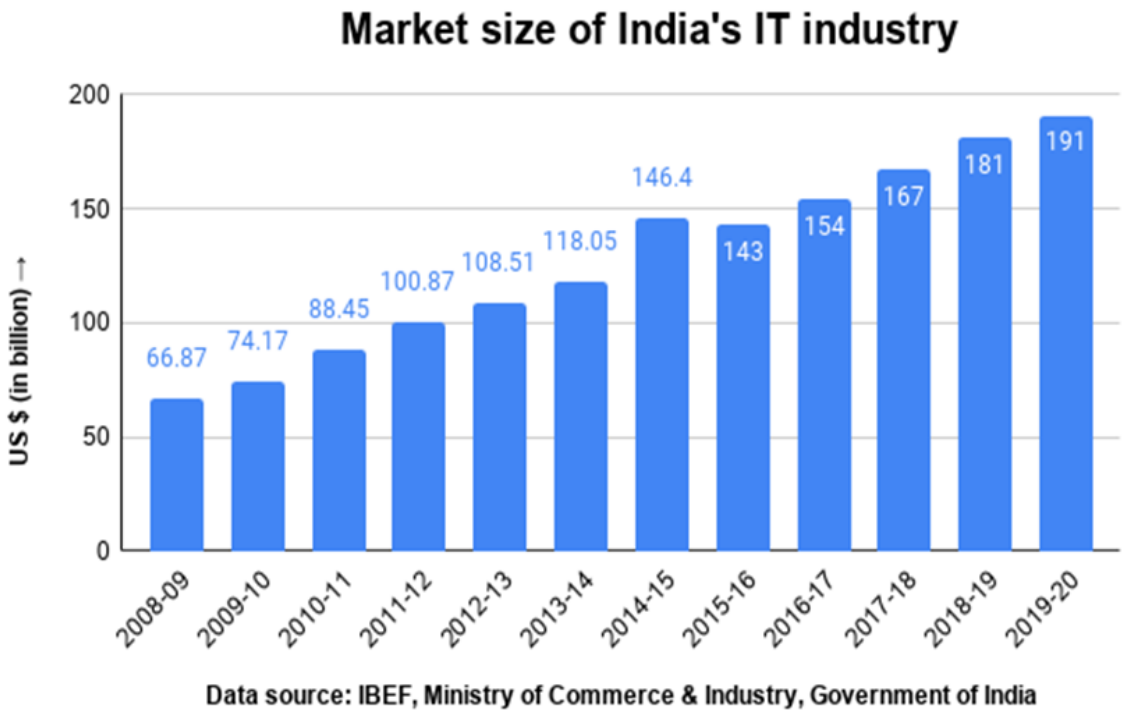
Appropriating Digital Technology for Automation of Indian Agriculture

Dr. Nachiket Kotwaliwale
Director, ICAR-CIPHET

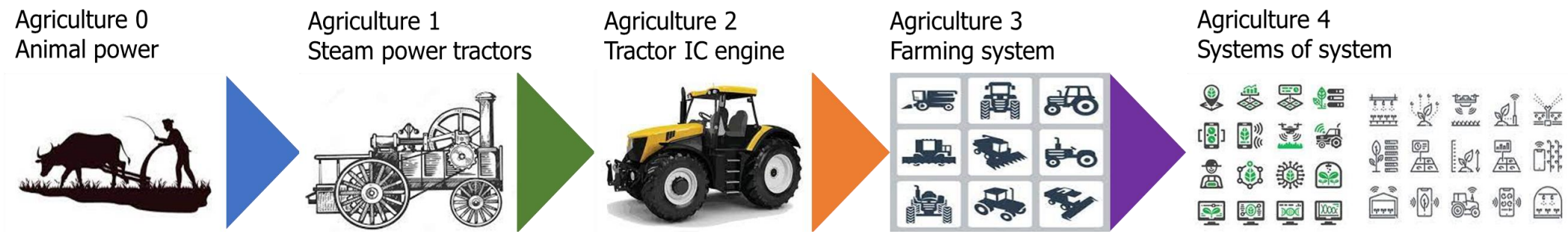
IT advancement in Indian Agriculture



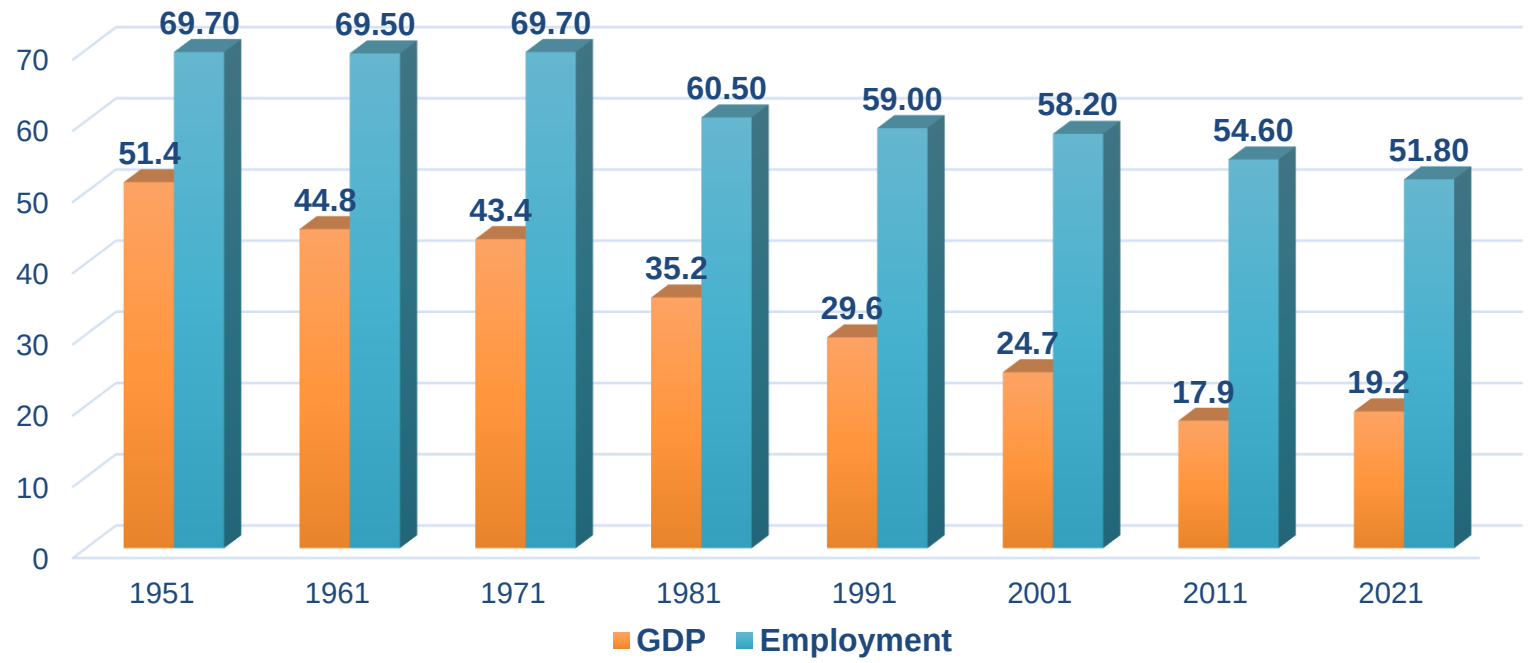
- **INDIA**: The largest sourcing destination (67%) for the information technology (IT) industry
- Information technology (IT) is increasingly being used in agriculture to improve efficiency, productivity and labour dependency.
- IT can play a leading role in many phases of agriculture.

Development in Agriculture System

Mechanization in Agriculture:	Digitization in Agriculture:
❑ India has been making efforts to increase mechanization in agriculture to enhance efficiency and productivity. ❑ Tractor usage has been widespread, especially in regions with larger landholdings.	❑ **Precision Farming:** Farmers are adopting precision farming techniques with the use of sensors, GPS, and data analytics for optimized resource use. ❑ **Mobile Apps**: Several mobile applications provide farmers with information on weather forecasts, market prices, and crop management.

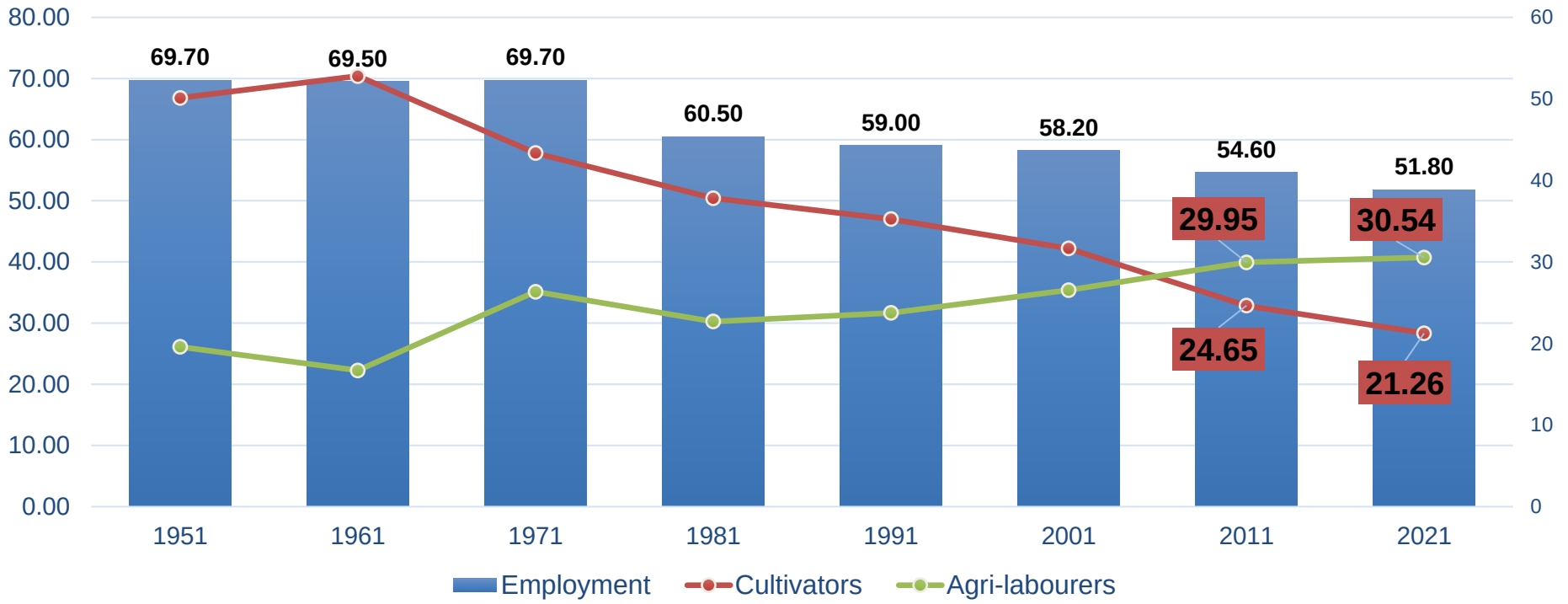


Share of agriculture in GDP and employment of India



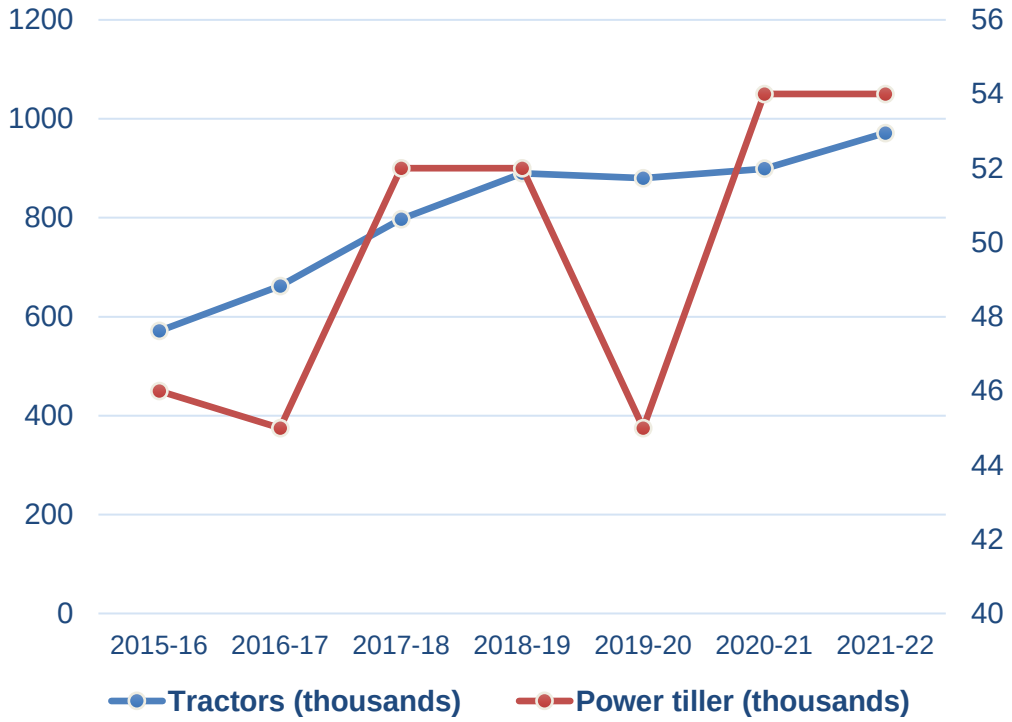
(Source: Agricultural Statistics at Glance (2022-23), MOSPI, Government of India)

Composition of cultivators and agri-labourers in total agricultural workers



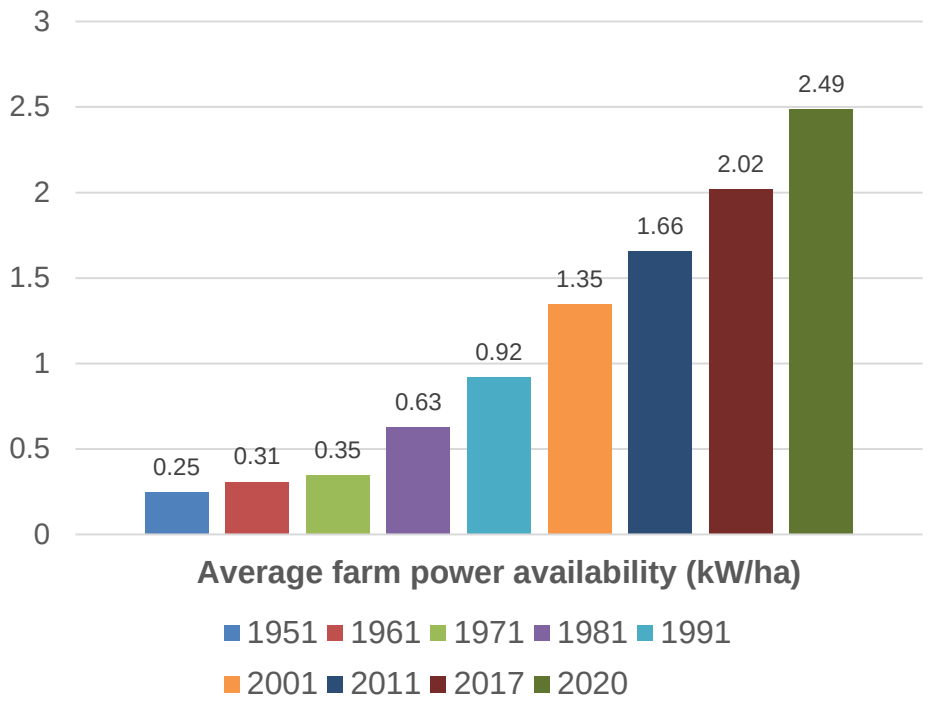
(Source: Agricultural Statistics at Glance (2022-23), MOSPI, Government of India)

Level of farm mechanization



Trend in sale of tractors and power tillers

(Source: Agricultural Statistics at a Glance, 2022)



Average farm power availability in India

Source: NCAER, 2023 (https://www.ncaer.org/wp-content/uploads/2023/02/NCAER-Report-Making-India-Feb-2023.pdf)

Agriculture unit operations & issues

- **Land Preparation:** Inefficient manual plowing and leveling
- **Seeding and Planting:** Inconsistent seed spacing and depth
- **Crop Care:** Lack of real-time monitoring for pest and disease control.
- **Irrigation:** Inefficient water use and over-irrigation.
- **Fertilization:** Inaccurate application leading to nutrient imbalances.
- **Harvesting:** Manual harvesting is labor-intensive and time-consuming.
- **Post-Harvest Operations:** Inadequate post-harvest handling leading to losses.
- **Transportation:** Inefficient transportation leading to delays and spoilage.
- **Marketing and Sales:** Limited market access for smallholder farmers

Emerging technologies

- Artificial Intelligence
- Internet of Things
- Big data
- Robotics
- Cobots
- Drone technology
- Blockchain

AI and IoT in Agriculture

- Robots
- Drones
- Remote sensors
- Computer imaging
- Machine learning
- Analytical tools

Cultivation Phase

Seed selection
Land preparation
Water irrigation
Seed sowing

Monitoring Phase

Monitoring & data collection
Disease identification
Weed control
Use of Fertiliser & Pesticides

Harvesting Phase

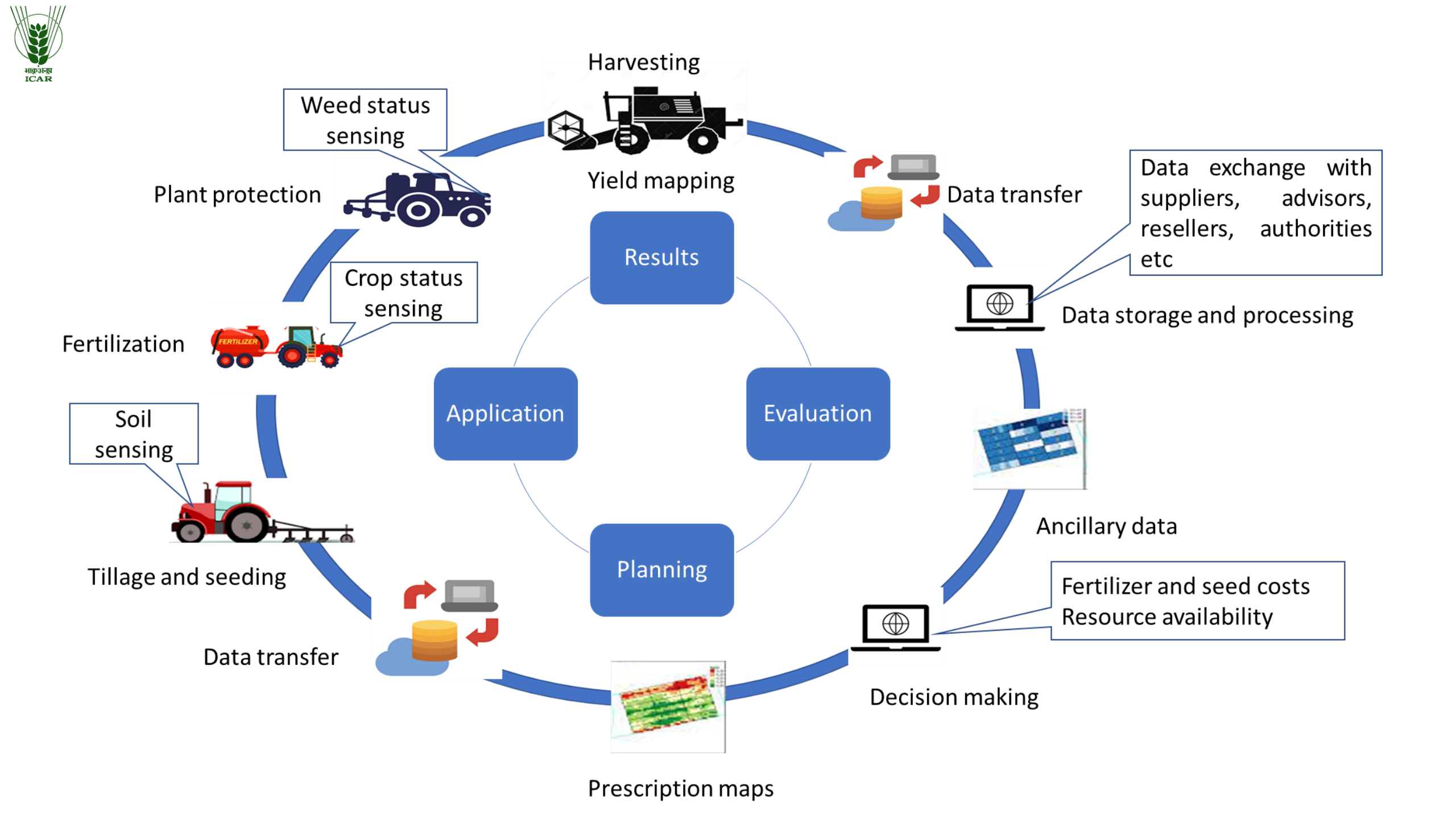
Segmentation
Cutting
Picking of Crop and fruits
Storing
Selling

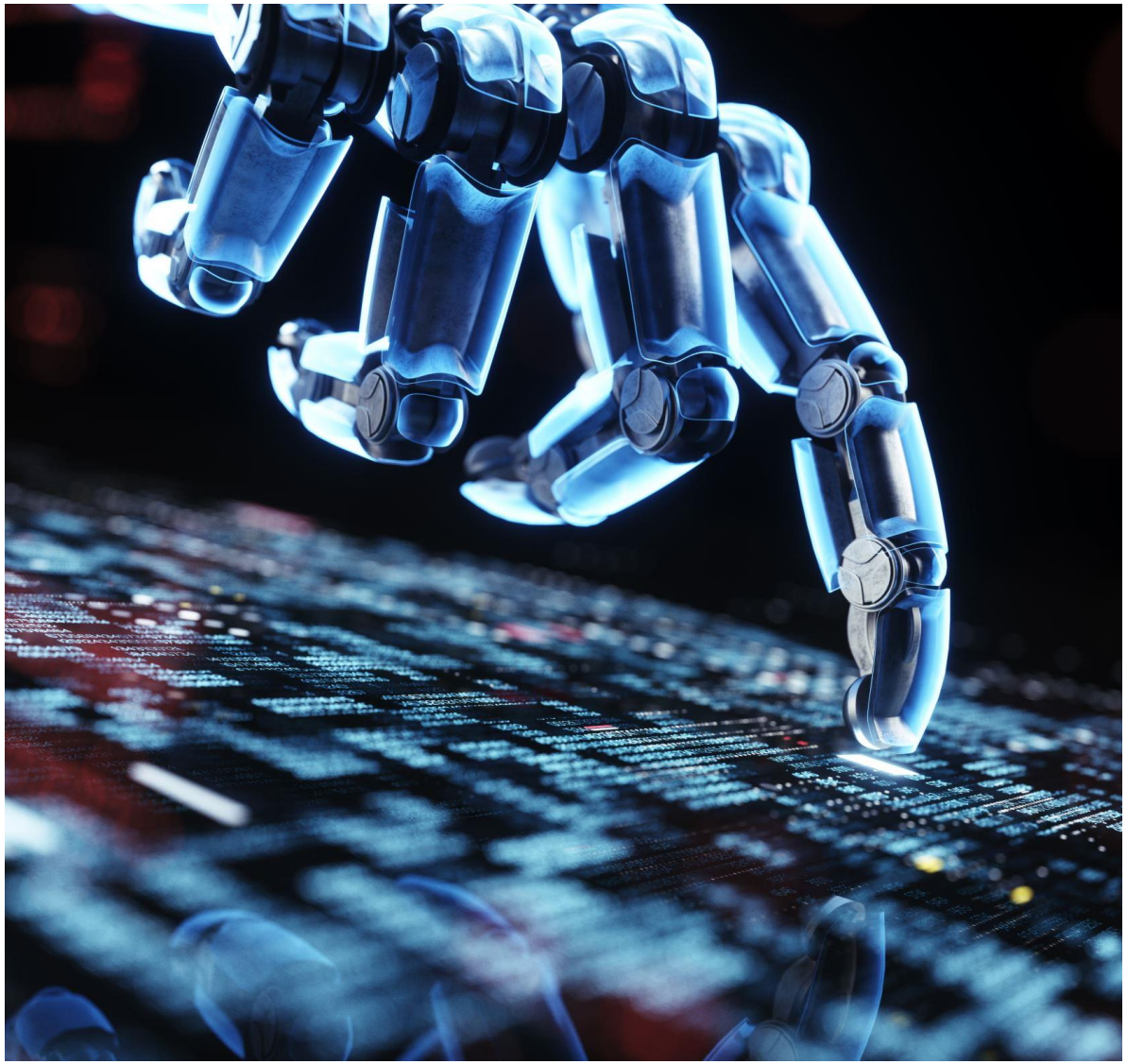
Post-harvest Phase

Post-harvest technology
Packaging and storage
Transportation

Digital technologies in Agriculture

1. **Precision Agriculture:**
    1. Utilizing GPS, sensors, and data analytics for precise resource management.
    2. Addressing resource scarcity and optimizing input use.
2. **IoT and Sensors:**
    1. Continuous monitoring of crops, soil, weather, grain storage and animal conditions.
    2. Enhancing decision-making and minimizing risks.
3. **Machine Learning and AI:**
    1. Predictive analytics for pest detection, disease prevention, and yield forecasting.
    2. Improving efficiency and reducing losses.
4. **Blockchain:**
    1. Transparent and secure supply chain management.
    2. Ensuring food safety and traceability.
5. **Drones and Satellite Imaging:**
    1. Monitoring large agricultural areas for crop health assessment.
    2. Aiding in precision farming and disaster management.
6. **Mobile Applications:**
    1. Providing farmers with real-time information on weather, market prices, and best practices.
    2. Enhancing accessibility and knowledge dissemination.


Harvesting
Yield mapping
Data transfer
Data exchange with suppliers, advisors, resellers, authorities etc
Data storage and processing
Ancillary data
Fertilizer and seed costs
Resource availability
Decision making
Prescription maps
Data transfer
Tillage and seeding
Soil sensing
Fertilization
Crop status sensing
Plant protection
Weed status sensing
Results
Evaluation
Planning
Application



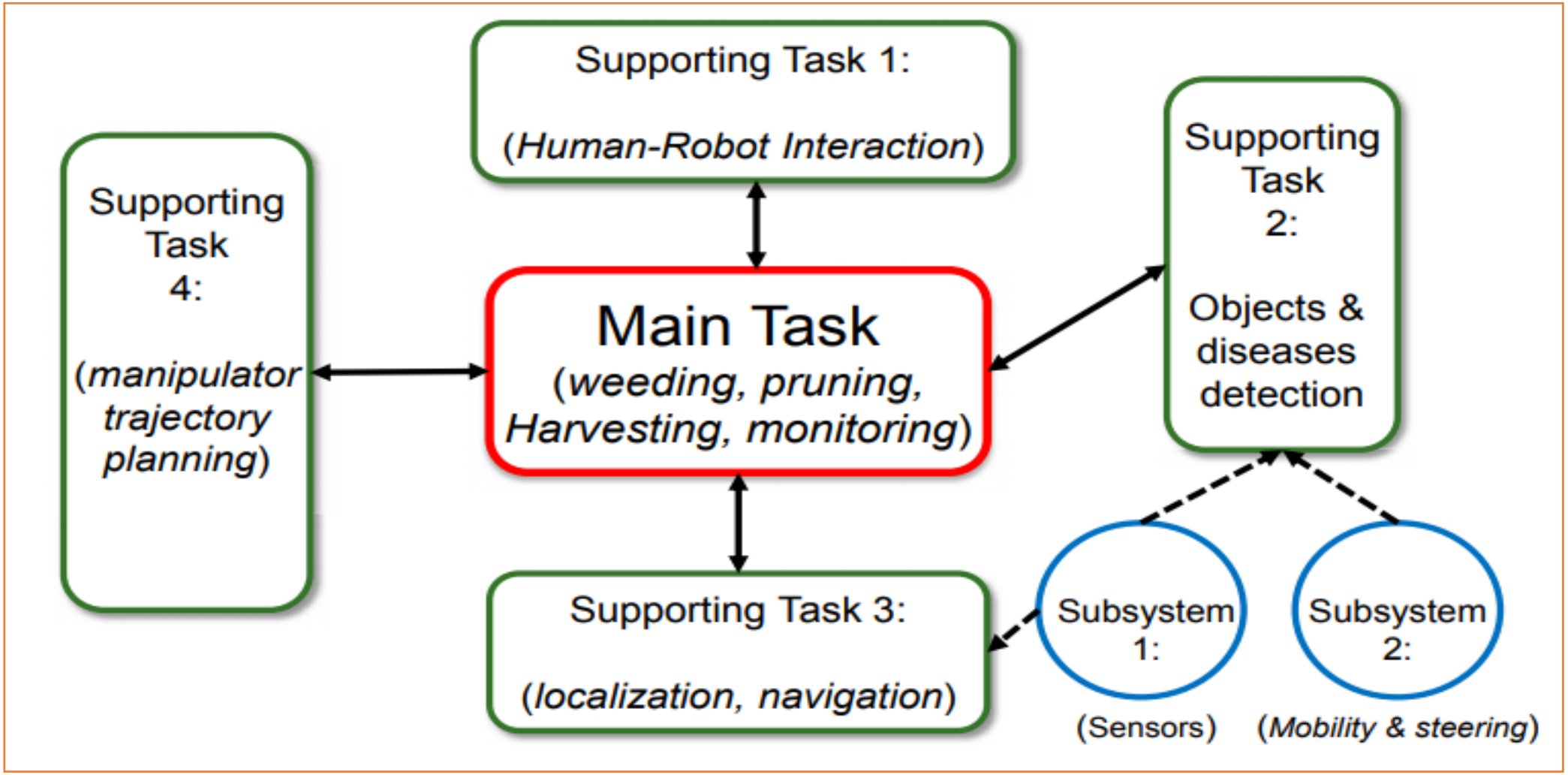
Robotics

- Grafting
- Transplanting
- Weeding
- Spraying
- Planting
- Irrigation
- Fruit picking
- Harvesting of crop
- Post harvest quality & food safety management
- Storage and inventory management

Autonomous Robot Systems (ARS)

- ARS developed to perform tasks, make decisions and act in real time without human intervention
- It used for crop production are composed of numerous subsystems and devices that enable them to operate and perform their tasks (Van Henten et al., 2013).
  - Path and Trajectory planning,
  - Navigation or guidance abilities,
  - Mobility,
  - Steering and control,
  - Sensing,
  - Manipulators or similar functional devices,
  - Manage individual or simultaneous unexpected events, and
  - Autonomy (Some level).

Structure of Sub-Systems in Agricultural Robot System



Weed detecting robot in sugarcane fields

- The robotic model employs a Raspberry Pi based control system placed in a moving vehicle.
- An automated image classification system has been designed which extracts leaf textures and employs a fuzzy real-time classification technique.
- Totally 48 features have been extracted from each texture image and finally 9 features are selected for the weed identification system.
- Weed detecting robotic model uses a fuzzy real time classifier on leaf textures.

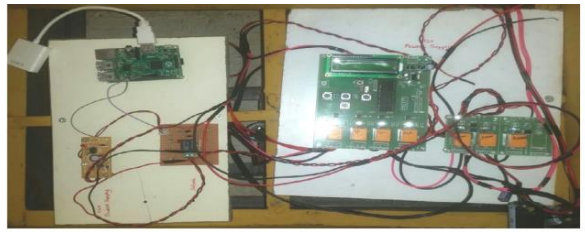
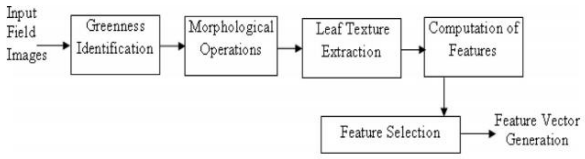


Fig. 4. The hardware implementation of colour based Algorithm.



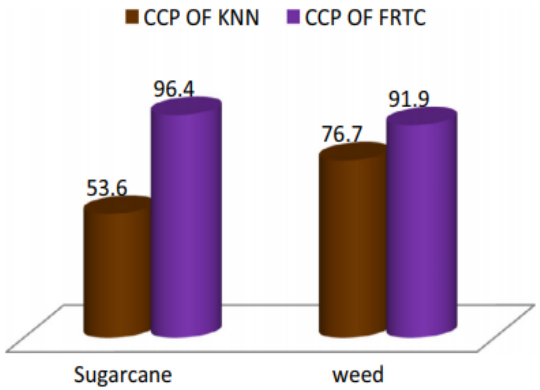


Fig. 12. Performance comparison between k-NN and FRTC.

(Source: Sujaritha, M., Annadurai, S., Satheeshkumar, J., Sharan, S.K. and Mahesh, L., 2017. Weed detecting robot in sugarcane fields using fuzzy real time classifier. Computers and electronics in agriculture, 134, pp.160-171)

Robotic Precision Planter :

- Wireless control through microprocessor using Wi-Fi module
- **Controls:** Traction wheel control, steering control, seeding mechanism control in three Cartesian coordinates.
- Total time: for completion of one block is 3 min 40 s

Indian Agricultural Robots

Cotton Harvesting

The arm is fitted with a tube that has vacuum maintained in it that sucks out the cotton boll and collects it in one go.

(Source: Link:https://economictimes.indiatimes.com/smallbiz/startups/features/robot-harvester-this-precision-farm-machine-can-shape-the-future-of-india)

Robotic transplanter

Automatic Transplanting Mechanism

1. Pneumatic actuated gripper for grasping and releasing the plug type seedling
2. The transplanting rate of developed mechanism was set as 20 – 25 seedlings/minute.

Robotic Rice Pellet Seeder

1. The control of the seeder is done remotely from the telemetry controller.
2. The basic feature of the controller are the two Joy sticks for right and left moment.

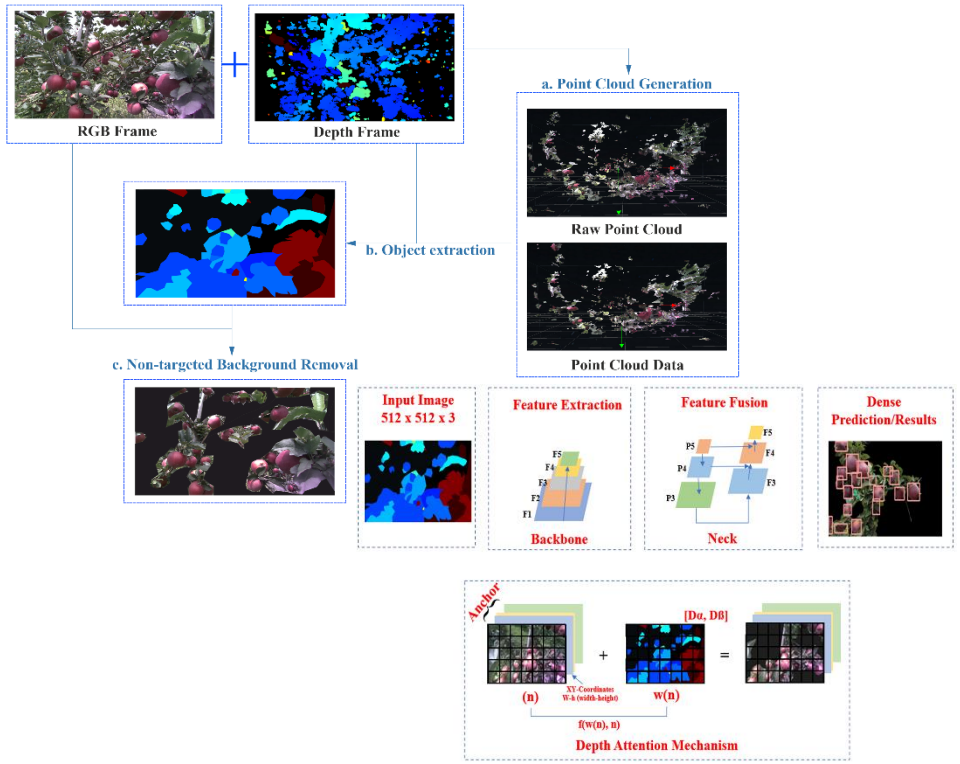
Robotic apple harvester fruit detection and localization using depth data

Data Collection

Apple Variety: Red Velox
Location: Orchards of Kashmir
Image Categories: Sunny, Shady, occluded

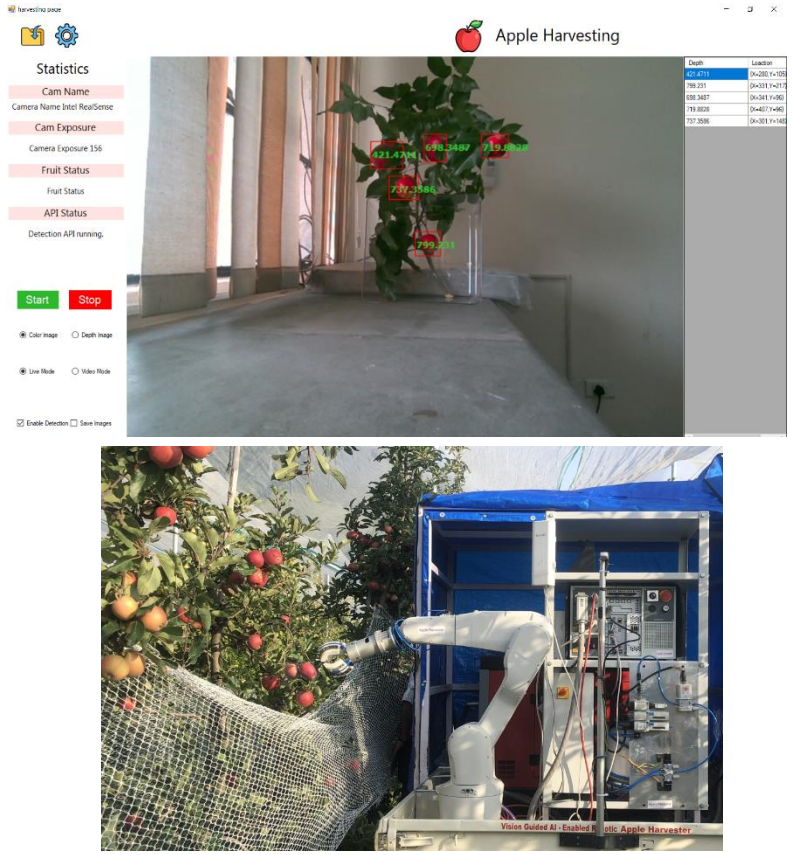
Image corpus created:
Red Velox
Red Gala

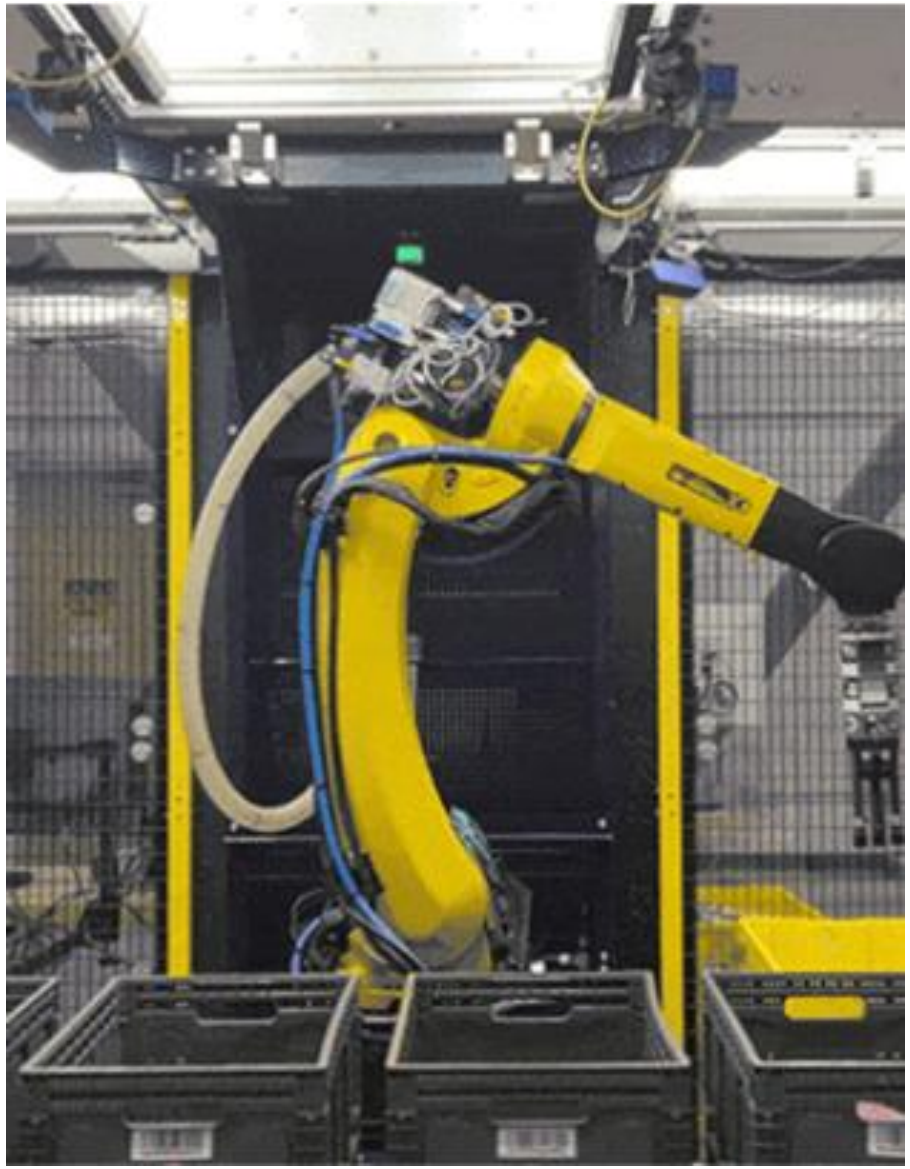
Detection model development with depth fusion

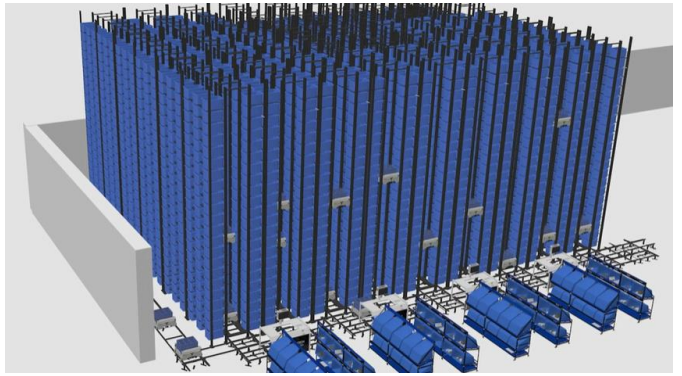


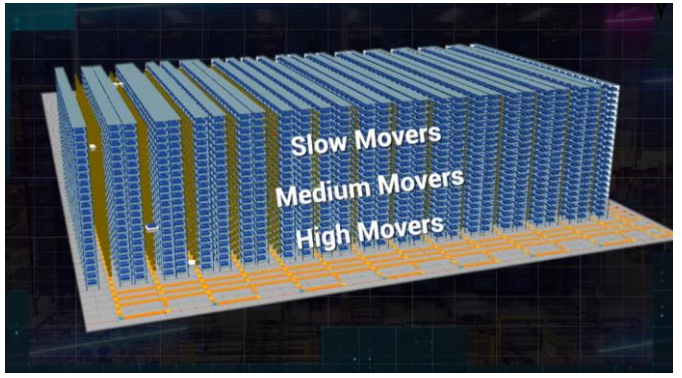
Achieved detection accuracy of 94% with YOLOv5 and 96% with YOLOv7

Detection model communication on lab simulated setup





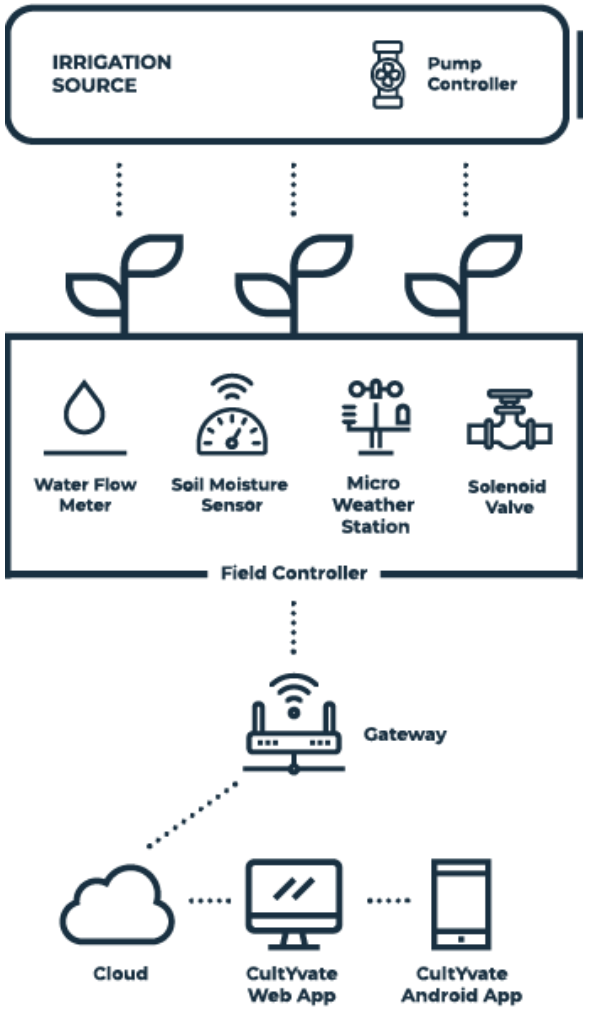




Robots in warehouse management

(Source: amazon.com)

IoT based smart irrigation system




Receiver ESP 8266


Relay board


Solar panel

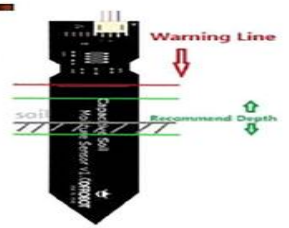

DHT11


DS18B20 Soil temperature


ESP 32


Transmitter

Solenoid valve and pump



Soil moisture sensor

Automatic Irrigation System for Rice

- The water level sensor for detection of ponding water in the rice field
- Water level sensor operates with solar power and transmits signals to the controller wirelessly
- The developed controller operates the pump based on water level above and below the threshold limits.

Water Level Sensor for Rice Field

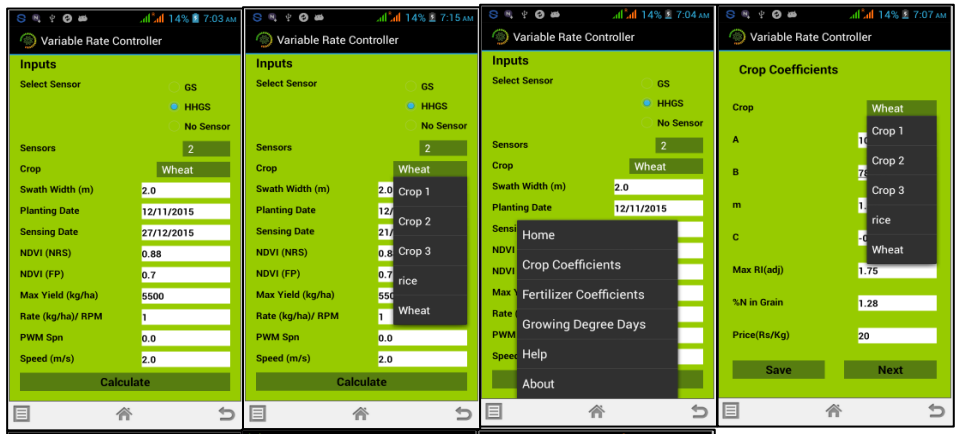
Controller

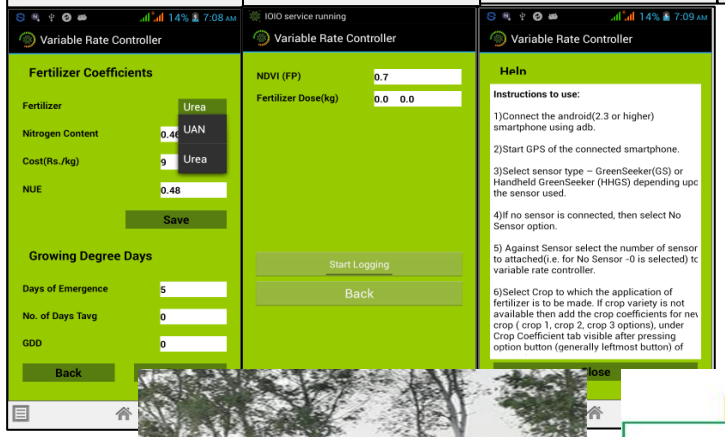
Water Level Indicator

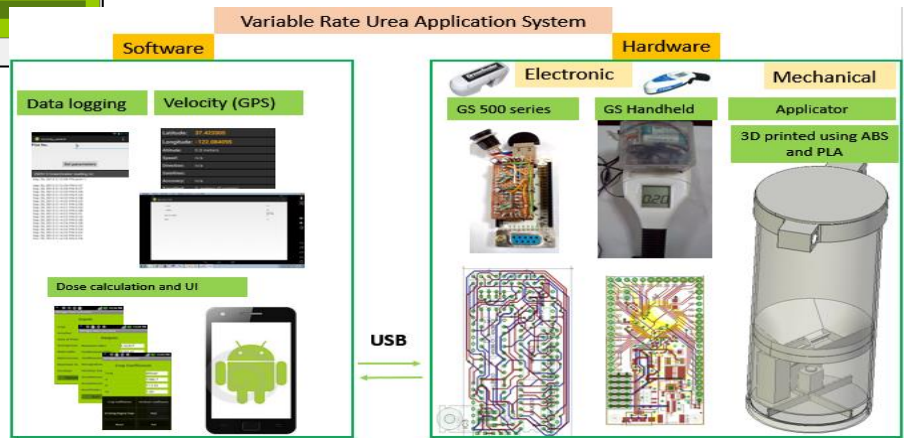
Field View

Real time soil moisture-based sprinkler irrigation system

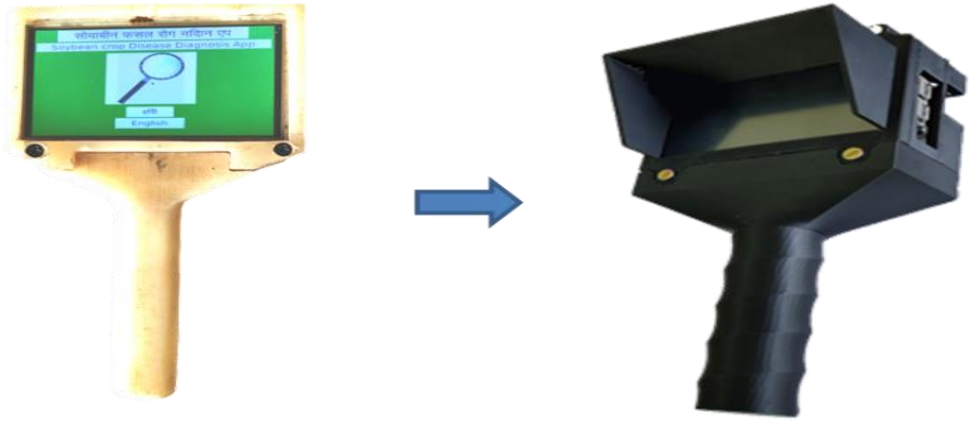
Fertigation system based on plant needs







Plant disease diagnostics based on AI



Hand held Device

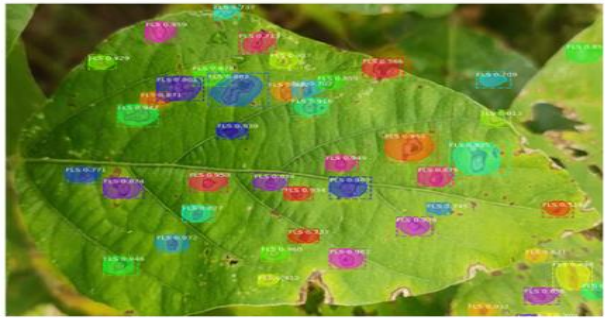
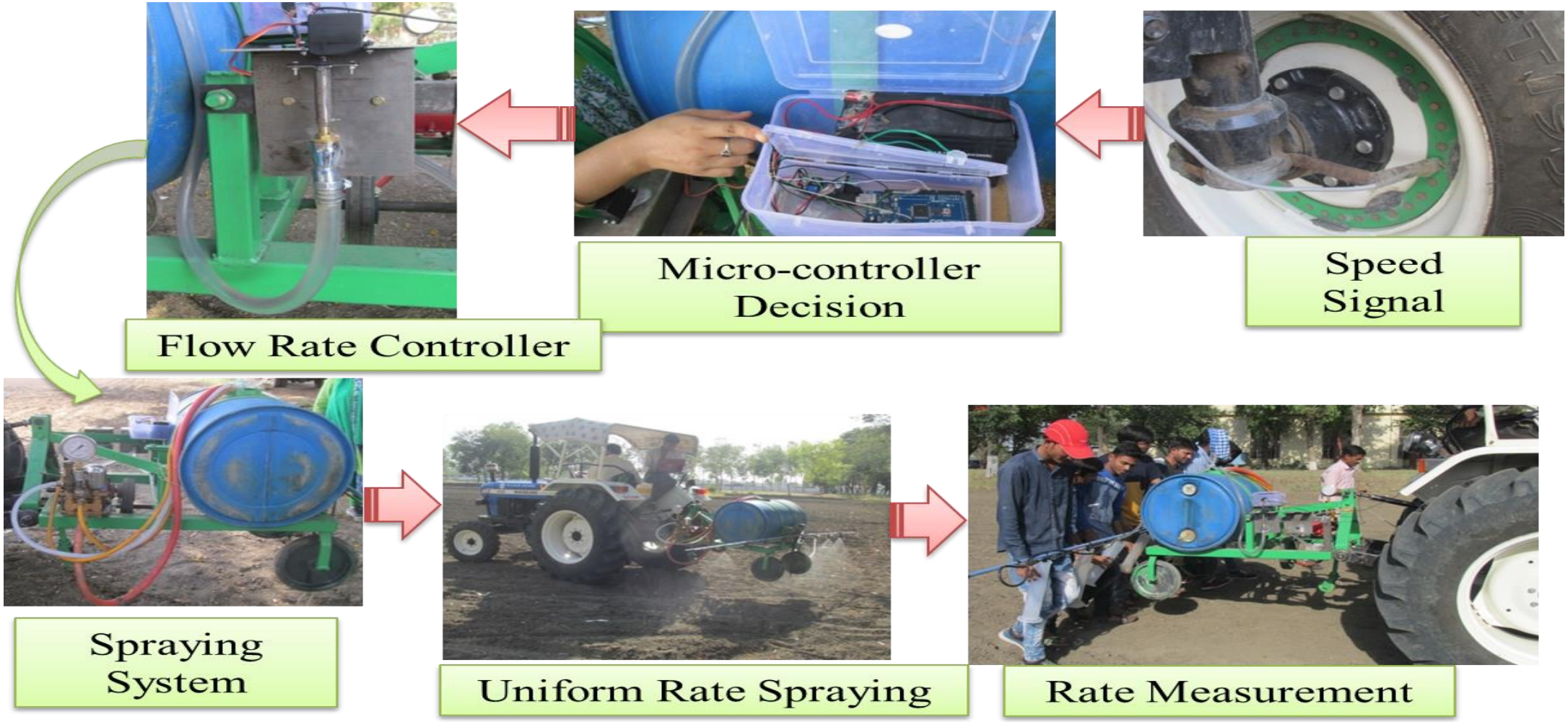


Image segmentation

GUI of Mobile App

Real-time uniform rate spraying system

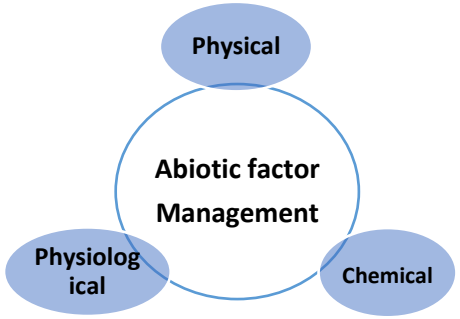


- Rate of chemical spraying - independent of forward speed
- No chemical loss during turning at head lands

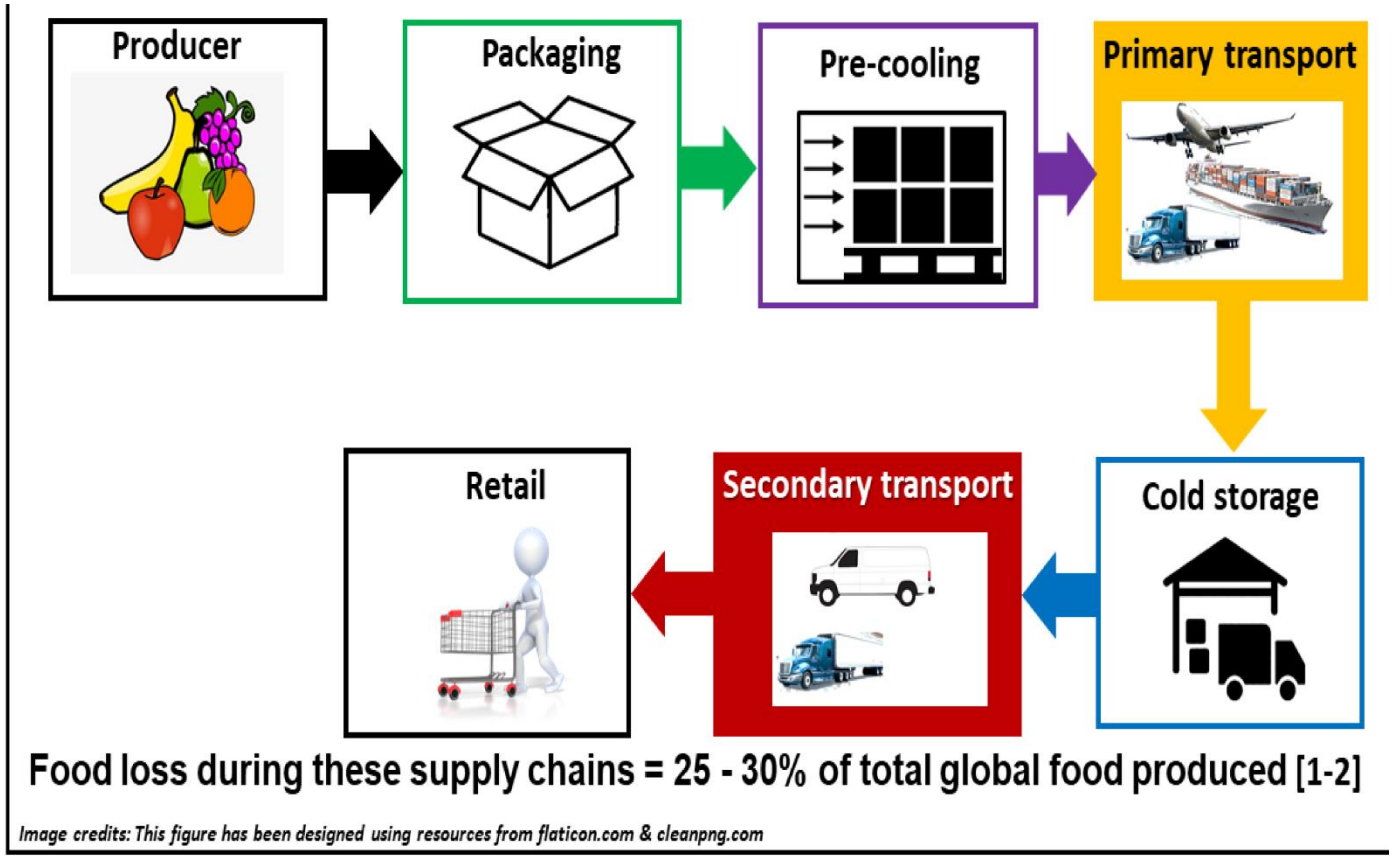
More areas to be covered

- Seed quality detection
- On-field pest management
- On the go soil sampling and quality detection
- Picking/ harvesting of commercial crops
- Scouting for crop insurance

Post-harvest operations



- **Losses** of agricultural produce are a major problem
- **Wide variety of factors**: physical, microbial, chemical, insect/pests etc. Growing conditions to handling at the retail level.
- **Need for efficient** handling, storage, transport & marketing of agricultural produce to reduce losses and improve the lives of farmers.



Post-harvest unit operations and Losses

Producer

Heat

• Rain
• Humidity

Contamination

Pre-processing → Transport → Storage → Processing and packaging → Marketing

- Broken grains
- Excessive dehulling, trimming

- Spillage
- Bruising
- Breakage
- Leakage

- Insect
- Moulds
- Bacteria
- Rodents
- Birds
- Sprouting
- Rancidity
- Overripening

- Inefficiency
- Excessive peeling, trimming & polishing

- Unsafe foods
- Quality losses

Consumer

Quality sensing system for packaged Mushroom

Display

Power LED

Test pass LED

Test Fail LED

Enclosure

Motor Switch

Charging Point

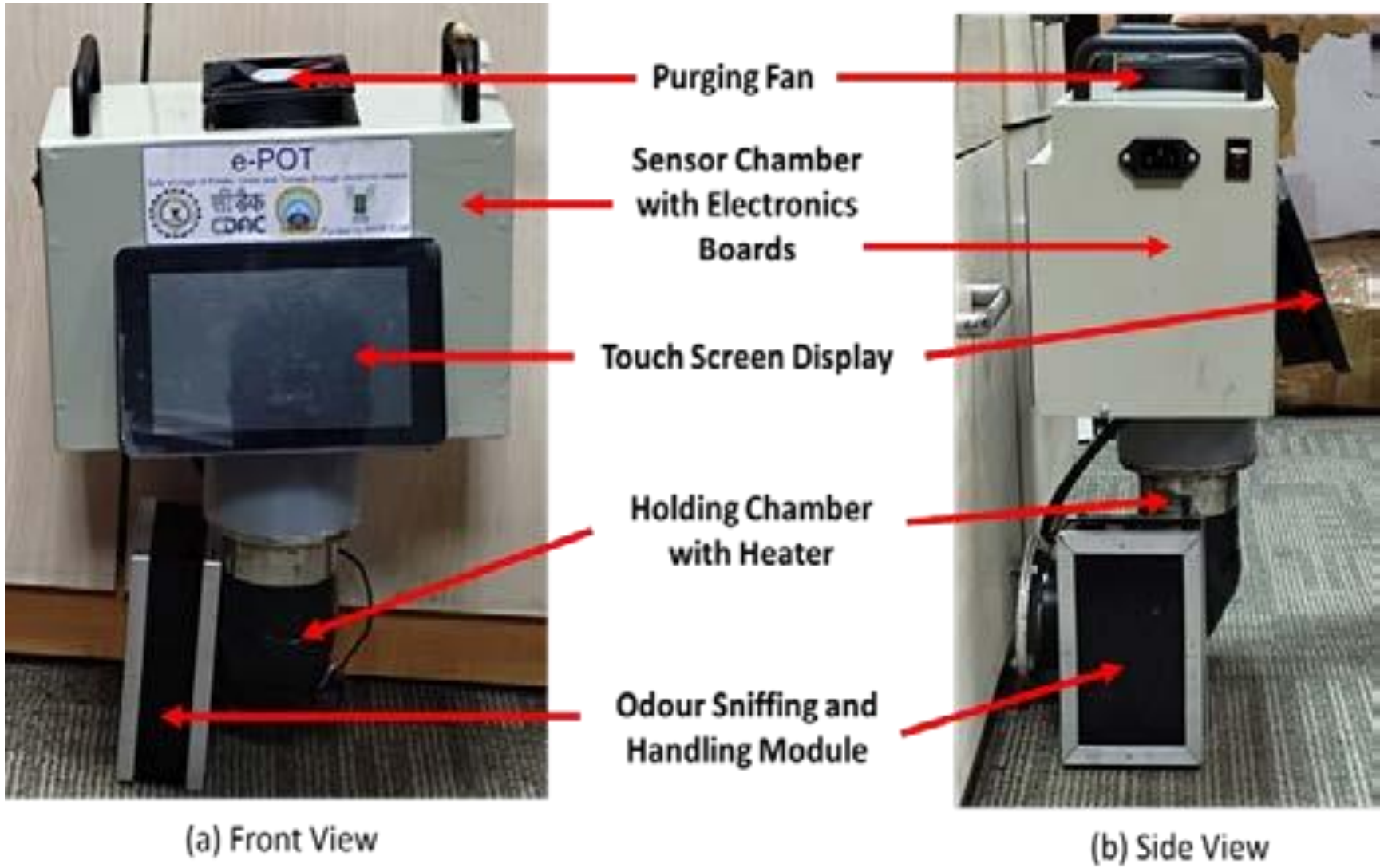
Power Switch

Inlet Syringe with Filter

Outlet Syringe

Packaged Mushroom quality can be evaluated

Post-harvest quality evaluation

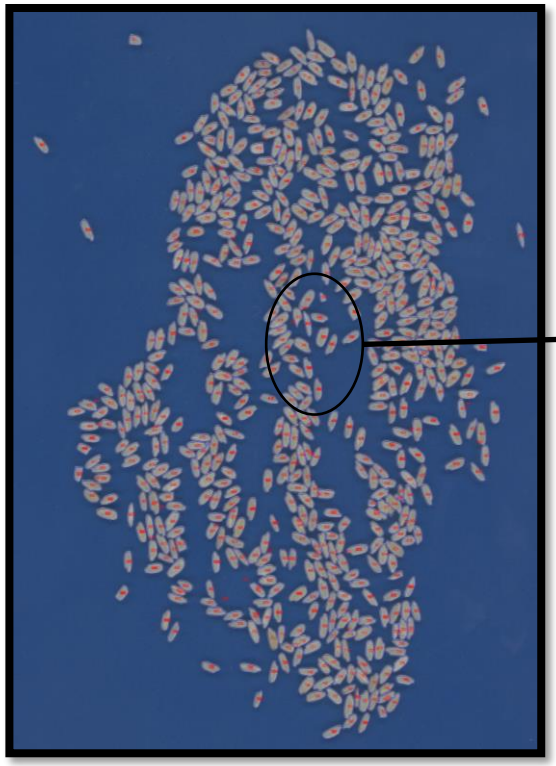


e-POT device.

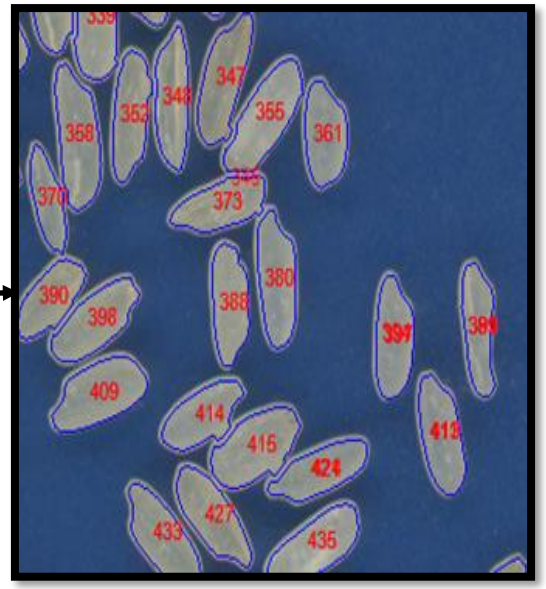
AI enabled machine vision based grain analyzer

Scanner with computer

Rice Images from scanner

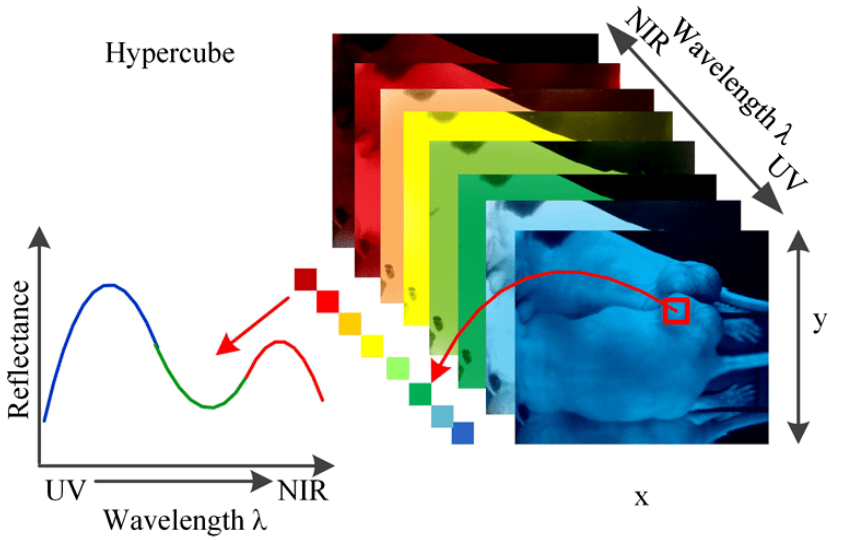


Rice Grain Segmentation



Individual rice grain identification

Hyperspectral imaging for safety and quality

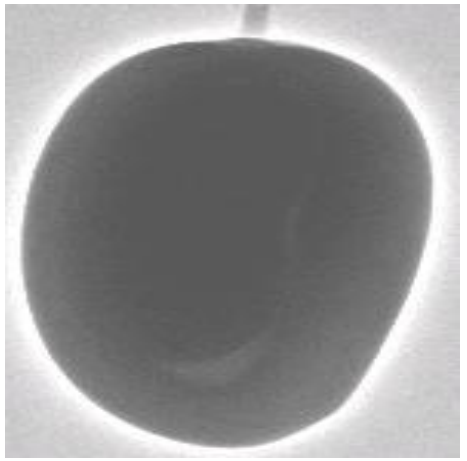


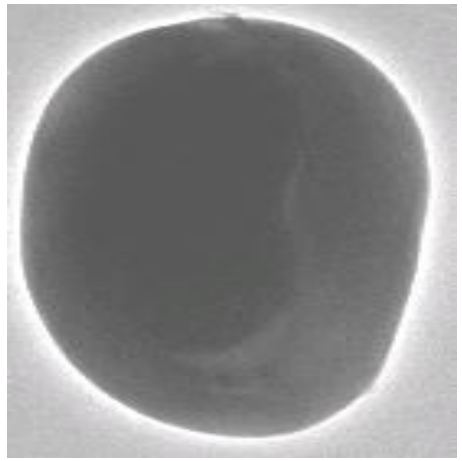
- **Freeze damage to cucumbers**
- **Nitrates in leafy vegetables**
- **Aflatoxin detection**

Radiography setup

Good fruit

Fruit from outside

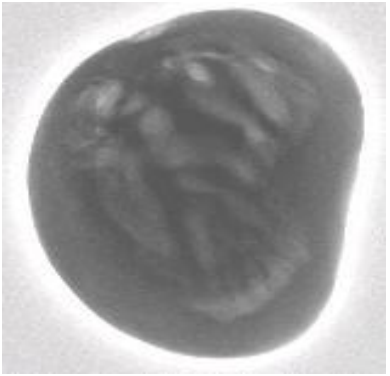




Radiographs

Fruit from outside

Cut away image



Radiograph

Fruit with internal disorders not visible from outside

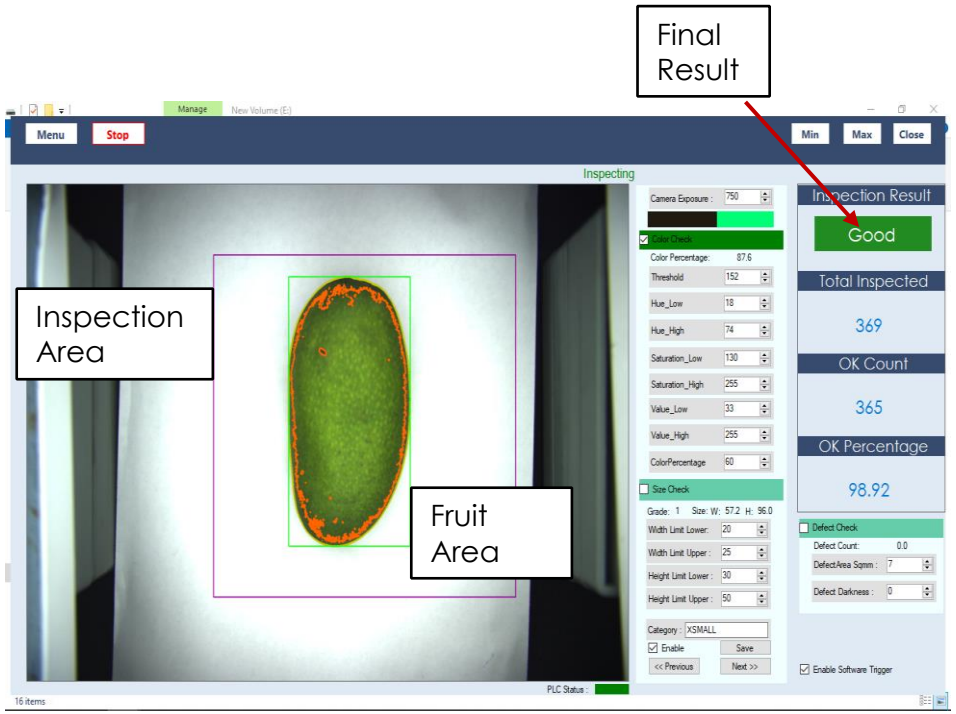
Image (Visual and X-Ray) based sorting & grading systems

Imaging Chamber

Imaging Sensor (inside)-

Illumination System

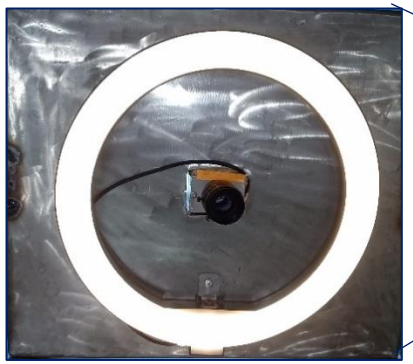
Machine vision camera setup is being developed for mango



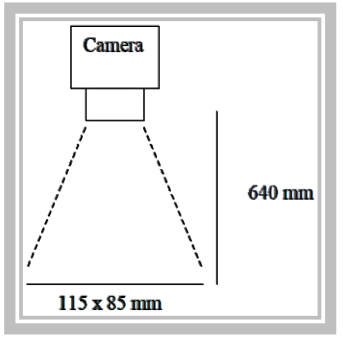
Software developed using vision camera (under testing for grading and surface defects detection)

Using radiography (internal defects in mango)

Imaging chamber



Outlets



Sorting: Color, Size(Weight), Defects(Sun- burning, Plague, thrips attack, blemishes etc.)

Image based quality measurement systems

Colour based sorting of fruits

- **Uses sensors to accept or reject a product based on its colour**
- **Capacity ~ 400 kg/h**
- **Presently suitable for round fruits**

Technology developed at ICAR-CIAE, Bhopal

The Supply Chain

IoT solutions in Food Supply Chain

WAREHOUSING

- Quality monitoring, real-time monitoring
- Safety and security
- Collaborative warehousing

INVENTORY MANAGEMENT

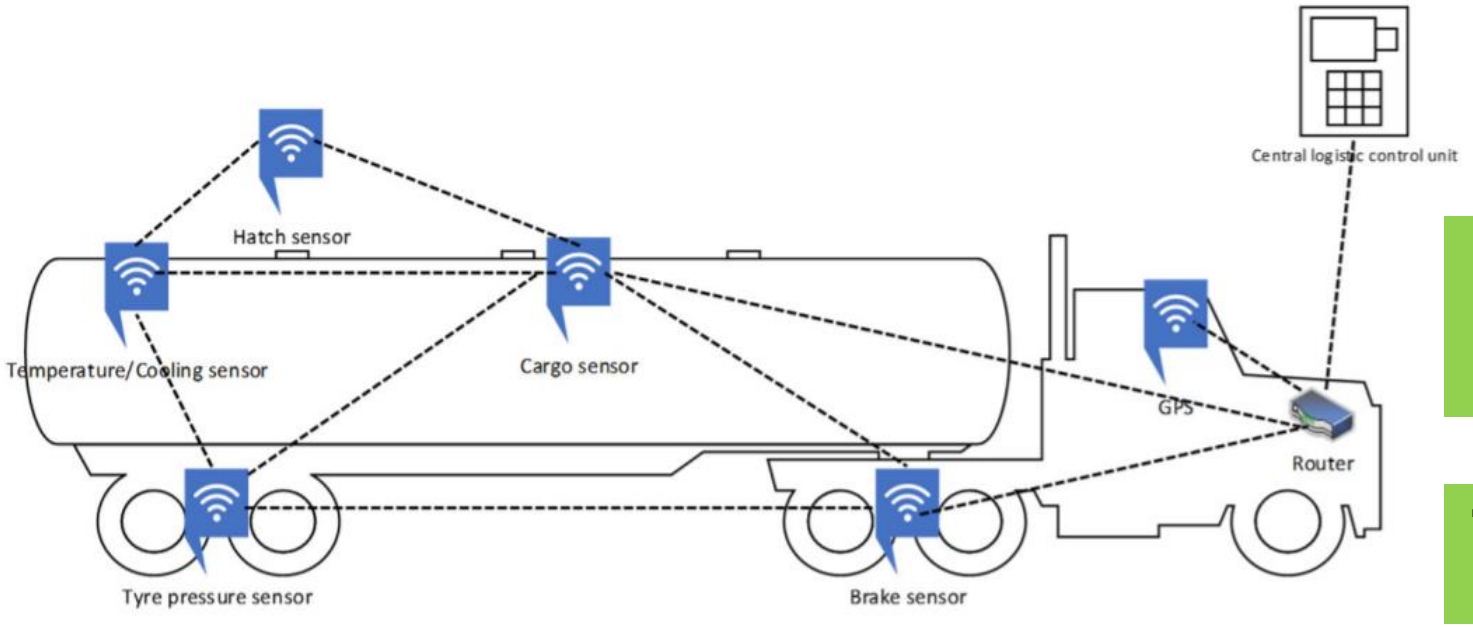
- Information sharing
- Inventory accuracy
- Self replenishment

LOGISTIC

- Real-time environmental monitoring
- Quality-controlled logistics
- Accurate and timely delivery

IoT Enabled Logistic

- Capacity sensing
- Planning and reporting
- Route optimisation
- Energy management
- Fault detection and resolution

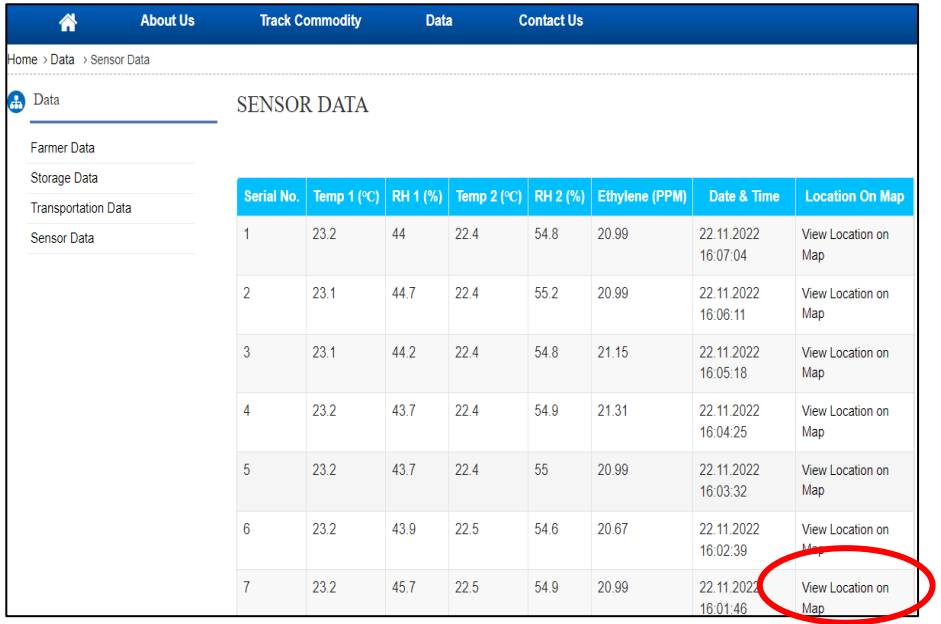


- Environmental monitoring and management
- Threat detection and prevention
- Real-time traceability

Sensor-based monitoring system for supply chain management of banana

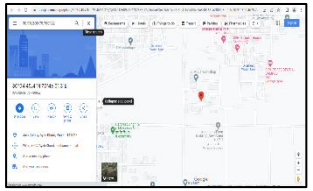
Sensor (temperature, RH, ethylene) based system

Tracking website home page



Serial No.	Temp 1 (°C)	RH 1 (%)	Temp 2 (°C)	RH 2 (%)	Ethylene (PPM)	Date & Time	Location On Map
1	23.2	44	22.4	54.8	20.99	22.11.2022 16:07:04	View Location on Map
2	23.1	44.7	22.4	55.2	20.99	22.11.2022 16:06:11	View Location on Map
3	23.1	44.2	22.4	54.8	21.15	22.11.2022 16:05:18	View Location on Map
4	23.2	43.7	22.4	54.9	21.31	22.11.2022 16:04:25	View Location on Map
5	23.2	43.7	22.4	55	20.99	22.11.2022 16:03:32	View Location on Map
6	23.2	43.9	22.5	54.6	20.67	22.11.2022 16:02.39	View Location on Map
7	23.2	45.7	22.5	54.9	20.99	22.11.2022 16:01:46	View Location on Map

Sensor data log page

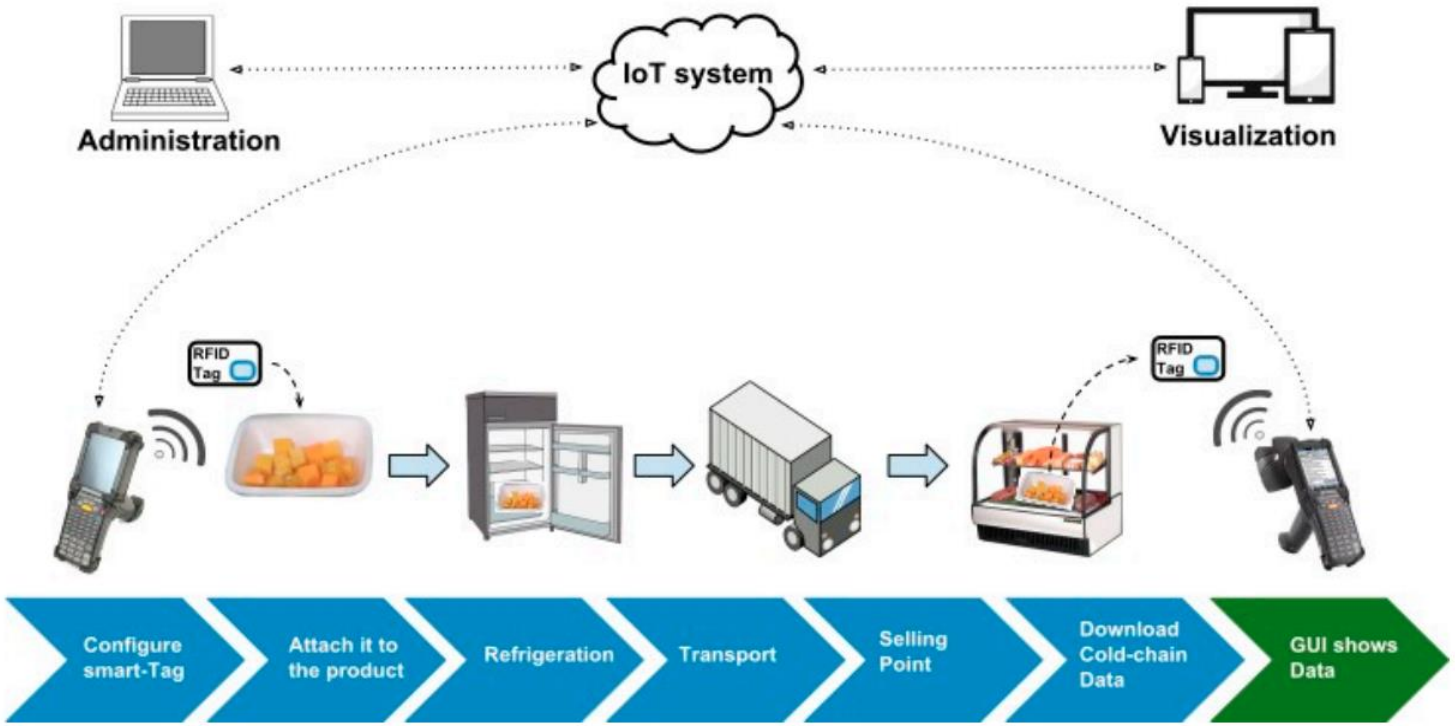


Location tracking

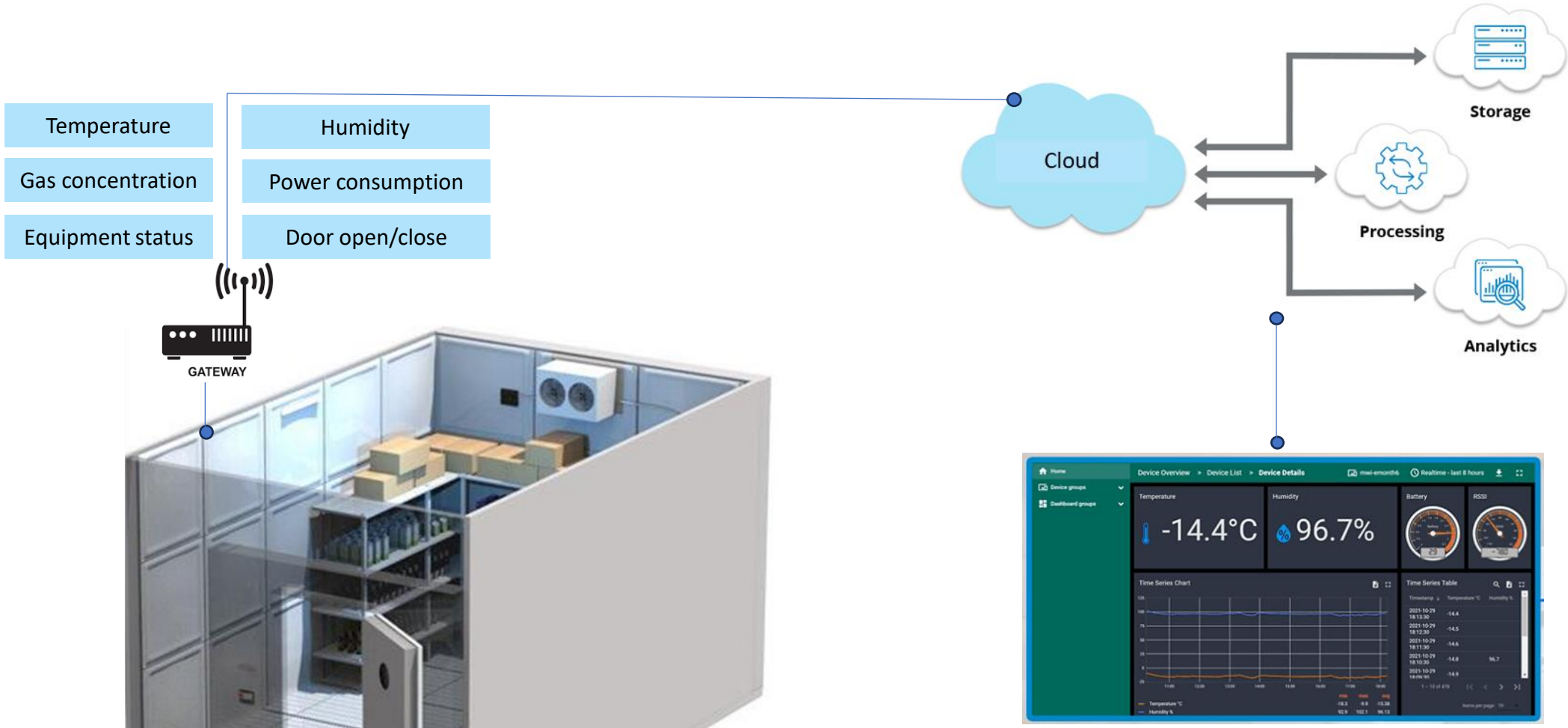
- **Sensor-based system is being developed for monitoring the banana during transportation ;**
- **sensor data, traceability related data and location etc. can be fetched using web based software**

Radio Frequency Identification (RFID)

- It includes a sensor, a tag and a reader which communicates with each other via radio transmission.
- RFID tags can store an EPC (Electronic Product Code) for logistics management purposes and number of temperature readings if equipped with the appropriate sensor and battery power.



Post harvest quality maintenance



Cold Room Monitoring & Control

Smart Storage

Challenges in Digitalizing Agriculture

Limited Awareness and Education

Affordability and Access

Connectivity Issues

Language and Literacy Barriers

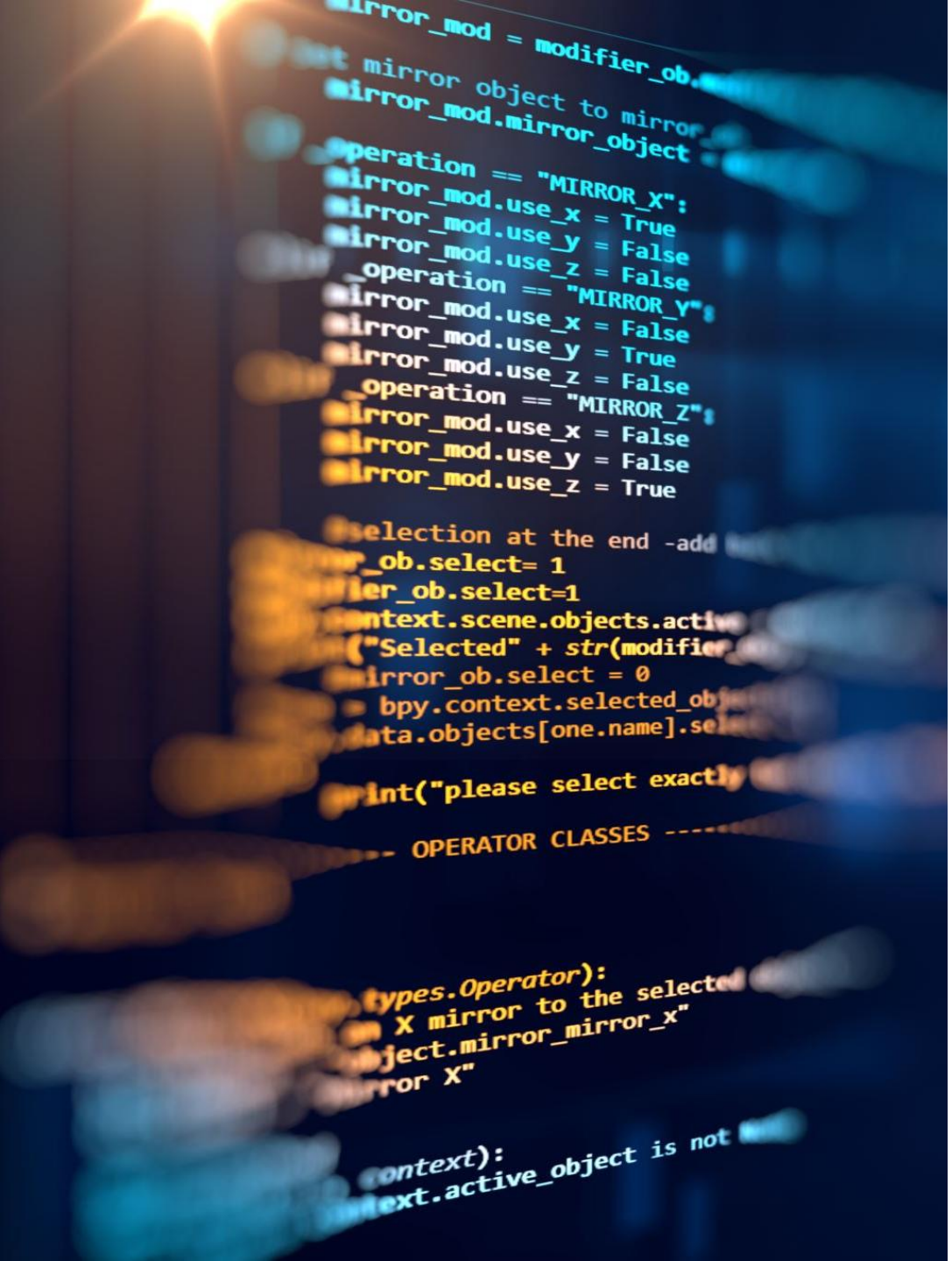
Complexity of Technology

Traditional Mindset and Resistance to Change

Fragmented Agriculture Landscape

Shortage of Local Support and Training

Limited Government Support and Infrastructure



What is required to be done?

- Ample data collection
  - Uniform protocols for data collection
- Logic development
- Compatible hardware development
- HRD

Thank You

Acknowledgements:

Er. Shaghaf Kaukab
Dr. Bikram Jyoti
Ms. Soumya Mohapatra