

Computer software engineering and smart agriculture

Abd El-Rahman Abd-El Raouf Ahmed^{1,*}

¹Agricultural Engineering Research Institute, Agricultural Research Center, Egypt

*Author for correspondence:
Email: abdo_aaaa2000@yahoo.com

Received date: December 17, 2025
Accepted date: December 19, 2025

Copyright: © 2025 Abd El-Raouf AE, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Introduction

Software engineering is a science concerned with the design, development, selection, and maintenance of computer applications and systems. It is a discipline that applies engineering principles to software creation and hardware development, ensuring that applications are practical, reliable, and meet the requirements of users in various sectors.

Software engineering includes

- Writing code to create software applications that perform specific tasks.
- Testing software to ensure it is free of defects and meets quality standards.
- Understanding user needs and designing software systems that meet those needs.
- Continuously updating software to add new features, fix bugs, and improve performance [1]

Types of software engineering

- **Application software engineering:** Developing user-oriented applications such as mobile and desktop applications.
- **Systems software engineering:** Working on operating systems, compilers, and network management software.
- **Embedded software engineering:** Developing software for hardware devices such as the Internet of Things, automotive systems, and various other sectors [1].

Computer Software Engineer

A computer software engineer is responsible for the design, development, testing, and maintenance of software systems. Working across multiple sectors, including healthcare, finance, gaming, cybersecurity, and more, software engineers design, develop, and maintain software that supports these diverse industries [2].

The tasks of a software engineer include

- **Software design and development:** Writing clean and efficient code to build applications and systems.
- **Testing and debugging:** Identifying and fixing bugs in software to ensure reliability.
- **Teamwork:** Working alongside designers, product managers, and IT specialists.
- **Maintenance and updates:** Ensuring software remains up-to-date and effective.
- **Technical documentation:** Writing manuals and guides for developers and future users.

Essential skills for a software engineer include

- Proficiency in programming languages (Python, Java, C++, JavaScript).
- Knowledge of software development methodologies (Agile, Scrum, DevOps).
- Experience with cloud computing and database management.
- Familiarity with version control systems (Git, GitHub) [3].

The role of software engineering in developing digital infrastructure across various sectors

This field encompasses all aspects of software platform development (such as social networks and cloud computing), the development of adaptable and reliable embedded systems, architectural design engineering, software modeling, process and product metrics, web engineering, project management, risk management, and the development of software/software systems (AI-based systems) in diverse application areas, such as agriculture, the aviation industry, and more [1].

Key Applications of Geographic Information Systems (GIS) in Agriculture for Predictability and Sustainable Growth

Reasons for implementing GIS software in agribusiness

- Recent advancements in GIS in agriculture are helping to overcome many of the challenges facing this sector.
- Agribusinesses struggle to manage massive amounts of spatial data, and effectively presenting this data is essential for decision-makers, including farmers and investors, to understand it.
- GIS software enables agricultural companies to organize essential information across datasets, visualize it, and use it for forecasting in various agricultural operations.
- It helps improve planting, fertilization, and harvesting processes, crop forecasting, and natural hazard prediction. It enables agricultural businesses to maximize the yield of every acre [3].

Smart agriculture

Smart agriculture primarily refers to leveraging modern technology in farming. By deploying Internet of Things (IoT) sensors and various data collection devices, farmers can make informed decisions to optimize all agricultural operations, including livestock and crop production.

The core principles of smart agriculture include

- Monitoring and data-driven decision-making.
- Precise management of inputs (water, fertilizers, pesticides, etc.).
- Automation and remote control of agricultural activities.
- Integration of various emerging technologies (sensors, connectivity, artificial intelligence, and drones) [1].

IoT architecture for smart agriculture

The IoT architecture for smart agriculture comprises four integrated layers: perception, network, cloud, and application.

These layers enable efficient data collection, secure transmission, and reliable storage.

- 1. Sensor and actuator layer:** Sensors and actuators deployed in the field to collect data (soil moisture, temperature, light, pH) and control operations (irrigation and fertilization).
- 2. Network layer:** Facilitates data transfer between the sensor/actuator and cloud layers using LoRaWAN, cellular networks, etc.
- 3. Cloud layer:** A cloud platform for processing, storing, and analyzing data from the sensors, providing insights for data-driven decision-making.
- 4. Application layer:** User-friendly applications and interfaces that allow farmers to monitor farm conditions and make informed decisions to optimize crop production and resource utilization.

Practical applications of the IoT in agriculture

Modern agricultural practices encounter challenges related to operational efficiency and environmental effects.

To address these challenges in modern agriculture systems, this research proposes a comprehensive framework for smart farming. The proposed framework comprises three technology integrations: 1) an efficient integration of renewable energy resources (RERs) with solar panels and battery energy storage systems (BESS), 2) an IoT-based environmental monitoring for precision irrigation, and 3) an android application-controlled precision robotic system for targeted chemical application. [4].

IoT technologies have become entrenched in almost every area of agriculture

Soil and Crop Monitoring [5]

Through sensors that monitor soil moisture, nutrients, and temperature, farmers gain valuable insights into the condition of their soil and crops. This allows them to use the data to predict problems and implement preventative measures.

Precision agriculture and input management

Instead of applying standardized inputs (water, fertilizers, pesticides) to entire fields, precision agriculture and variable rate technologies tailor inputs based on detailed data and specific conditions at the plant, row, or region level. This significantly reduces waste.

Livestock monitoring and management

From tracking cattle and dairy products to monitoring poultry, IoT technology improves and simplifies livestock management. Smart ear tags, wearable biometric devices, video cameras, and environmental sensors provide valuable insights into animal health, nutrition, and growth.

Automating greenhouses and indoor farming

Traditional greenhouses and emerging indoor vertical farms are becoming IoT-enabled, controlled environments. Every factor can be sensed and optimized, from climate control and supplemental lighting to nutrient and water management [1].

Weather and environmental monitoring

Weather stations equipped with smart sensors and advanced connectivity enable highly accurate crop climate monitoring. Data flows to platforms that analyze potential risks, such as frost, drought, rainfall, and pest pressure, to issue real-time alerts for intervention.

Smart irrigation and water management

With IoT-enabled water monitoring and smart irrigation systems, farmers can maintain optimal moisture levels while optimizing water use. Integrated weather data and soil sensors enable automatic drip irrigation schedules, tailored to the region, crop, and growth cycle.

Supply chain traceability and transparency

Using the unique identifiers of connected IoT sensors and devices, agribusinesses can automatically record a digital trail to track crops from field to transport, processing, distribution, and retail. This promotes transparency and accountability across the supply chain.

IoT technologies support smart agriculture

While smart agriculture encompasses many emerging technologies, the Internet of Things (IoT) serves as the foundation, integrating and connecting tools such as:

IoT sensors and devices

A vast array of connected sensors deployed across fields measure and monitor key data points such as humidity, temperature, rainfall, soil nutrients, leaf health, equipment operation, and more.

Advanced sensor types include:

- Soil moisture, temperature, nitrate, pH, and electrical conductivity sensors.
- Environmental sensors for wind, humidity, light, carbon dioxide, water level, and fire detection.
- Motion sensors and cameras for tracking biometrics and livestock behavior [4].

Communication technologies

Data captured by sensors requires reliable mechanisms for transferring it to cloud computing platforms and software applications for analysis and action [5].

Based on connectivity, bandwidth, and power requirements, smart farming solutions integrate technologies such as:

- Low-power wide area networks (LPWANs) like LoRaWAN, SigFox, and LTE-M.
- Cellular connectivity (NB-operational technologies for remote control, 4G/5G for video).
- Satellite connectivity for complete coverage of remote areas.
- Wi-Fi, Bluetooth, and other short-range wireless communication technologies.

GPS data

GPS is a satellite-based navigation system that provides geographic location information, helping to define field boundaries, assess soil properties, map crop yields, and track livestock movements and status.

Cloud computing and data analytics

With millions of data points flowing from IoT sensors across the farm, highly scalable cloud computing platforms and big data analytics are critical to smart farming. Cloud computing systems, such as AWS IoT and Microsoft Azure IoT, provide the infrastructure needed to incubate, process, and visualize sensor data at scale [5].

Monitoring tools

Remote sensors can monitor the physical and chemical properties of objects. This includes remote monitoring tools that provide real-time data on livestock health, soil fertility, and pest infestation.

Variable rate technology

Variable rate irrigation (VRT) technology helps implement different agricultural inputs in the field without requiring manual adjustments. You can integrate VRT with GIS and real-time sensor data to optimize irrigation, chemical blends, and other processes.

Public databases

Public agricultural databases contain various types of information related to agriculture. This includes historical data on crop yields, terrain complexity, weather patterns, and soil composition. These databases can also include information on broader socioeconomic and environmental factors that influence agriculture.

Drones and aerial photography

Unmanned aerial vehicles (UAVs) or drones equipped with high-resolution cameras provide aerial images of entire crop fields. When combined with machine learning techniques, these images can be used to assess the overall condition of crops, identify gaps in irrigation systems, pinpoint pest and weed infestations, and much more. Drones can also be used for targeted pesticide spraying [2].

Robots and autonomous vehicles

Smart machines such as autonomous tractors and swarms of robots can automate labor-intensive field tasks like planting, pruning, weeding, and harvesting using a combination of GPS, computer vision, sensors, and autonomous navigation. Geographic Information System (GIS) data can also help guide drones [3].

Benefits of IoT in smart agriculture

In particular, we consider four reference scenarios, namely, irrigation systems, plantation and crop monitoring, tree monitoring, and livestock monitoring, which exhibit heterogeneous requirements in terms of network bandwidth, density, sensors' complexity, and energy demand, as well as latency in the decision process [4].

IoT in agriculture, as in other sectors, offers numerous advantages.

- **Increased efficiency:** IoT in agriculture enables farmers to easily monitor their crops in real-time. They gain insights that help them predict problems before they occur, making them faster. Product is also likely to reach market more quickly and easily when crops are identified.
- **Resource conservation:** With IoT-enabled precision agriculture, resources like water, energy, and land can be optimized by precisely allocating the right amounts based on data from field sensors [4].

- **Sustainable practices:** IoT-enabled smart agriculture reduces pesticide and fertilizer use, resulting in cleaner production and a smaller environmental footprint than traditional methods.
- **Agility:** Real-time monitoring and forecasting systems allow farmers to respond quickly to changes in weather, crop conditions, and potential threats, minimizing losses and protecting crops.
- **Reduced operating costs:** Resource consumption, operational costs, and human error can be significantly reduced by automating crop planting, processing, and harvesting processes.
- **Improved product quality:** IoT in agriculture significantly contributes to improved production. By using connected systems, farmers can now maximize nutritional value and improve product quality [4].

The result of implementing a Geographic Information System (GIS) program is an interactive field map that displays crop location and health status, topography, soil type, fertilization, and other

important details. Now, let's see how companies are using this information and technology in agricultural operations.

References

1. Potharlanka JL. An IoT Based Architecture for Smart Farming. December 2019. International Journal of Control and Automation. 2019;12(9):31–40.
2. Jacobson I, Lawson HB, Ng PW, McMahon PE, Goedicke M. The Essentials of Modern Software Engineering. Association for Computing Machinery and Morgan & Claypool Publishers; 2019.
3. Sommerville I. Software engineering. 9th edn. Boston: Addison-Wesley; 2011.
4. Pagano A, Croce D, Tinnirello I, Vitale G. A survey on LoRa for smart agriculture: Current trends and future perspectives. IEEE Internet of Things Journal. 2022 Dec 20;10(4):3664–79.
5. Rehman AU, Alamoudi Y, Khalid HM, Morchid A, Muyeen SM, Abdelaziz AY. Smart agriculture technology: An integrated framework of renewable energy resources, IoT-based energy management, and precision robotics. Cleaner Energy Systems. 2024 Dec 1;9:100132.