Everything You Wanted to Know About Smart Agriculture

**Keynote** – OITS International Conference on Information Technology (OCIT 2023)

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Homepage: [www.smohanty.org](http://www.smohanty.org)

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University of North Texas, USA.
Outline

- Need for Smart Agriculture
- Agriculture → Smart Agriculture
- Factors affecting type of crop
- Technologies used in Smart Agriculture
- Smart Agriculture – Case Studies
- Challenges and Issues in Smart Agriculture
- Smart Agriculture Applications
- Smart Agriculture & FL
- Supply chain- Practical Implementation
- Security and Privacy Challenges in Smart Agriculture
Smart Agriculture – Drivers → The Need
Global Population Explosion

- Global population expected to be 9 billion by 2050 compared to the current population of 7.8 billion.
- Population $\Rightarrow$ Demand for natural resources $\Rightarrow$ Demand for food
- Need of the Time: Make the agriculture utilize fewer natural resources, increase yield and make the farms climate independent.
World Hunger

- According to world hunger clock, 828 million people are undernourished.
- Controlling population is one way of tackling with raise in demand of food.
- Increase the agriculture production is one more remedy which can reduce World hunger.
The factors determine the type of crop that can be farmed based on different environmental properties:

- Climate
- Elevation
- Slope
- Soil
- Water availability
- ...
- ...

Can we Have Any Crop, at Any Place?
Any Crop, Any Place: Vicious Negative Feedback Cycle

- Land usage for other needs
  - Growth is population is causing the need for residential land which is reducing the amount of arable land available for farming.
  - Growth in population $\rightarrow$ Need for residential land
  - Growth in population $\rightarrow$ Demand for farm products
  - Demand for farm products $\rightarrow$ Need for farmland (Paradoxical)

Vicious Negative Feedback Cycle:
Population Increase $\rightarrow$ Increase in Need for Residential Land $\rightarrow$ Decrease in Farm Land $\rightarrow$ Increased Demand for Farm Products
Agricultural Land Reduction is a Global Crisis

Population control techniques are in place and still have not effectively solving the food scarcity.

Need to make farms climate and environment resistant.

Finding ways to cultivate and produce reasonable yield in non-favorable conditions.

Reduce need of resources such as farm area.

Agriculture or farming is the practice of cultivating plants and livestock.
Benefits of Smart Agriculture

- Crop Production Efficiency Increase
- Operational Cost Reduction
- Optimization of Fertilizers, Pesticides
- Real Time Data Provision
- Green House Gas & Soil Erosion Reduction
- Water Conservation
- Smart Agriculture Benefits

Agriculture → Smart Agriculture: Broad Overview
After 10,000 BC humans settled down in villages.  
- Neolithic village at Chatal Huyuk in Anatolia (now Turkey) of area 13 hectares built in 7,000 BC.  
- Partial reconstruction of the village gives an idea of buildings.

“First true cities arose in Mesopotamia, and in the Indus and Nile valleys sometime around 3500 BCE.”  
-- LeGates and Stout 2016, The City Reader

Indus Valley Civilization  
(3300 BCE to 1300 BCE)
Agriculture or farming is the practice of cultivating plants and livestock.

Agriculture played a Key Role in the growth of civilization.

Ancient Egypt
- 15th century BC (1500 BC to 1401 BC)
Agriculture is the Key Factor of Civilization

- **10,000 BC**: Farming started by Ancient Egyptian Civilization on the Nile River.
- **9,000 BC**: Indus Valley civilization started wheat and barley.
- **8,000 BC**: Sumerians started to live in villages near the Tigris and Euphrates rivers and made a canal system for irrigation.
- **8,000 BC**: Asian rice was domesticated on the Pearl River in southern China.
- **3,000 BC**: Americas farmed squash, beans, and cacao.
- **2,500 BC**: Animal-drawn plough in the Indus Valley Civilization.
Agricultural Evolutions & Industrial Revolutions

Agriculture 1.0
- Indigenous Tools
- Manual work
- Animal Power

Industry 1.0
- Mass production
- Electrical Energy

Green Revolution 1784
- Steam engine and waterpower

Agriculture 2.0
- Tractor
- Fertilizer
- Pesticide

1870
- Industry 2.0

Agriculture 3.0
- Variable rate application
- Yield Monitoring
- Guidance System

1950
- Industry 3.0

1969
- Groups for Precision Agriculture

Agriculture 4.0
- Remote Sensing
- Trustworthy Supply chain
- Autonomous Farming

2011
- Industry 4.0

2017
- Remote Sensing
- Trustworthy Supply chain
- Autonomous Farming

2030
- Industry 4.0 in Agriculture

2050
- AI
- IoT
- Bigdata
- Blockchain

“Smart Agriculture” refers to the usage of technologies like Internet-of-Agro-Things (IoAT), AI, sensors, location systems, and robots on the farm to improve agricultural productivity while optimizing the human labor and land usage.

### Agriculture to Smart Agriculture

- **Traditional agriculture:**
  - manual labor
  - low productivity
  - Climate dependency
  - Limited by geography

- **Smart Agriculture:**
  - Sustainable
  - Intelligent
  - Efficient
  - Eco-friendly

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**Smart Agriculture Market Worth US$18.21 Billion By 2025.**


Internet-of-Agro-Things (IoAT) is the backbone of Smart Agriculture

Smart Agriculture Architecture

UAVs takes images, sprays fertilizers.

Self-Driving Tractors sow with precision, plant trees at the right depth. Productivity Increases.

Smart Collars provides information on cattle health and their movement.

Smart Sensors collect data from soil and air. Decision taken for irrigation and fertilization.

Cloud stores data.

Edge Devices compute locally and take decisions.

Smart Agriculture Apps

“Fhasal : Buy Crop from farmers”
Buy genuine corps directly from farmer and help them to make 2x profit.

Soil Sampler
Farmis
Contains ads

4.3
1.02K reviews
100K+ Downloads
Everyone

BoosterAGRO
Booster Ag Tech, Inc.

Install
Add to wishlist

You don’t have any devices
You can share this with your family. Learn more about Family Library

Crop Farmers App
Smart Agriculture - Prof./Dr. Saraju Mohanty
Smart Agriculture – Technologies
Smart Agriculture Technologies

Driverless Tractors

Autonomous Vehicle
- In charge of solving the autonomous guidance problem
  - Perception systems
  - Machine vision-based
  - LIDAR
  - Range sensors
- Comm. systems
  - Wired/wireless
  - Routers
- Localization systems
  - GPS
  - IMU
- Controllers
  - Vehicle controller

Autonomous Implementations
- In charge of solving the autonomous crop operation problem
  - Perception systems
  - Machine vision-based
  - LIDAR
- Localization systems
  - GPS
- Controllers
  - Implement controller
- Comm. systems
  - Wired
- Actuators systems
  - Hydraulic actuators
  - Electric actuators

System integration
Autonomous and Robotic Labor

- Due to migration of people from rural areas to urban areas, there is shortage in labor for farming.
- Use of Autonomous and Robotic labor can increase the productivity and quality of work.
Drones or UAV for Smart Agriculture

- An automated flying tool which has pre-planned flight and controlled by remote is called a drone.

- Usage includes:
  - Imaging for identification of weeds.
  - Fertilizer and weedicide applications.
  - Weather forecasting.

- Makes use of different sensors, actuators and GPS.
Planting and Sowing Tools

- Unlike other autonomous applications implemented in the farms, using autonomous robots for planting and sowing is successful.
- It is easy to implement and perform the operations.
- Before planting, seedbed must be prepared for creating favorable conditions.
Automatic Irrigation Systems

- Surface Drip Irrigation (SDI) is used to distribute the water evenly in the farm.
- These SDI are typically controlled manually to increase the efficiency.
- Using moisture sensors to integrate to the SDI can help in better crop yield.
- IoT sensors are integrated with SDI which can also be linked with fertigation (Irrigation water plus fertilizer).
Livestock Monitoring System

Source: https://www.sensaphone.com/industries/livestock
Livestock Health Monitoring Instruments


Thermometer for horses, dogs, sheep, pigs and cows

Cattle Stomach Healthcare

Livestock Heat Stress Monitor

qPCR to diagnose a poultry herd about the presence of bacteria and viruses from air sample

pH, and Oxidation Reduction Potential (ORP) Sensor for Fish Farm
Smart Agriculture - Sensors

Measured Parameters at Agricultural Devices

- Crop
  - Underground Sensors
    - Soil Moisture
    - Soil pH
    - Soil Chemical Composition (N₂, S, Ammonia)
  - On UAV Sensors/Cameras
    - Image
      - Thermal Image
      - RGB Image
      - Multi Spectral Image
      - LiDAR Image
  - Environmental Parameters
    - Air Humidity
    - Air Temperature
    - Wind Speed
    - Solar Radiation

- Livestock
  - Wearable Collar
    - Location
    - Body vitals
    - Reproductive Cycle
    - Milking Time
    - Feeding Time

- Greenhouse (GH)
  - Light Intensity
  - GH Humidity
  - GH Temperature
  - Precipitation
  - GH Quality
  - Soil Moisture
  - Soil pH
  - Wind Speed
  - CO₂

- Hydroponics
  - Room Humidity
  - Room Temperature
  - Water Temperature
  - Water Level
  - Soil Moisture
  - Light Intensity
  - Soil pH


https://www.aliexpress.us/item/3256803422818261.html?gatewayAdapt=glo2usa4itemAdapt&_randl_shipto=US


RK330-01

Smart Electronic Systems Laboratory (SESL)
Smart Agriculture – Communication Technology

Connectivity Layer-1: Near Range ZigBee, Wi-Fi, Z-Wave, Bluetooth, Radio Frequency Identification (RFID), and Near Field Communication (NFC).

Connectivity Layer-2: Cellular Technologies like Ground Penetrating Radar Services (GPRS), Long-Term Evolution (LTE), 3G/4G, and 5G.

Crop Health, Weeding and Spraying

- Integration of image processing and artificial intelligence techniques into the farming for monitoring the health of the field by detecting disease patches, weed patches.
- This helps in spraying the herbicides, pesticides.
RFID Technology

Selected RFID Attacks

Physical RFID Threats
- Disabling Tags
- Tag Modification
- Cloning Tags
- Reverse Engineering and Physical Exploration

RFID Channel Threats
- Eavesdropping
- Snooping
- Skimming
- Replay Attack
- Relay Attacks
- Electromagnetic Interference

System Threats
- Counterfeiting and Spoofing Attacks
- Tracing and Tracking
- Password Decoding
- Denial of Service (DoS) Attacks

Numerous Applications

Source: Khattab 2017: Springer 2017 RFID Security
Smart Agriculture – AI/ML Technology

- Crop Management
- Soil Management
- Smart Irrigation
- Pest / Disease Control
- Weed Control
- Livestock Management
- Alternative Farming

Agriculture Data – Acquisition Interface

Data Acquisition is an interface that is used to collect the data from the external environment and send it to the internal systems. Data acquisition technologies mainly includes:

- Serial ports for connecting multiple instruments for automatic data acquisition.
- USB interface.
- Wireless communication modules.
- Sensors and Actuators.
- Satellite systems.

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Agriculture Data – Storage

Data Storage Technology

- Direct Attached Storage (DAS): A storage device is attached directly to the host system to record data.
- Network Attached Storage (NAS): A device is connected to the network which serves the purpose of storage.
- Storage Area Network (SAN): A network of storage devices are connected to network of servers.

Databases are the software application used for performing data storage operations:

- Relational database: follows relational model
- Non-relational databases
Agriculture Data – Processing Technologies

- Millions of IoT devices → generates large amounts of data
- Need for efficient Big data analytics methods
- Artificial Intelligence plays a major role in extracting information from such large data.
- Conventional AI methods are resource intensive
- Tiny ML is a promising application in IoT based systems.
# Roles of Blockchain in A-CPS

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**Land Registration**

**Supply Chain**

**Farmer Incentives**

Roles of Blockchain in A-CPS - Private Vs Public

Private Blockchain

- Raw Materials Data
- Storage Companies Data
- Manufacturing Companies Data
- Distributors Data
- Shoppers

Relevant Permissioned Nodes

Public Blockchain

- Logistics Data
- Participating Permissionless Nodes


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Smart Agriculture – Some Challenges
Smart Agriculture – Challenges

Power Availability
Networking and Communication
Reliability
Scalability
Farmer’s Learning Curve
Big Data Challenges
AI Challenges

Hardware Security
Data Security and Privacy
Natural Disaster
Technical Malfunction

Challenges

Learning Curve for Smart Agriculture can be Long

- Smart Agriculture requires setting up of IoT architecture and sensor networks.
- Errors in such setup can lead to drastic losses in the farms.
- Farmers should be thoroughly acquainted with usage of this technology.
Connectivity can be an Issue in Rural Areas

- Reliable internet connectivity is not possible in many of the remote villages in the world.
- Network performance and bandwidth requirements may not be achieved because lack of the infrastructure as in urban areas.
- Delay in real-time applications if computing is dependent on IoT-cloud.
Energy Depletion Risks

- Smart agriculture may reduce need for resources but needs lot of data centers.

- All the infrastructure used will consume large amounts of energy which may cause energy depletion.
Lack of Scalability and Configurability

- Farms can be any size, single owner can have large farms or several small farms.
- Same technology should be capable enough to handle different variety of farmlands in dimension and nature.
- Technologies used should be self-configurable.
Technical Failures

- Even most resilient systems will have failure due to unforeseen events.
- Such events in Smart Agriculture can incur large losses both in terms of money and quality of products.
- Food safety can be compromised because of such issues.
Bigdata in Smart Agriculture

- Millions of IoT devices work in smart agriculture and generate large amounts of data.
- Inferring and extracting information from such large data is impossible and needs efficient data analytics tools.

**Bigdata**

1. Technical Issues
2. Social Issues
Security Issues in IoAT

- Smart Farms are Hackable Farms: IoT in Agriculture can improve the efficiency in productivity and feed 8.5 billion people by 2030. But it can also become vulnerable to various cyber security threats.

  https://spectrum.ieee.org/cybersecurity-report-how-smart-farming-can-be-hacked


- DHS report highlights that implementation of advanced precision farming technology in livestock monitoring and crop management sectors is also bringing new cybersecurity issues along with efficiency.

Smart Agriculture - Security Challenges

- Harsh Environment
- Threats from equipment
  - High voltage pulses
  - Interference
- Unauthorized access
- Interception of node communication
- Malicious data attacks
- Control system intrusion

Smart Agriculture - Security Challenges

Cyber Attacks

Data Attacks
- Insider Data Leakage
- Cloud Data Leakage
- False Injection

Network and Equipment Attacks
- Radio Jamming
- Malware Injection
- Denial of Service

Supply Chain Attacks
- Third Party Attack
- Software Update Attacks
- Data Fabrication

Other Attacks
- Cloud Computing
- Cyber Terrorism
- Compliance and Regulation Invalidation

Smart Agriculture Case Studies – AI/ML Solutions
Smart Agriculture – IoAT/A-CPS in Action

IoAT or A-CPS Based Smart Agriculture

Data Collection

IoAT-Sensor Level

IoAT-Device Level

Measures Taken

IoAT Cloud/Edge Level

Resolution

IoAT Cloud/Edge Level

Prognostics

IoAT-Edge Level

Crop Damage and Disease Problem

- Disease prevents the growth of plants.
  - Affect quality of the crop.
  - Reduce final yield.

- Farmers need to –
  - Monitor the field regularly.
  - Detect disease early.
  - Identify the disease.
  - Know about the severity of the disease (many of them).
  - Determine the extent of damage (from disasters).

Our sCrop: A Device for Automatic Disease Prediction, Crop Selection, and Irrigation in IoAT

Sensory Block

- Powering Module
  - Solar Panel
  - Battery (Backup Power)
- Solar Sensor Node Data Hub
  - Crop Image (from camera sensor)
- Soil Moisture Data (from soil moisture sensor)

Storage and Data Analysis Block

- Cloud Storage and Analytics
- Data Storage
- Data Analysis and providing actionable Insights
- Edge Computed Intelligent Actions
  - Automated Irrigation (taking into consideration of external environmental data)
  - Biotic Stress Control (by monitoring the moisture level)
- Crop Disease Prediction
- Deep Learning Image Classifier (health/diseased)
- Average soil moisture required for the crop selected by the farmer

End User Block

- Crop Disease Prediction
- Cloud Storage and Analytics
- Data Storage
- Data Analysis and providing actionable Insights
- Edge Computed Intelligent Actions
  - Automated Irrigation (taking into consideration of external environmental data)
  - Biotic Stress Control (by monitoring the moisture level)
- Crop Image
- Crop Disease Prediction
- Deep Learning Image Classifier (health/diseased)
- Average soil moisture required for the crop selected by the farmer
- Farmer's crop choice
- sCrop Mobile Application
  - Real-time crop disease prediction notifications
  - Live Irrigation Tracker
- Farmer selects the crop
  - He is going to cultivate
  - From the options in the app
- Moisture values
- Crop Image

Our sCrop: A Device for Automatic Disease Prediction, Crop Selection, and Irrigation in IoAT

sCrop Device Prototype with Irrigation

sCrop App

Healthy Tomato

Infected Tomato

sCrop Accuracy – 99.24%

Our eCrop: A Framework for Automatic Crop Damage Estimation

Heat Damaged Corn Field

1 → UAV takes Photo of Corn Ear

2 → Damage Area Detection of Corn Ear

3 → 50% of Damaged Area Selection

4 → Damage Type Detection for Corn Kernel and Process is Repeated for the Selected Area

A User (Farmer, Adjuster)

Our eCrop: A Framework for Automatic Crop Damage Estimation

If a damage type is identified, then a grid is updated with 1.

Our aGROdet: A Framework for Plant Disease Detection and Leaf Damage Estimation

- Detect plant diseases.
- Estimate corresponding leaf damage.

Identification of the disease -
- Convolutional neural network-based method.

Estimation of the severity of leaf damage –
- Pixel-based thresholding method.

Regular monitoring of fields and checking conditions of the plants through aGROdet can detect the disease early.

Our aGROdet: Plant Disease Detection

- The augmented and preprocessed data is used for training the network.
- Adam optimizer with an initial learning rate of 0.001.
- Model trained for 75 epochs.
- Model trained with and without a reduced learning rate of factor 0.1.
- Trained model is saved for future inference.
- Model evaluated using unseen 5,562 images.
- Implemented in Keras with TensorFlow back end.

Our aGROdet: Damage Area Detection

Start

Detection of Shadow around the Leaf

Shadow Removal

Leaf Mask Creation

Merging of Mask and Input Image

Recoloration of Black Background

Damage Mask Creation

Our aGROdet 2.0: An Automated Real Time Approach for Multiclass Plant Disease Detection

- Manual observation is still the most common method of detecting plant diseases.
  - Labor intensive.
  - Ineffective.
  - Requires expert services.
    - Expensive.
- Wrong identification causes wrong use of pesticides.
  - Causes secondary damage.
- Automatic and accurate monitoring of plant disease and damage estimation are necessary along with disease identification.

Our aGROdet 2.0: An Automated Real Time Approach for Multiclass Plant Disease Detection

- Photo of the leaves are taken.
- They are resized to 256x256 to be detected using the trained model.
- A Mask Region-based Convolutional Neural Network (R-CNN) is used to detect the disease along with the disease localization.
- Here, the problem is considered as an object detection problem.
- Object detection is a task in computer vision that involves identifying the presence of one or more items in each image as well as their location and the category of object that they belong to.

Our aGROdet 2.0: An Automated Real Time Approach for Multiclass Plant Disease Detection

- Early detection of the plant diseases.
- Fully automatic method.
- No expert service is needed for disease detection.
- Very little effort is needed from the users’ side. Users only need to take pictures of the damaged leaves.
- This process is the first step of disease severity estimation.
- Estimation of disease severity plays a pivotal role in calculating the optimal quantity of pesticides.

Lite-Agro: Our Light-Duty IoAT-Edge AI

Proposed Lite-Agro System

*Camera for Visual*  
*Edge-Server for TinyML*  
*Power Source*  
*Training for TinyML*

### Proposed Lite-Agro System

![Diagram of Lite-Agro System](Image)

<table>
<thead>
<tr>
<th>Works</th>
<th>Dataset</th>
<th>Resolution Size</th>
<th>Model</th>
<th>Recognition Accuracy</th>
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Our LiveCare - IoT-Based Cattle Healthcare Framework

## Smart Agriculture - Datasets for AI

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<th>Dataset Format</th>
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Smart Agriculture Case Studies - Cybersecurity Solutions
A-CPS with Integrated AI and Cybersecurity

Smart Agriculture Cybersecurity - Solutions

- Developing IoAT-Edge and IoAT-cloud centric network model
- Integrate A-CPS with Security-by-Design (SbD) and Privacy-by-Design (PbD) measures right at the design phase.
- Using Intrusion detection systems
- PUF based energy-efficient solutions for integrated security
- Blockchain based solutions for data and device integrity
- Physical countermeasures
  - Machine learning based countermeasures
- Constant security analysis
Our Security-by-Design Approach for Robust IoAT

IoAT Devices

- Air Hygrometer (PUF)
- Drone (PUF)
- Temperature Sensor (PUF)

IoAT-Edge Server

Secure Communication between PUF Embedded IoAT device and Edge Server

Edge Server authenticates the devices using the PUF key of each electronic device which is the fingerprint for that device

Our G-DaM: Introduction-Ground Water Data

- Groundwater is 1.69% of total water on earth.
- Source of sustenance.
- Data collected from diverse sources.
- Helps in Increasing Food Production
- Checking Water Availability
- Predicting Water supplies.
- Analysis of Contaminant Water.

Our G-DaM: Proposed Architecture

Our G-DaM: Distributed Storage

Off-chain Groundwater Data Storage with synched ledger

IPFS Network

Ethereum Network

Distributed Storage

Generate Hash

Hash Values

Nodes/Users Participating

Various Data Collected

Sources:
Our sFarm: A Distributed Ledger based Remote Crop Monitoring System

Transaction generation

Raspberry Pi 4
Model B

DHT11 and Node MCU

pH Sensor and Node MCU

Dielectric Soil moisture sensor and Node MCU

Monitoring Dashboard

Farmers

Our sFarm: Solution

- Tangle is a data structure behind the IOTA which is a Directed Acyclic Graph (DAG).
- Directed Acyclic Graphs (DAG) are the data structures which grow in one direction and doesn’t have cyclic structures within.
- Tangle is maintained and updated at all the nodes in the network.
- Any new transaction is published will be attached to the Tangle tips.
- Will be single source of truth.
CroPAiD: Our Novel Framework for Protection of Information in A-CPS

CroPAiD: Our Novel Framework for Protection of Information in A-CPS

Hash Function $H(X)$

Hash Keys

Input value

256 Kb Buffer Files/content identifiers

Hash(Crop Data)

IPFS NODE

Crop Data

IPFS-s/Kademlia algorithm

TANGLE NODE

Data Chaining

Ownership of data

Authentication

Encryption

1. Length of the Data.
2. Pub_key.
3. Priv_key.
4. Index of the next data position.
5. Signature.
6. Authorizing Signature.

CroPAiD: Our Novel Framework for Protection of Information in A-CPS

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<td>7GDAPOLKLOIUSDWKNMND4</td>
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</tbody>
</table>

Food Safety and Quality
Food Safety Vs Food Quality

Food safety is the process of preventing food from the risk that may affect it. It affect directly or indirectly to the consumers.

Food quality is to achieve all the food required characteristics that acceptable to consumer.

Source: https://inewtrition.com/ensuring-food-safety-quality/

Source: https://www.slideshare.net/ijazilhaqrana/food-safety-vs-food-quality
Fruit and Vegetable Safety and Quality?

Am I really eating what I think I am eating?


Fish Safety and Quality?

Am I eating a fish that is safe for my body?

Source: https://www.sciencedirect.com/science/article/pii/B9780128242964000074

Source: https://kiribatifishltd.com/quality-assurance/
Poultry Safety and Quality?

Is this Chicken Meat safe to eat?

Is this Egg safe to use?

World average consumption per person per year: 161 eggs (2018 data)

Source: https://hgic.clemson.edu/factsheet/safe-handling-of-poultry/

Source: https://www.teachkyag.org/lessons/learn-about-poultry-and-eggs

Source: https://www.meatpoultry.com/articles/22221-poultry-processing-tech-quality-controls

Source: https://www.teachkyag.org/lessons/learn-about-poultry-and-eggs

Smart Agriculture - Prof./Dr. Saraju Mohanty
Milk Safety and Quality?

Some germs linked to raw milk outbreaks

- Campylobacter
- E. coli
- Salmonella
- Listeria


How Safe is the Milk that I am Drinking?


Spoilage in the supply chain

Stages in Agricultural Product Distribution

1. Storage
2. Produce
3. Transportation
4. Packing and Processing

How to ensure safety and quality of food through legitimate supply chain?

Food Supply Chain: Farm → Dinning

How to ensure safety and quality of food through legitimate supply chain?

Time to Go Back to the Basics of Biosensors

Biosensors

Clinical
- In Vivo
  - Long-Term Implantable
    - Artificial Organs
  - Short-Term Invasive
    - Bedside Glucose Monitoring
- In Vitro
  - Singleshot
  - Multi-Analyses
    - Home Blood Glucose Monitor
    - Pathology Laboratory Glucose Monitoring

Nonclinical
- Single Analysis
  - Reactive Monitoring
- Multi-Analyses
- Reactive Monitoring
- Environmental Bioagent Detection
  - Anthrax, Plague, and Cholera
- Pollutant Monitoring, Fermentation Processes
- Fruit Ripening
- Pathology Laboratory Glucose Monitoring
- Home Blood Glucose Monitor
- Bedside Glucose Monitoring
- Artificial Organs
- Long-Term Implantable
- Short-Term Invasive

Food Safety and Security

- Changes in:
  - Climate-smart farming
  - Eco-friendly farming

- Improved:
  - Larger growth
  - Economic stability of farmers
Food Labelling

■ Changes in:
  □ Bar code usage
  □ 2D visual tags
  □ Efficient warehouse management
  □ Tag base identification technologies

■ Improved:
  □ Well organized fields
  □ Time saving
Our Food-Care: A Device for Detection of Fertilizer Contamination in Fruits and Vegetables

Quartz cuvettes of length 10mm for sample solution.

Peak absorbance spectrum of 265nm at different nitrate concentrations.

Contamination Level
- Acceptable
- Moderate
- Severe
- Dangerous

Need for Device which is:
- Portable
- Works with dry or wet samples
- User safe
- Accurate
- IoT-Enable

Fruit and Vegetables - Nitride Contaminated?

Imbalance Diet is a Global Issue

- Imbalanced diet can be either more or fewer of certain nutrients than the body needs.
- In 2017, 11 million deaths and 255 million disability-adjusted life-years (DALYs) were attributable to dietary risk factors.
- Eating wrong type of food is potential cause of a dietary imbalance:

Source: https://obesity-diet.nutritionalconference.com/events-list/imbalanced-diet-effects-and-causes
https://www.thelancet.com/article/S0140-6736(19)30041-8/fulltext
Automatic Diet Monitoring & Control - Our Vision

Captures Food Images

Automatic Food Image Analysis

IoT Cloud

Automatically monitors food intake to determine if the eating is stress-eating or normal-eating.

Smart Healthcare – Diet Monitoring - iLog


iLog- Fully Automated Detection System with 98% accuracy.
# Smart Healthcare - Diet Monitoring - iLog 2.0

<table>
<thead>
<tr>
<th>Food Item</th>
<th>Saturated Fat (g)</th>
<th>Sugar (g)</th>
<th>Sodium (mg)</th>
<th>Protein (g)</th>
<th>Carbohydrates (g)</th>
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<tbody>
<tr>
<td>Fries</td>
<td>6.44</td>
<td>1.56</td>
<td>244</td>
<td>4.03</td>
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<td>Burger</td>
<td>6.87</td>
<td>4.67</td>
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<td>17.29</td>
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<tr>
<td>Ketchup</td>
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<td>3.2</td>
<td>136</td>
<td>0.2</td>
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<td>Total</td>
<td>13.31</td>
<td>9.43</td>
<td>861</td>
<td>21.52</td>
<td>87.11</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Food Item</th>
<th>Saturated Fat (g)</th>
<th>Sugar (g)</th>
<th>Sodium (mg)</th>
<th>Protein (g)</th>
<th>Carbohydrates (g)</th>
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<tbody>
<tr>
<td>Rice</td>
<td>0.3</td>
<td>0.3</td>
<td>6</td>
<td>12.9</td>
<td>135</td>
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<td>Salad</td>
<td>0.8</td>
<td>3.9</td>
<td>264</td>
<td>1.1</td>
<td>7</td>
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<tr>
<td>Total</td>
<td>1.1</td>
<td>4.2</td>
<td>270</td>
<td>14</td>
<td>142</td>
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Smart Healthcare – Diet Prediction – Smart-Log

Start

OCR

Nutrition Facts of the Food item

Automatic food quantity estimation

Food Item ID
Obtain Nutrition information for each food item
Nutrient Value of the food item
Timestamp when weight of the food item is altered

Calculate nutrition information of all the food items in the meal using a machine learning model

Classify the food items using a machine learning model

For Future Meal Predictions

Meal ID
Nutrient Value of the meal
Food item quantity
Timestamp to compute meal type

Smart-Log Prediction Accuracy - 98.6%

Smart Agriculture – Supply Chain
Execution errors – like mistakes in inventory data, missing shipments, and duplicate payments are difficult to detect in real-time.

For companies with large number of transactions each day, it is difficult to assess and fix these issues.
Food Traceability Using Efficient Supply Chain

Centralized System

Blockchain based Decentralized System

Agriculture Supply Chain

Consumers ➢ Who are the stake holders?
➢ What is the role of each stake holder?

Producers

Web

Storage ➢

Packaging and Processing

Our agroString: Visibility and Provenance in Agriculture through a Private Blockchain

## Our agroString: Comparative Perspectives

<table>
<thead>
<tr>
<th>Application</th>
<th>Blockchain</th>
<th>Latency</th>
<th>Off-chain Storage</th>
<th>Transaction Cost</th>
<th>Financial Application</th>
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<tr>
<td>Fish Supplychain [16]</td>
<td>RFID</td>
<td>Not used</td>
<td>High</td>
<td>Centralized</td>
<td>Low</td>
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<tr>
<td>agro food Supplychain [17]</td>
<td>RFID</td>
<td>Ethereum</td>
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<td>High</td>
<td>Centralized</td>
<td>Low</td>
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<tr>
<td>Traceability System [21]</td>
<td>Hyperledger</td>
<td>0.5 s</td>
<td>Used-Database</td>
<td>Hyperledger-No Cost</td>
<td>No</td>
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<tr>
<td>agroString [Current-Paper]</td>
<td>Corda</td>
<td>1 ms</td>
<td>Not Used</td>
<td>No Cost</td>
<td>Yes</td>
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</table>

1 KB = 0.032 Eth[40] 1MB= 32.768 1Eth= 1944.84 [38]

Is there a Reward for Doing Great Job in Farming?
Impact of Agriculture Finance on Farm Yield

Value Chain Financing

Agricultural Finance

Direct Financing

- Use of New Technology
- Improved access to banking services
- Adopting new technology easily

- Use of Traditional Tools
- Separation from the financial Services
- Isolation from financing

- Increased crop production
- Income is Increased

- Decreased crop production
- Low Yield
- Reduced Income

Our IncentiveChain: Blockchain Crypto-Incentive for Effective Usage of Power and Water in Smart Farming

- Water & energy use in different domains.
- Present Scenario: Electricity & water wastage
- Farming as main source for water and energy wastage.
- Recognizing farmers as main entity in farming.

Our IncentiveChain: The Idea

Farming fields

Farmer

Using water & electricity on farms

Water meter

Electricity meter

No of Units saved during farming

Converting saved units to ether cryptocurrency

Providing ether rewards to farmers for saving resources

Our IncentiveChain: Architecture

Farmer Registers for Incentive Chain through utility service companies

Agricultural Department

Utility Company

Service Provider

Technology Platform

Ethereum Data Provider

Cryptocurrency

Smart Contract

Customer Utility Bills

Smart Agriculture and Federated Learning
Smart Agriculture – AI/ML Workflow

**TinyML - Key for Smart Cities and Smart Villages**

**TRAIN:** Iterate until you achieve satisfactory performance.

- ACCESS and PREPROCESS DATA
- EXTRACT FEATURES
- TRAIN MODEL
- OPTIMIZE PARAMETERS
- MODEL

**PREDICT:** Integrate trained models into applications.

- CAPTURE SENSOR DATA
- EXTRACT FEATURES
- RUN MODEL
- PREDICTION

Needs Significant:
- Computational Resource
- Computation Energy

Solution: Reduce Training Time and/or Computational Resource

Needs:
- Computational Resource
- Computation Energy

Solution: TinyML

What is Federated Learning (FL)?

❑ Federated Learning is way of model training in ML for heterogeneous and distributed data.

❑ It preserves the Privacy of data.

❑ Data does not come to the Model. Here Model is taken to the data.

Motivation of Federated Learning (FL)

- Quality data exists at different location on various edge devices.
- Data privacy laws control the movement of data.
- FL is the way to provide ML solution without breaking privacy laws.

Collaborative Edge Computing is Cost Effective Sustainable Computing for Smart Villages

Collaborative edge computing connects the IoT-edges of multiple organizations that can be near or far from each other → Providing bigger computational capability at the edge with lower design and operation cost.

Collaborative Edge Computing is Cost Effective Sustainable Computing for Smart Villages

Cloud Computing

GSM (3G, 4G, and 5G), LTE

IoT Gateways and Routers

ZigBee, Bluetooth, etc.

TinyML at IoT-End

Temperature and Humidity

Smoke and Gas

Light and Touch

Rain and Dust

IoT Devices Sensor and Actuators

Wireless Monitoring Infrastructure

Agricultural advisory (aerial survey, irrigation, milking schedule, …)

Healthcare advisory (vaccination, therapy, …)

Our Fortified-Edge: PUF based Authentication in Collaborative Edge Computing

Our Fortified-Edge 2.0: ML based Monitoring and Authentication of PUF-Integrated Secure EDC

- Secure, Low Latency Authentication
- Device identification
- Intrusion detection
- Attack Prevention
- EDC Monitoring
- Resilient against malicious Requests
- ML model suitable for a smaller dataset

Our Fortified-Edge 2.0: ML based Monitoring and Authentication of PUF-Integrated Secure EDC

Conclusions and Future Research
Smart Agriculture - Multifold Research Possibility

Levels
- Field Level
  - Food Production
- Processing & Distribution Level
  - Processing
  - Distribution
- Consumer Level
  - Retail & Food Services

Levels
- Planting, Growth, Harvesting
- Food Production

Affecting Factors
- Drought, Flood, Frost, Disease, Hail, Wildfire, Storm, Humidity, Soil Nutrients, pH of Water

Effects
- Crop Damage, Crop Loss, Crop Growth Reduction, Crop Yield Reduction, and Finally Financial Loss of the Farmers.

Research Areas
- Crop damage Estimation, Yield Estimation, Insurance Processing Automation, Growth Estimation
- Supply Chain disruption
- Supply Chain Management
- AI/ML, Block Chain, Advanced Analytics, 3D Printing, IoT, Robotics

Technologies
- AI/ML/Deep Learning, Block Chain, PUF, Robotics, IoT, UAV
- AI/ML, Block Chain, Advanced Analytics, 3D Printing, IoT, Robotics
- AI/ML, Analytics, Data Collection, Statistics, Mathematics, Sociology

Smart Agriculture - Research Problems

Research Problems: A-CPS Perspective

AI / ML
- Extreme Temperatures
- Operable Sensors
- Real Time Data Analysis and Decision
- Thermal and Infrared Image Dataset for Crop Field
- UAV Taken Image Dataset Creation
- TinyML Device
- Low computational decision methods
- Data Compression Methods
- Use of Unsupervised and Semi-supervised Learning Methods
- Public Dataset Creation

Blockchain
- Immutable Data Storage Mechanisms
- Optimizing Computational Resource
- Optimizing Design time
- Optimizing Energy Efficiency

PUF Based
- PUF's Impact to Environmental Effects
- Reliability and Tamper Resistance
- PUF’s Impact to Environmental Effects
- Reliability and Tamper Resistance

Research Problems: IoAT Perspectives

Physical
- Natural Disaster Disruption
  - Delay
  - Data Integrity
- Hardware Availability
- Physical Threats
  - Coverage Area
  - Equipment Wear and Tear
  - Vandalism

Cyber
- Distributed Denial of Services (DDoS)
- Man in the Middle Attacks
- Fake Data Injection

Socio-Financial
- Technical Skill Gap and Ease of Usage
- Lack of Financial Resources and Affordable Hardware

Conclusion

- Smart Agriculture is a very needed advancement for sustainability of humans in coming years.
- Technologies in Smart Agriculture are improving, and new technologies are being introduced everyday.
- Smart agriculture research is very challenging as involves diverse form of life (plant, animal …) and stake holder (farmer, engineers, distributor, insurance …).
- Having A-CPS with limited network connectivity and power supply is challenging.
- Educating farmers is the main challenge.
- Not many years far from realizing dream of hunger free society.
Future Research

- Research in educating farmers with technology usage.
- Efficient energy consumption techniques as millions of IoT devices will involve.
- Blockchain in transparent chains for increasing consumer awareness and safety.
- Efficient sensors and actuator technologies.
- Big data analytics and AI methods.
- Communication and Connectivity Technologies
- Secure and privacy compliance approaches.