An Electrically Driven, Computer Controlled Robotics Platform For Orchard Use

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Abstract

As automation in agriculture progresses, more automation systems will be placed into farms & orchards. This poster introduces a platform built for transporting robotics modules through a kiwifruit orchard. Key requirements, design details and a general hardware overview are presented. The platform is controlled either by remote control or computer generated drive commands - facilitating autonomous navigation. In-orchard testing shows the system is well suited for the target application, achieving accurate speed control and repeatable positioning.

Key Requirements

- Be fully drive-by-wire
- Capable of carrying a 1000 kg payload
- Accomodate a standard kiwifruit bin
- Provide room for robotic modules
- Have on-board power generation
- Accomodate sensors required for use with autonomous navigation
- Be suited for use in kiwifruit orchards, including ascending slopes of up to 20°

Introduction

Kiwifruit is New Zealand's largest horticultural export by value [1]. With the government's target of doubling the country's primary exports for the thirteen year period ending 2025 [2], there will be increased demand for labor during this period. Increasing automation in the kiwifruit industry offers a way to increase exports without having to increase demand on a casual or seasonal workforce.

The mobile platform presented here is designed specifically for carrying robotic modules through kiwifruit orchards. Those modules have been developed as part of a wider project involving The University of Auckland, The University of Waikato, Plant and Food Research, and Robotics Plus Ltd. There are currently two robotic modules: a kiwifruit flower pollination module and a kiwifruit harvester. In order for these modules to act fully autonomously they require a base platform that is also fully autonomous.

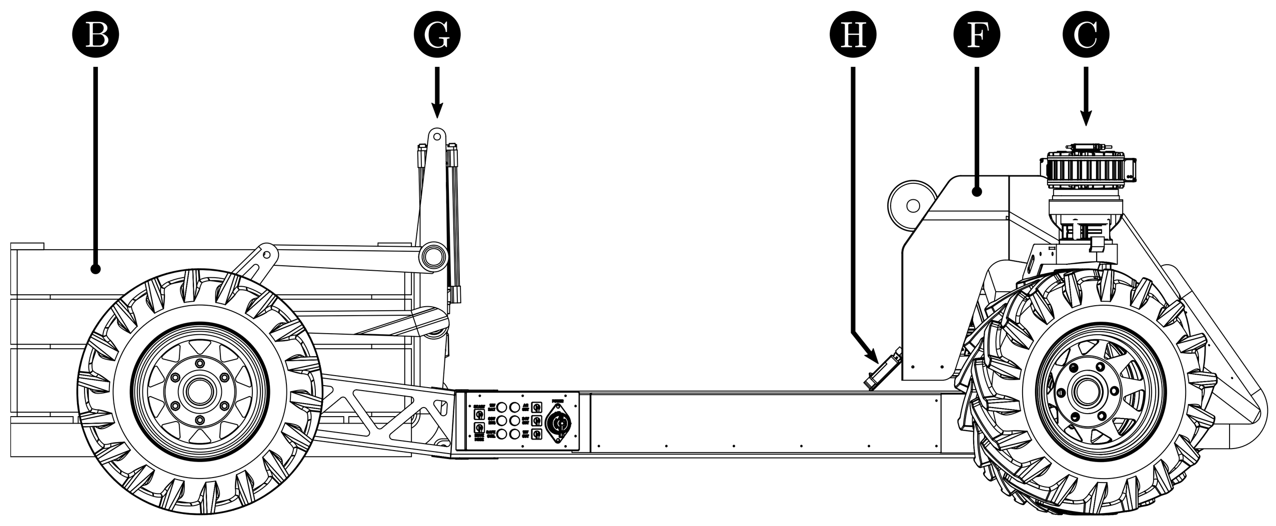
By creating an orchard specific heavy-duty vehicle that can be controlled by computer, much of the complexity of developing the pollination and harvesting modules has been removed. Keeping the platform's components modular means it can be structurally reconfigured while re-using much of the systems already developed here.

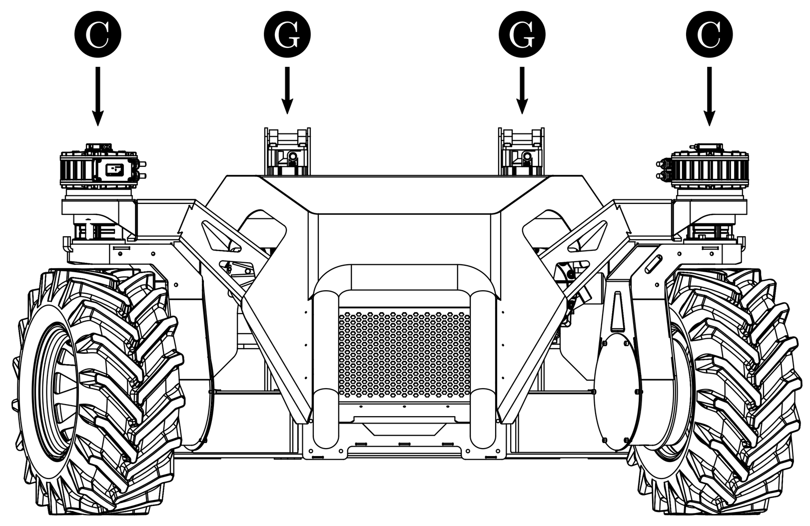
[1] Statistics New Zealand, "Annual fruit exports hit $2 billion for first time", 2017. [Online]. Available: stats.govt.nz/browse_for_stats/industry_sectors/imports_and_exports/OverseasMerchandiseTrade_MRJun15-x1.aspx [Accessed: 2017-09-25].

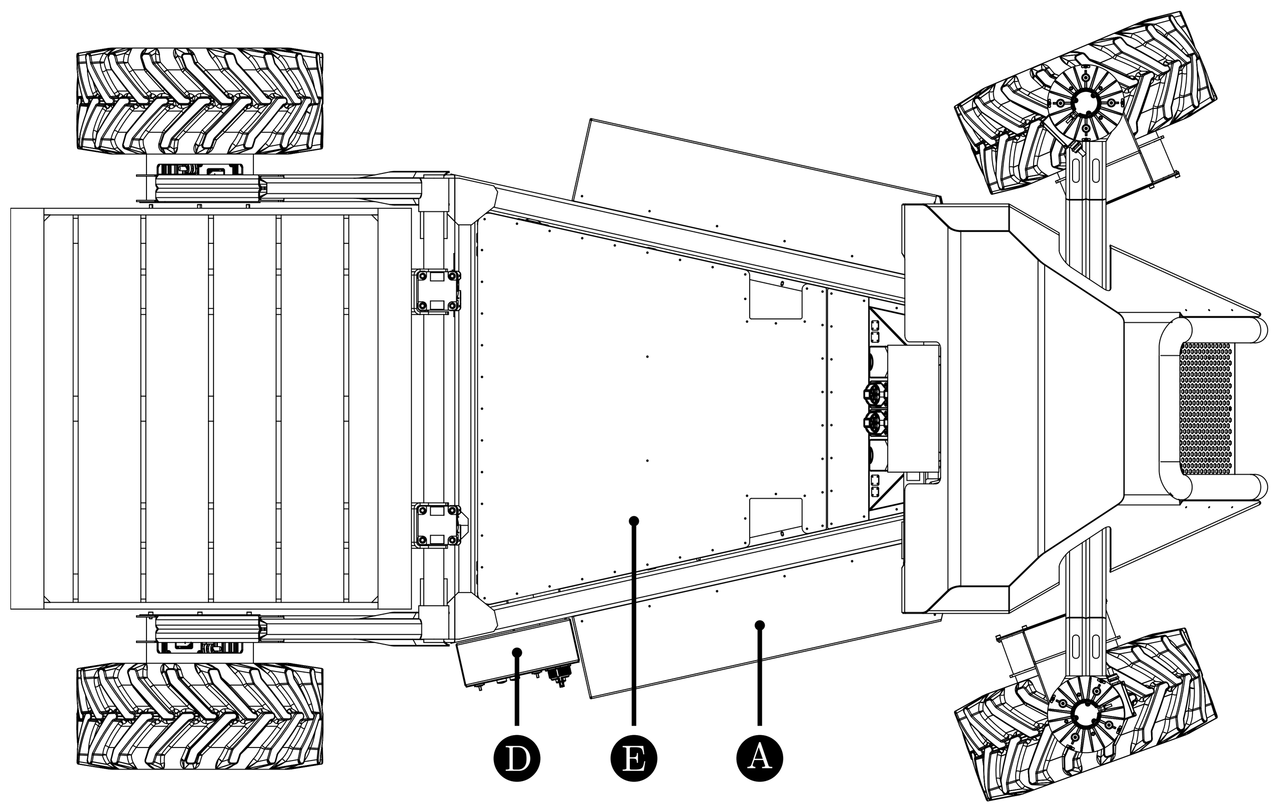
[2] Ministry for Primary Industries, "Growing exports", 2017. [Online]. Available: http:// www.mpi.govt.nz/exporting/overview/growing-exports/. [Accessed: 2017-09-25].

[3] Jason Timmins, "Seasonal Employment Patterns in the Horticultural Industry", Statistics New Zealand and Department of Labour 2009.

Design & Fabrication







- A Battery box
- B Kiwifruit bin
- C Steering motors
- D Operator's panel
- E Electrical cabinet
- F Power generation
- G Bin lifting mechanism
- H External connection panel

Track-width: 1840 mm
Wheelbase: 2670 mm
Turning circle: 6400 mm

The design can be broken down into the following parts:

1. Structural chassis with front pivoting axel,
2. Fully electric drive system,
3. Weather sealed electrical cabinets, and
4. Power generation unit

Computer Aided Design (CAD) software was used to design the chassis, check for manufacturablilty, and estimate the total weight. Simulation of the chassis using finite element analysis techniques guided design decisions, ensuring it is capable of carrying a 1000 kg payload. The design was fabricated from laser cut and folded sheet metal that was welded together and then powder coated.

Electric drive motors with in-built gearboxes are fitted to the chassis and wired to the electrical cabinet. The vehicle is four wheel drive with an additional two motors used to control the steering angle of the front wheels. Each of the four drive motors are 6.4 kW brushless AC motors with a 40:1 fixed-ratio planetary gearbox. The two steering motors are the same except for having a higher gear ratio and lower power rating. Because the front two wheels are controlled independently, steering angles of 90° are possible. This allows the platform to pivot about the center of its rear wheels, giving it a relatively small turning circle.

The electrical cabinet contains motor controllers, power supplies, control relays, high-voltage switch-gear and a control PC. Six on-board motor controllers are connected to the main PC via a Controller Area Network (CAN) bus. Software calculates wheel velocities and steering angles based on Ackermann steering geometry to eliminate the need for mechanical differentials.

A power generation unit is housed at the front of the platform. This unit contains an air cooled petrol engine connected via a heavy-duty timing belt to an electrical generator and air compressor. An embedded control module manages the engine and adjusts its operating speed to match the system's current demand for power. This module can also enable and disable the air compressor and electrical generator when not needed.

A fuel tank situated above the rear right-hand wheel can hold enough energy to power the platform under light loads for approximately 48 hours. The electrical generator is capable of supplying 14 kW of power for charging the on-board batteries. This makes the platform a series-hybrid petrol-electric vehicle, meaning it is also capable of operating without its engine running. A pack of thirty 90 A h lithium-iron-phosphate ($LiFePO_4$) batteries are fitted to pods mounted to each side of the chassis. The low-slung design of the platform gives room for the modules to operate under the orchard canopy.

Results & Further Work

The platform has proven capable of driving through kiwifruit orchards using its four wheel electric drive system. Drivability tests indicate no loss of control while loaded with a test mass of 1000 kg. The vehicle has been used to guide pollination and harvesting modules through orchard environments while providing power and compressed air. During these operations the module area at the provided sufficient space to operate under kiwifruit canopies. Once fully charged, the battery pack is capable of powering the vehicle under light loads for approximately four hours. Load testing of the power system shows it is sufficient for powering modules and driving simultaneously. The platform's tight turning circle allows the platform to turn between rows of a pergola style kiwifruit orchard making it well suited to this environment. In many cases it is capable of turning around in the space within a single row. This is something not possible with a traditional orchard tractor, and relatively difficult for a quad-bike. Lidar and camera based sensors have been fitted to the vehicle for tests involving autonomous navigation. The specific sensors selected proved useful for autonomously navigating an entire orchard block unassisted. Future work will focus on enabling the platform to drive autonomously.

Affiliations & Acknowledgements

Mark H. Jones, Matthew Seabright, Josh Barnett, Gordon Neshausen, and Mike Duke are affiliated with The University of Waikato. Alistair Scarfe is affiliated with Robotics Plus Ltd. This research was supported by the New Zealand Ministry for Business, Innovation and Employment (MBIE) on contract UOAX1414. The authors acknowledge contributions from Phillip Ross, and Erin Simms who were involved with the design and fabrication of the platform. **For correspondence regarding this poster email: mark@roboticsplus.co.nz**