# INDOOR AGRICULTURE AUTOMATION WITH ORLAR

## Design and Control of an Automated Nursery Pot Collection System


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**Team TheGs**

Tran Duc Anh s3924590
Phan Tuan Anh s3924671
Le Nguyen Hao s3963228
Tran Tuan Thanh s3978948
Quach Thanh Son s3925341

**Academic Supervisors**

Tran Quang Minh
Byron Anthony Mason

**Industry Supervisors**

Leo Monnier
Lyndal Hugo

**Company: ORLAR TECHNOLOGY**


## 1. WHAT IS THE PROBLEMS ?

As indoor agriculture scales up, thousands of nursery pots must be removed and collected after the vegetative stage. **Manually locating, loosening, removing, and transporting each pot is repetitive, time-consuming, and physically demanding**, making the process difficult to maintain efficiently at high production volumes. A reliable automated solution is therefore needed to improve the speed and consistency of nursery pot collection.

## 2. WHY AUTOMATE THIS TASK ?

Automating nursery pot collection can make the process ***faster, more reliable, and easier to scale*** while reducing the burden on workers.

**Reduce Labor:** Minimize repetitive and physically demanding tasks.

**Increase Efficiency:** Shorten collection time and support continuous operation.

**Improve Consistency:** Achieve repeatable positioning, gripping, and handling.

**Enable Scalability:** Handle larger production volumes with less human intervention.

## 3. ORLAR AUTOMATED POT COLLECTION SYSTEM

A robotic system integrating **computer vision, 3-axis motion, and a specialized gripper** to automate nursery-pot collection in indoor agriculture.

**Computer Vision -** Pot detection
**3-Axis Gantry -** Precise positioning
**Precision Gripper -** Pot handling

## 4. HOW DOES IT WORK ?

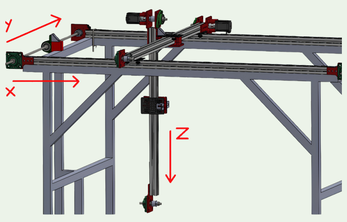
The ORLAR system follows an automated sequence to **locate, remove, and collect** nursery pots:

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| **DETECT** | **POSITION** | **GRIP** | **TWIST** | **LIFT & TRANSFER** | **REPEAT** |
| The camera identifies the position of the nursery pot. | The 3-axis gantry moves the gripper to the detected location. | The gripper securely holds the nursery pot. | A controlled twisting motion helps separate the roots from the growing area. | The pot is lifted and moved to the collection area. | The pot is lift and move to the collection area |

## 5. WHAT ENGINEERING DID THE TEAM ACTUALLY DESIGN?

### 3-AXIS GANTRY DESIGN

A custom gantry was designed to provide stable, precise, and repeatable 3D positioning of the collection mechanism throughout the growing area. The X, Y, and Z axes work together to accurately position the gripper for nursery-pot collection.

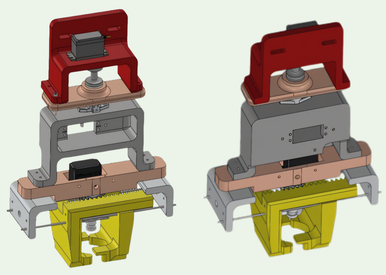



**X - Horizontal Movement**: Controls left/right positioning.
**Y - Longitudinal Movement**: Controls forward/backward positioning.
**Z - Vertical Movement**: Controls the approach and lifting motion.

**Design Focus:**
Workspace Coverage • Structural Stability • Positioning Accuracy • Repeatability

### PRECISION GRIPPER DESIGN

A specialized end-effector was designed to securely grip, twist, and remove nursery pots while maintaining stable handling throughout the collection process.

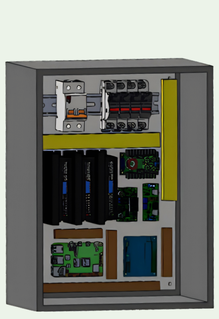


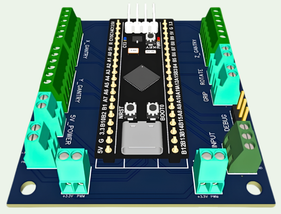
**GRIP** — Provides a secure hold on the nursery pot.
**TWIST** — Applies controlled rotation to help separate the roots.
**LIFT** — Maintains a stable grip during removal and transfer.

**Design Focus:**
Grip Strength • Controlled Rotation • Stability • Repeatability

### ELECTRICAL & CONTROL INTEGRATION

A centralized electrical system was designed to integrate the **controller, motor drivers, power components, and control hardware** for the vision, gantry, and gripper systems. The custom PCB simplifies and organizes electrical connections, while the electrical cabinet provides a **structured, protected, and maintainable hardware layout.**

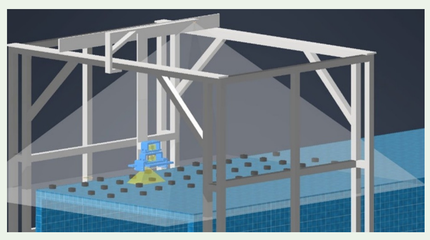




**Design Focus:**
Wiring Organization • System Reliability • Electrical Safety • Maintainability

### COMPUTER VISION – GLOBAL CAMERA & GRIPPER CAMERA

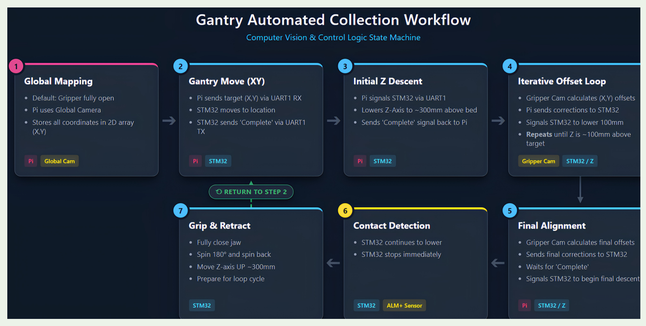
**Two cameras work together to ensure accurate pot positioning.** The **Global Camera** (grey lighting) maps the workspace and determines each pot's coordinates, while the **Gripper Camera** (yellow lighting) checks the pot's position during Z-axis descent. The **Raspberry Pi 4** processes the images, calculates positional offsets, and commands the gantry to correct the alignment.



**GLOBAL CAMERA** → Find the pot
**GRIPPER CAMERA** → Center the gripper
**RASPBERRY PI 4** → Process & correct

**Design Focus:**
Workspace Coverage • Positioning Accuracy • Real-Time Correction • Alignment Reliability

### CONTROL LOGIC STATE MACHINE




**CONTROL SEQUENCE**
**GLOBAL MAPPING → XY POSITIONING → Z DESCENT → OFFSET CORRECTION → FINAL ALIGNMENT → CONTACT DETECTION → GRIP & RETRACT**

The control system uses a **state-machine strategy** to coordinate the Global Camera, Gripper Camera, gantry, and gripper throughout the collection cycle. The **Global Camera** first maps the workspace and provides the initial coordinates of each nursery pot. The gantry then moves to the selected pot, where the **Gripper Camera is activated during Z-axis descent** to monitor the pot position and detect any offset. The Raspberry Pi processes the camera feedback and commands the gantry to correct the position until the gripper is properly aligned. **Contact detection** then confirms the gripping position before the pot is removed.

**Design Focus:**
Coordinated Vision • Position Correction • Controlled Motion • Repeatability

## 6. Testing & Validation

**COMPUTER VISION: 199/200 pots detected (99.5%)** with approximately **±5 mm positioning accuracy**, demonstrating reliable pot localization for automated positioning.

**GRIPPER:** Successfully demonstrated the complete **grip → twist → lift** sequence, maintaining a secure hold throughout pot removal and transfer.

**GANTRY:** Demonstrated coordinated **X, Y, and Z-axis motion** across the required workspace, providing stable movement and positioning for the collection mechanism.

**ELECTRICAL & PCB:** Successfully integrated the **controller, motor drivers, gantry, and gripper** through the custom PCB and electrical cabinet, enabling coordinated operation of the complete system.

## 7. Future Development

**COMPUTER VISION**: Upgrade to **RGB-D or ToF sensing** for accurate distance measurement and develop correction algorithms for camera tilt and distortion.

**GRIPPER**: Upgrade to an **industrial-grade aluminum end-effector** with pneumatic/electric actuation and force sensing for precise gripping control.

**GANTRY**: Future upgrades will include **closed-loop and higher-torque motors** for improved accuracy and speed, a **Z-axis brake** for safety, **industrial linear rails and a reinforced X-axis** for greater stability, and **upgraded motor drivers** for improved electrical and thermal protection.

**ELECTRICAL & PCB**: Upgrade the electrical system toward **industrial-grade reliability and maintainability** through improved power distribution, electrical protection, modular PCB design, and organized industrial wiring.