor navigation for Directed Machines®' Land Care Robots®

Spotlight on Directed Machines

Directed Machines is a technology leader in the smart agriculture and renewable energy sector. The Seattle, Washington-based company develops and markets Land Care Robots (LCRs) for a wide range of vertical markets including golf courses, farms, ranches, solar farms, and nurseries. The LCR is a heavy-duty, solar-electric machine that can perform many types of land care tasks such as mowing, hauling, security monitoring, grading, and plowing, either under operator control or in autonomous mode.

At a Glance

The LCR autonomously navigates using Intel RealSense depth cameras in conjunction with Raspberry Pi microcontrollers. The machine vision system is anchored by two Intel RealSense Depth Camera D455s, which include an inertial measurement unit (IMU) for refined depth awareness. In addition to navigation, the cameras equip the robots with dynamic obstacle avoidance capabilities, and include an IR illuminator for night time operation.

directed machines

Introduction: Advanced Vision Technology at a Low Price

As farmers and renewable energy providers attempt to make up for labor shortfalls with automation and increased mechanization, a new line of autonomous robots from Directed Machines offers a cost-effective way to complement the efforts of human workers. Intel RealSense depth cameras help these robots to perceive, interpret, and understand their surroundings, fueling a burgeoning market for affordable heavy-duty, autonomous machines.

The Smart Agriculture industry was valued at $11.5 billion in 2021 and is expected to reach $24.3 billion by 2028, a compound annual growth rate of more than 11 percent.[1] The market is flourishing due to innovative technologies such as IoT, artificial intelligence (AI), and 3D vision systems that allow robots to work autonomously without human intervention.

According to Dan Abramson, co-founder, and chief operating officer at Directed Machines, there are many uses for robots in agriculture and renewable energy. "Our company's self-directed, mechanized assistants can manage vegetation, tow heavy loads of equipment and supplies, provide security intelligence, and assess the health of plants and site assets," he explains. "However, like all autonomous vehicles, we have to hit the right price point before we can penetrate the market at scale."

Directed Machines has found the optimal balance between price and performance by designing core mathematical systems that enable its Land Care Robots (LCRs) to operate effectively using inexpensive compute and sensing equipment. "Our compute sensor platform is at least an order of magnitude less expensive than what other robotics companies offer, allowing us to sell autonomous tractors for as low as US $16,999," says George Chrysanthakopoulos, CEO at Directed Machines. "That's because we use a Raspberry Pi as our CPU, rather than a more expensive computing platform, and we use Intel RealSense depth cameras, which offer great capabilities at a great price."

Intel RealSense depth cameras allow the LCR to navigate using machine vision in structured environments such as orchards and solar farms, as well as unstructured environments like ranches, parks, and golf courses, some of which comprise thousands of acres.

"Intel RealSense depth cameras fit perfectly into our low-cost, feature-rich sensor suite," Abramson adds. "Thanks to careful coordination with the Intel RealSense Depth Camera 455, Land Care Robots are fully autonomous and capable of completing multiple tasks without supervision or user intervention."

[1] BlueWeave Consulting, Smart Agriculture Market stats, May 2022.

LCRs working cooperatively in a blueberry farm

A Better Way to Navigate

Most autonomous vehicles designed for smart agriculture or renewable energy navigate using global positioning system (GPS) data. Depth cameras are typically used to detect and avoid obstacles, not for navigation. However, GPS navigation is not effective in structured environments, where the GPS signals are often occluded. "Trees and solar panels can interfere with the GPS signal and introduce a lot of positional error," Abramson explains. "For this reason, we use Intel RealSense depth camera D455 as our primary navigation sensors, and GPS devices as our secondary sensors. We can achieve centimeter precision using machine vision, a massive improvement over GPS in challenging environments and vitally important when operating equipment around critical infrastructure."

The LCR autonomously navigates using the Intel RealSense depth cameras in conjunction with programmable Raspberry Pi 4 RP2040 microcontrollers. There is no need for April tags or QR codes or any other type of localization symbols. The robot perceives its surroundings in real time and navigates accordingly. By using a probabilistic graph-like (topological) approach commonly called simultaneous localization and mapping, the LCR eliminates the additional overhead of first mapping the environment and then storing/updating localization data.

The LCR features an Autonomous Task Editor that allows customers to set up work plans and delineate boundaries through a browser-based interface. For example, if the robot is being used for vegetation management, customers can exclude certain areas such as flower beds. "We have stayed away from SLAM-based technologies," Abramson says. "We have a completely different set of methodologies and mathematical frameworks that we use to do our autonomous navigation."

Advanced Vision Technology for Precision Tasks

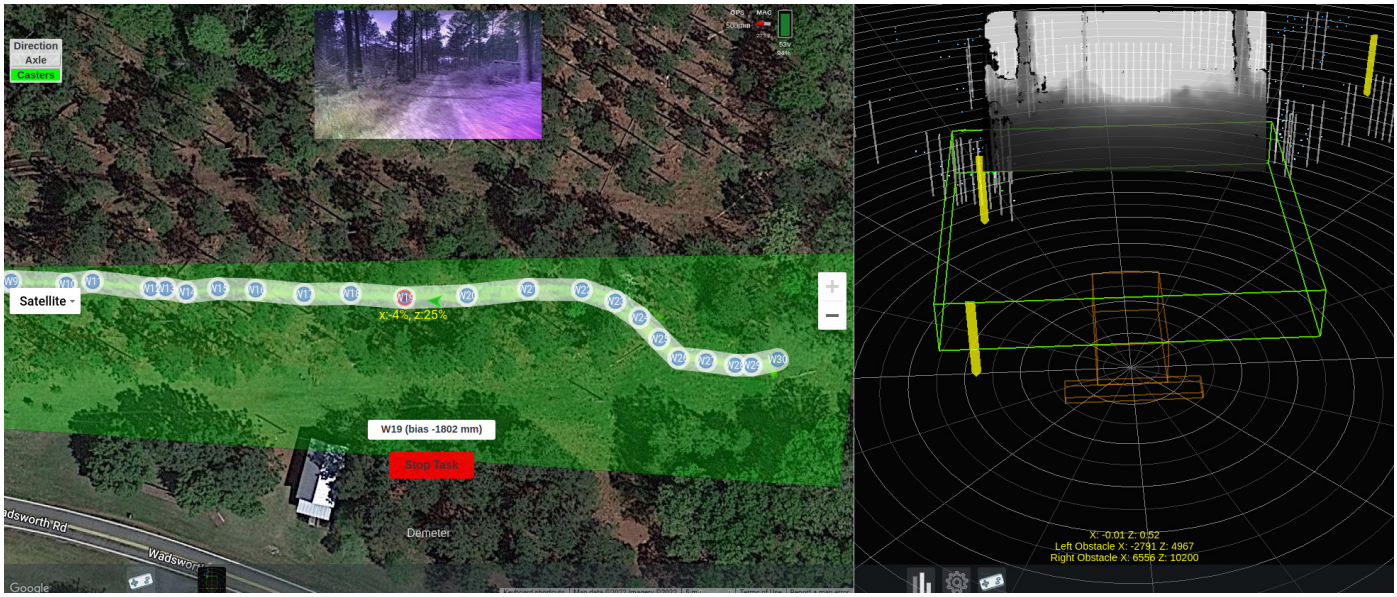
Directed Machine's sensor suite is anchored by two Intel RealSense Depth Camera D455s, which include an inertial measurement unit (IMU) for refined depth awareness. There are two data streams for each camera: RGB data and depth perception data. In addition to navigation, the Intel RealSense depth cameras equip the Land Care Robots with dynamic obstacle avoidance. To improve the stability of the RGB image and the correspondence between the depth and RGB images, the RGB sensor includes a global shutter and is matched to the depth field of view. A compact form factor makes it easy to unobtrusively mount the cameras on the LCR's solar panel.

"Having a wide field of view is extremely important because each robot only needs two cameras to operate in all types of topographies and climate zones, including open areas and challenging structured areas," Abramson explains.

LCR with 8' mower deck managing the vegetation on a solar farm

The LCR samples the depth image at 15 frames per second. The data is channeled through several layers of heavy filtering to remove artifacts and transform it into data representations that can be efficiently manipulated by the CPU: semantic filtering, 2D filtering, and 1D filtering. Since Intel RealSense technology processes the depth data within the camera, it takes much of the load off the robot's CPU. This is one of the reasons that Directed Machines can use a low cost, highly efficient compute processor such as the Raspberry Pi to interpret the visual data.

"A lot of our competitors rely on software running on an expensive GPU to perform those calculations," Abramson says. "Intel RealSense technology has already manipulated the data and put it in a usable form by the time it gets to the



LCR travelling autonomously on a GPS-occluded forest path map, showing transformed depth image and RGB image

CPU, so we can use a much more cost-effective Raspberry Pi board."

A near infrared projector, also known as an illuminator, enables the camera to capture depth data even in total darkness. Being able to work at night effectively doubles the useful work time of the robot. It allows work to be performed during off hours at parks, golf courses, and other areas that are busy during the day. When placed in sentry mode, the cameras can identify intruders and alert stakeholders. "The same LCR can mow grass or haul equipment during the day, then do security work at night, accelerating ROI and improving the value proposition for our customers," Abramson notes.

Exceptional Value and Quality for Robotics Customers

Intel helped Directed Machines select the Intel RealSense Depth Camera D455 and integrate it with the LCR's machine vision system. "The Intel RealSense team has been incredible," Abramson says. "It's like we have a knowledgeable and responsive friend on board. They have helped us incorporate their technology and develop future plans to use it within our product line."

According to Abramson, customers benefit from Intel RealSense technology due to its high quality and low price. "The cost/benefit ratio is better than any other depth cameras out there," he says. "Our bill of material cost is much lower than if we had used LiDAR sensors, for instance. We can pass on those savings to customers in terms of lower prices."

In addition to its comparatively low cost, Directed Machines selected Intel RealSense technology because it has a solid Linux kernel, which integrates well with many OS options available for the Raspberry Pi. Abramson appreciates the exceptional quality of the Intel RealSense Depth Camera D455 with its many unique features. "We tested a bunch of different depth cameras, and we chose Intel RealSense technology as the best one for our application," Abramson concludes. "We are firmly committed to the Intel RealSense depth cameras and sensors."

Challenge

Most autonomous vehicles designed for smart agriculture and renewable energy navigate use global positioning system (GPS) data. However, GPS navigation is not effective in structured environments, such as orchards and solar farms, where the GPS signals are often occluded and noisy.

Solution

The LCR autonomously navigates using Intel RealSense Depth Camera D455, in conjunction with Raspberry Pi microcontrollers. The robot perceives its surroundings in real time, allowing it to operate with centimeter accuracy in both structured and unstructured environments.

Results

Intel RealSense technology provides more features and more value for a lower price than Directed Machines could obtain from competing depth cameras, allowing the company to reduce costs, increase performance, and bring more value to its customers.

Learn More

Directed Machines:

https://www.directedmachines.com

Intel RealSense Technology:

https://www.intelrealsense.com

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