Automated Trolley for Green House Pollination

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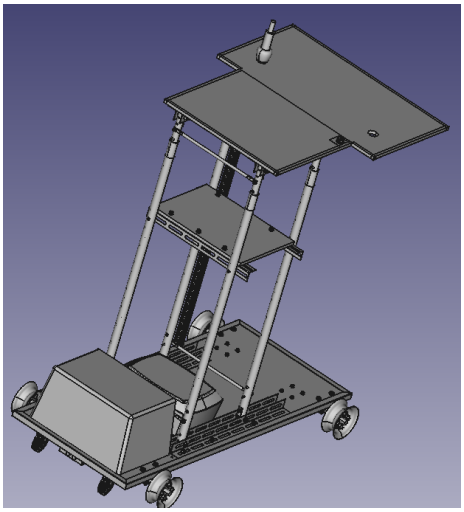
1 Overview

Our robot platform for pollination in greenhouses is designed to enhance the process of pollination within greenhouses. It is a prototype that consists of a custom-made trolley that houses a Universal Robots robotic arm (UR-5e) mounted on top. The main features of the robot are its compact size (footprint) and high mobility. It supports a total weight of up to 350kg and achieves the required speed of 1m/s. The robot is designed to run on a flat surface using the rails in a greenhouse.

The platform uses two 12V batteries (5kg weight each), for a supply voltage of 24V. It can achieve an acceleration of $0.2m/s^2$. With a desired operating time of 4.5 hours and a total efficiency of 65%, this robot is built to be reliable and efficient. The charger specifications are 24VDC 7.5A 10-step battery charger and 12vDC 4A 8-step battery charger. The motor specifications include 24 Volt, 25A rated load, 2.5A no load, with a gear ratio of 79:11 and a weight of 2.2kg. The controller configuration features a potentiometer for speed regulation and a built-in off switch for power-saving.



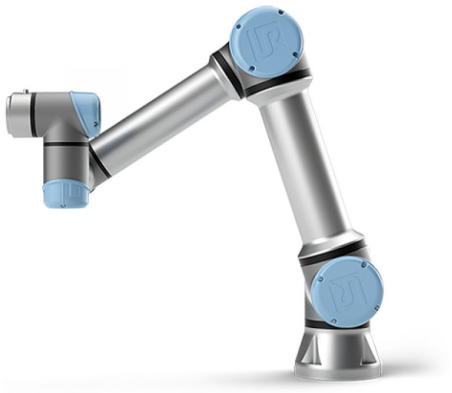


Fig. 1. (Left) Drawing of the complete platform with the housing for motor, electronics and batteries at the bottom, and the mounting plate for the robot arm on top. For image recognition and controlling the platform, a small computer or laptop should be mounted on the platform. (Right) The Universal Robots UR5e robot arm, intended to move a device to support pollination as its end-effector. Not pictured is the control box for the robot arm that also needs to be housed on the platform.

2 Assembly / storage

Figure 2 shows additional components of the system in case a rebuild becomes necessary. The components shown can usually remain on the system, and the electronics, batteries, and motor are covered with a plastic cover to protect against moisture. It may still be advisable to remove the platform and/or sensitive components from the greenhouse environment when not in use. The robot arm can be mounted relatively quickly using a custom-designed rail at the top of the platform. Both robot arm and control box can be operated at up to 90% relative humidity (non-condensing). The UR5e control box is about 12kg, and the robot arm approx. 20kg, so that assembly of the arm on top of the robot may require two persons.

To fully assemble the robot back after storage, the UR5e arm has to be attached to the top of the platform. The robot control box can be placed on the bottom platform, and connected to the battery. For a camera and a laptop to be connected, the camera will be mounted in the camera pole, and connected to the laptop. The laptop also should connect to (somewhere), to then control the robot arm.

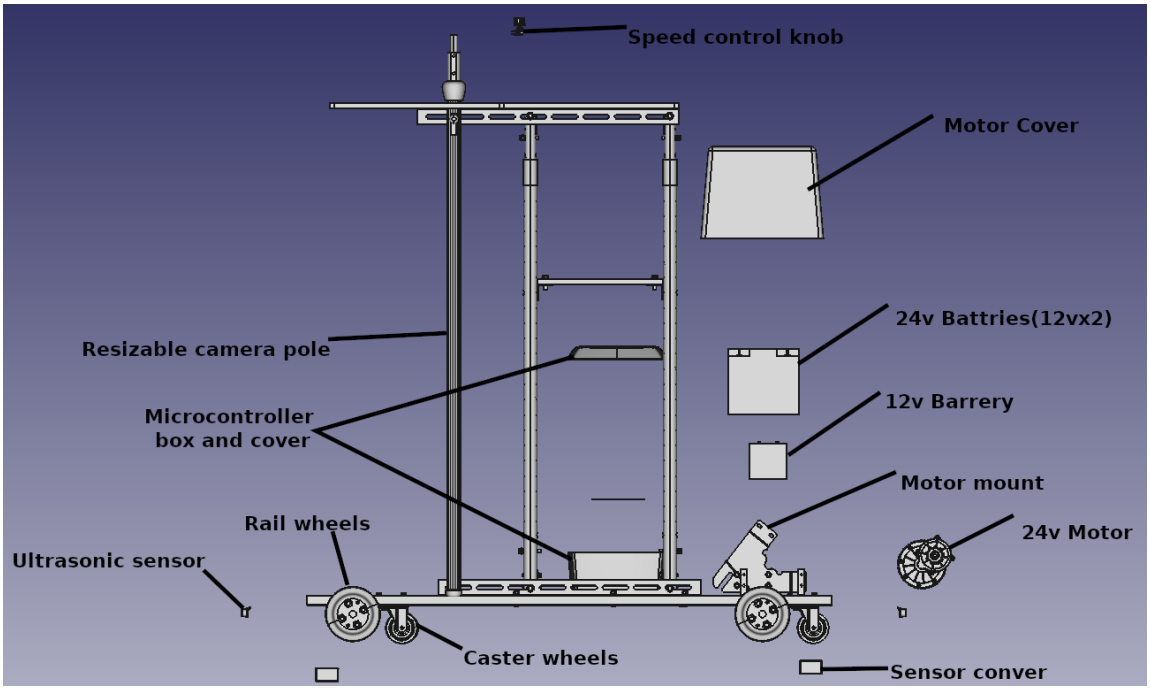


Fig. 2. Side view showing additional components of the system: Ultrasonic sensors at the end of the platform can be used to detect the end of the rail. The additional caster wheels are intended to aid manual relocation of the platform from one rail to the next. The camera used to identify flowers will have a fixed position near the robot arm.

3 Operation

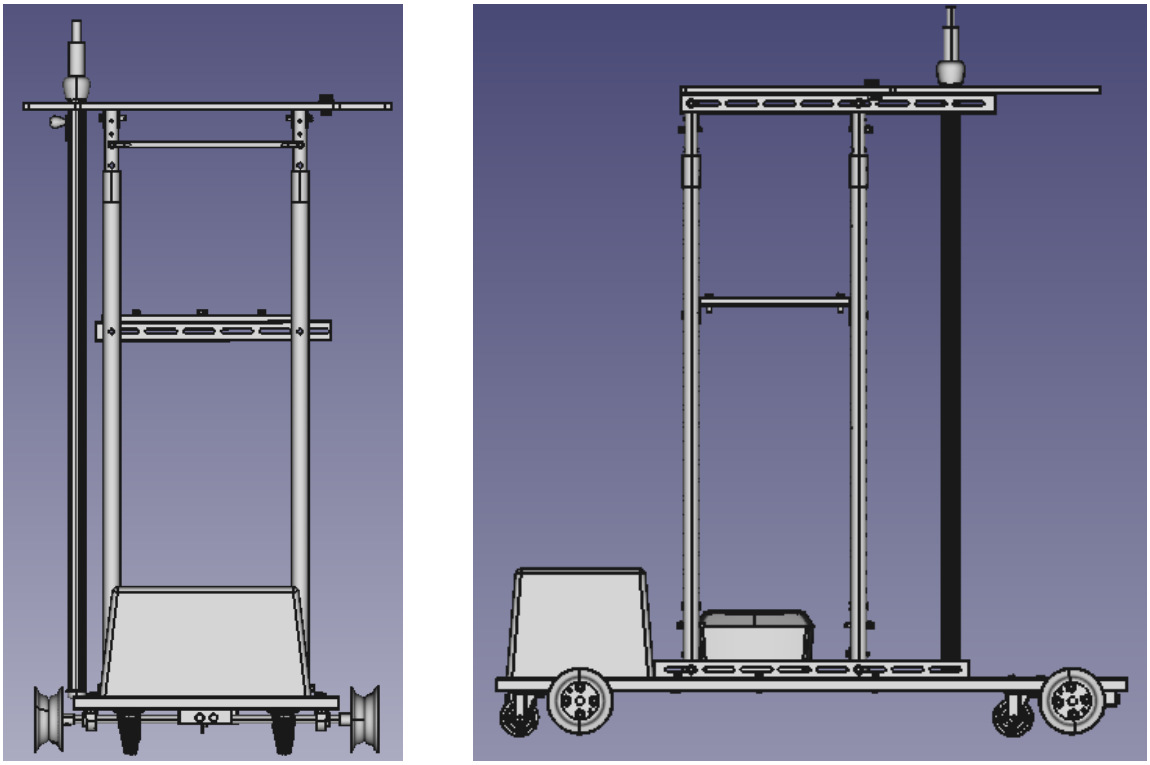


Fig. 3. Front and Side view schematics of the platform.

Once everything is connected, the platform can be operated. For fully automatic control, a lot of this will depend on the specific control program installed on the laptop, with the idea that this computer controls the arm based on data gathered from the camera. In the current configuration, the platform supports manual operation of the motor.

Independent of how the control of the arm and the computer works, a few first steps are necessary:

3.1 Turning on the platform

The trolley has 2 separate controllers which need to be turn on first.

1. Micro-controller
   To turn on the micro-controller, flip the toggle switch towards `on`. It is located on motor cover.
2. Motor power controller
   To turn on the motor power controller, rotate the emergency switches to enable it (see Fig. 4).

3. Finally, check for the motor speed knob: if motor speed knob is turned off rotate it counter clockwise to set the speed of motor and turning on motor power controller.

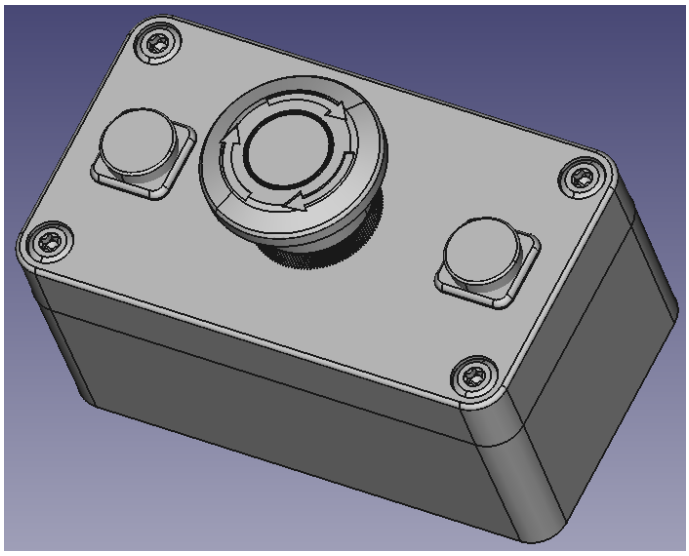


Fig. 4. Drawing of the run on emergency switch.

To turn the platform off, follow the above procedure in reverse order.

3.2 Moving the robot

The trolley motor can be manually operated: for forward movement, press the left push switch. To move the platform in reverse direction, press the right push switch on the handheld wired remote control.

For fully automatic operation, this control needs to be integrated into the control program. In case of problems with the control, you can also press the emergency stop button. This moving operation is controlled by micro-controller (MCU). The MCU sense the button press and switches the relay. Hence trolley operation can be easily converted to fully automatic operation. However, it is advisable to install moisture protected ultrasonic sensors to avoid accidents on automated trolley.

3.3 Charging

To charge the trolley and micro-controller battery, plugin AC plug to AC power socket. Charging of the batteries will take (some hours) if the batteries are discharged above 30%.

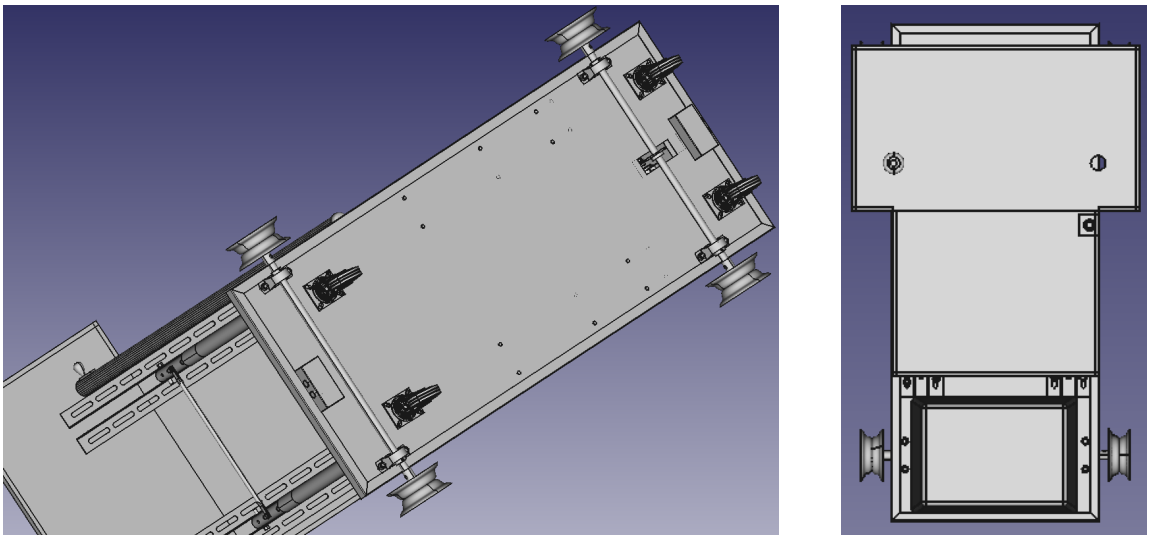


Fig. 5. Bottom view and top cross view schematics.

4 Further work and suggestions for next steps

Here is list of tasks that needs to be done:

1. The system could benefit from a better designed motor mount, to avoid issues with deformation and slippage of the chain, in particular under heavy loads.
2. The motor cover material is thin / not very durable, and there may be alternatives that better protect the motor from the inevitable humidity in a greenhouse environment.
3. The shafts are under heavy load and it may be necessary to replace them.
4. Install ultrasonic sensors for a platform auto-stop. This will prevent the platform from bumping into the wall and humans at either end of the tracks.
5. To better support the arm operating at different heights, as well as to ease assembly of the robot, a lifting platform may be a good idea.
6. The camera mount is fixed but adjustable. Some experiments will be necessary to verify this design choice: mounting the camera at different positions may require calibration of the camera / robot arm against each other, every time the camera is mounted. Possible fixes are the development of an automatic calibration procedure, or alternatively to mount the camera on a fixed (non-adjustable) position relative to the UR5e arm base. Another alternative may be to mount the camera on the end-effector.

5 Troubleshooting

Platform moving extremely slowly or not moving at all

- Check speed control knob
- Charge the batteries
- Check micro-controller

Battery not charging.

- Check battery connection
- Check battery power: if completely depleted (lower then 5 V) then use trickle charging

Appendix: Tech specs

General specs

- max. robot mass incl. payload: 350kg
- total driver motor: 1
- wheel radius: 61.5 mm (0.0615m)
- Required speed : 1m/s
- max incline : 0 degrees
- supply voltage: 24 V
- Acceleration: $0.2m/s^2$
- Desired operating time: (continuous operation) : 4.5h
- total efficiency: 65%

Chargers

- 24V DC 7.5A 10-Step battery charger
- 12 V DC 4A 8-Step battery charger

Motor specs

- 24 V, 25 A rated Load, 2.5 A no load
- 9 tooth sprocket for 1/2" x 1/8" pitch bike chain
- 8 Nm on the output sprocket @440 RPM
- Gear Ratio: 79:11 (7.18:1)
- Weight: 2.2 kg (alloy motor and frame)
- reversible operation: motor can run in either direction simply by swapping the motor leads to the opposite polarity
- 9 Tooth Sprocket for 1/2" x 1/8" Pitch Chain

Controller

- Output voltage: linear under load (from 10 V to 55 V max)
  (Suggested actual max. 48 V)
- Maximum current: 60A (Momentarily)
- Continuous current: 50A
- Speed regulation type: current regulation
- Speed regulation mode: potentiometer (linear)
- Supported motor type: DC brushed motor
- Speed range: 0–100%
- Control frequency: 15 kHz
- Wiring type: terminal Knob, with speed regulation (PWM) and a built in off switch that powers the controller off.
- Pot Specification: 100K (with switch)
- Wiring type: fence terminal block
- PCB size: 100 mm × 76 mm × 28 mm