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A Survey on Recent Research Trends Towards Near field Body Coupled Communication

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Abstract: Classic IoT-based smart agriculture is built on static sensor networks and a cloud-dominated architecture. While effective, such architectures tend to suffer from high latency, inefficient communication, and heavy power consumption due to continuous data transfer. To address this issue, we introduced Agro-Visconic – an IoT solution based on mobile computing that transfers intelligent data processing from the cloud to the edge of the network using Very Large-Scale Integration (VLSI). Instead of static architecture, our design features an autonomous robot as a mobile gateway. Thanks to AI-based visual processing performed on the FPGA platform through Verilog HDL programming, our solution is now completely cloudindependent and operates reliably even in places with no Internet access.

I. INTRODUCTION

Conventional crop monitoring entails physical inspection, which is both timeconsuming and subject to human error. Autonomous rovers can be employed as an alternative solution since they are able to traverse through the rows of the farm to gather high-resolution data at the plant level.

There has been a shift towards the digitization of agriculture, as a result of the growing demand to meet the increasing global population which is predicted to be 9.7 billion by 2050. Conventional methods of monitoring are often referred to as "scouting" where the farmers walk through the farms to identify any signs of stress or infestation in the crops. Not only is this conventional method very labor-intensive, but it can also be tedious and by the time humans spot a disease, the damage done has already caused crop losses. Autonomous rovers will facilitate a shift in precision agriculture where data is gathered at a granular level consistently. While drones or UAVs have been widely used in farming practices, ground based rovers have their unique strengths:

• Proximity and Image Resolution: The proximity of the rovers to the plants enables the capture of high-resolution images of the plant stem and underside of leaves, which cannot be captured using drones from high altitudes. • Durability: Due to limited battery life (20-40 minutes), the duration of operation by drones is restricted, whereas rovers have sufficient battery life and hence can operate for long durations. • Sensor Capacity: Robotic platforms offer a sturdy structure that supports large instruments like sensors, probes, samplers, and multispectral cameras.

The foremost concern during the development of automated agriculture solutions is the lack of structure of the environment. Such concerns include different lighting conditions, occlusions (leaf obscuring fruit), and muddy terrain. This study aims to analyze the potential of the application of neural networks and sensor fusion techniques, as proposed in literature, to address the problem caused by the unstructured environment. An analysis of the current capabilities of robotic crop inspection using CNNs will be provided.

This research aims to explore the synergy between robotics and artificial intelligence. The study will consider the physical aspects needed for locomotion through challenging environments (Chapter 2), computer vision technologies essential for precise diagnostics (Chapter 3),and sensors that make it possible to gather data from the full farm ecosystem (Chapter4).

1. The First Agricultural Revolution (Neolithic Revolution)

Period: Approx. 10,000 BCE This was the transition from nomadic hunting and gathering to settled farming.

- Key Shift: Humans began domesticating plants (wheat, barley) and animals (sheep, cattle).
- Impact: It led to the creation of permanent settlements, specialized labor, and the birth of civilizations.

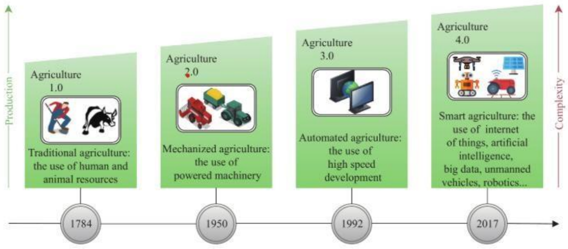

Fig 1: The Four Agricultural Revolutions

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3. The Second Agricultural Revolution (British Agricultural Revolution)

Period: 1700s early 1900s Coinciding with the Industrial Revolution, this phase introduced mechanization and improved land management.

- Key Shift: Inventions like Jethro Tull’s seed drill replaced hand sowing. The introduction of crop rotation kept soil fertile without leaving land fallow.
- Impact: Massive increases in food production supported the growing urban populations of the industrial age.

4. The Third Agricultural Revolution (The Green Revolution)

Period: 1950s to 1980s This era focused on biotechnology and chemical interventions to end global hunger.

- Key Shift: Development of HighYield Varieties (HYVs) of cereals (especially wheat and rice), the widespread use of synthetic fertilizers and pesticides, and advanced irrigation.
- Impact: Yields in developing nations skyrocketed, but it also led to environmental concerns regarding chemical runoff and biodiversity loss.

5. The Fourth Agricultural Revolution (Agriculture 4.0)

Period: Present Day Also known as the
Digital Revolution, this phase integrates the Internet of Things (IoT) with farming.

- Key Shift: Use of autonomous rovers, drones, AI driven crop diagnostics, and satellite data. It prioritizes Precision Agriculture applying the exact amount of water or fertilizer a single plant needs rather than treating the whole field.
- Impact: Increased efficiency and sustainability, reducing the environmental footprint of farming through high tech monitoring.

II.AUTONOMOUS NAVIGATION AND HARDWARE DESIGN

Rovers are designed with rugged chassis to handle uneven terrain, often utilizing GPS and Lidar for path planning.

- Modular Architectures: Modern rovers like the AgriRover use Raspberry Pi for vision processing and Arduino for motor control to maintain low cost yet high efficiency operations.
- Power Sustainability: To ensure long term field presence, researchers are integrating solar charging and high capacity battery packs into rover designs.

- Chassis Dynamics: Most research papers utilize a four-wheel drive (4WD) rocker bogie or a skid-steer mechanism. Skid steer systems are preferred for their high maneuverability in narrow crop rows, allowing the rover to turn in place (zero turn radius).
- Tire Specification: Research often highlights the use of deep tread pneumatic tires to maximize traction and minimize soil compaction, which

  is a critical concern for maintaining soil health and root aeration.

Navigation in a field is semi structured. While rows are often straight, the rover must account for weeds, fallen branches, or irrigation pipes.

- Simultaneous Localization and Mapping (SLAM): Using Lidar or Stereo Vision cameras (like the Intel RealSense), rovers build a 3D map of the environment while tracking their own location within it.
- GNSS and RTK Positioning: For high precision tasks like seed mapping, standard GPS is insufficient. Researchers implement Real Time Kinematic (RTK) GPS, which provides centimetres level accuracy by using a fixed base station to correct satellite signals.
- Obstacle Avoidance: Integration of Ultrasonic sensors and Infrared (IR) sensors acts as a fail safe. If the AI vision fails to identify a person or a tool in the path, these hardware level sensors trigger an emergency stop.

For a rover to be effective, the data it collects must be accessible. This section examines the protocols used to bridge the gap between the field and the end-user.

- Edge to Cloud Pipeline: Most modern rovers utilize an IoT (Internet of Things) architecture. Raw images are processed locally on the rover (Edge) to detect anomalies, and only the metadata (e.g: GPS coordinates and disease type) is sent to the cloud. This saves bandwidth and battery life.
- Connectivity Protocols: LoRaWAN: Ideal for large scale farms where cellular signal is weak. It allows the rover to transmit small packets of data over several kilometers with minimal power consumption.
- 5G and Wi-Fi 6: Used for high bandwidth tasks, such as streaming a live video feed to a remote operator or uploading high resolution multispectral maps.
- User Interface and Dashboards: Data is typically visualized through a web based dashboard or mobile app. These interfaces use **Geographic Information Systems (GIS)** to overlay plant health data onto a map of the farm, allowing the farmer to see exactly which hotspots require manual intervention or extra fertilizer.

III.PLANT HEALTH AND DISEASE DETECTION

Convolution Neural Network (CNN) Architecture:

In agricultural monitoring, the choice of CNN architecture is a tradeoff between accuracy and computational speed. Since rovers often process data on edge devices (like a Jetson Nano or Raspberry Pi), efficiency is key.

- VGG16 & InceptionResNetV2: These are deep, heavy models often used for offline analysis or high accuracy classification. VGG16 uses a simple structure of 3x3 convolutional filters to extract features, while InceptionResNetV2 uses residual connections to allow the network to be much deeper without losing data signal, achieving accuracy rates as high as 98% in controlled datasets like “PlantVillage”.
- YOLO (You Only Look Once): Unlike traditional classifiers, YOLO sees the entire image once and predicts both the bounding boxes (where the plant/leaf is) and the class (what disease it has).
- YOLOv5/v8: Recent studies show YOLOv8 outperforming YOLOv5 by approximately 3% in mAP (mean Average Precision), making it the current standard for real time fruit and leaf detection in moving rovers.

Ripeness and Defect Analysis:

Rovers do more than just spot sickness. They evaluate the commercial readiness of crops.

- Color Space Transformation: Models are often trained to convert standard RGB images into HSV (Hue, Saturation, Value) or LAB color spaces to better distinguish the subtle shifts from unripe green to harvestable red in crops like tomatoes or strawberries.
- Multi Stream Fusion: Advanced rovers use a multi stream approach where one CNN processes the shape of the fruit (defect detection) while another processes its texture and color (ripeness). A Stochastic Decision Fusion (SDF) layer then combines these results to give a final verdict.

The Data Pipeline:

The effectiveness of these models relies on a robust pipeline:

- Preprocessing:
  Normalizing brightness and contrast to account for the harsh, changing sunlight in the field.
- Augmentation:
  Artificially expanding the dataset by rotating or flipping images, which helps the rover recognize a plant even if it approaches it from a weird angle.
- Explainable AI (XAI):
  Newer models utilize Grad CAM (Gradient weighted Class Activation Mapping), which produces heatmaps showing why the rover thinks a leaf is diseased. This builds trust for the farmer, as they can see exactly which spots on the leaf triggered the alarm.

Table 1: Technical Specifications and Benefits of Rover Based Sensing

Model	Primary Use Case	Key Advantages
VGG16	Complex Disease ID	High Feature Extraction depth
YOLOv8	Real Time Scouting	Fast inference speed while the rover is moving
SqueezeNet	Lightweight Edge Ops	Extremely small file size for low power hardware
Wide ResNet	Ripeness Grading	High accuracy in identifying subtle color gradients

IV. MULTISPECTRAL AND IoT SENSOR FUNCTION

Beyond standard RGB cameras, rovers utilize advanced sensors to "see" beyond the visible spectrum.

- Infrared and NDVI: Multispectral cameras measure the relationship between Near Infrared (NIR) and red light to calculate the Normalized Difference Vegetation Index (NDVI). A high NDVI (e.g., 0.8) indicates a healthy plant, while lower values signal stress.
- Soil Analysis:
  Emerging multi function rovers carry NPK sensors to analyze soil nitrogen, phosphorus, and potassium levels in real time, bridging the gap between plant health and soil nutrient management.

Table 2: Sensor Features

Feature	Technology used	Benefit
Vision	CNNs	Accurate disease and ripeness identification.
Health Index	Multispectral Sensors	Detection of early stage stress.

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Connectivity	4G/ LoRaWAN/ WiFi	Remote monitoring and cloud based data storage.
Positioning	GPS Modules	Mapping precise locations of infected plants.

V. CHALLENGES AND FUTURE TRENDS

Despite progress, rovers face challenges such as high light intensity affecting sensor accuracy and navigation difficulties in unstructured environments. Future research is trending toward multi robot systems where fleets of rovers and drones (UAVs) collaborate to cover larger areas more efficiently.

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