agricultural and food domain, offering insights into their benefits and drawbacks.
2) This article emphasizes the critical role of choosing the right architectural pattern in agricultural robotics projects, showcasing how it significantly influences project outcomes.
3) It explores the application of architectural patterns in agriculture, offering valuable guidance for selecting appropriate patterns in diverse scenarios.
4) Identifying unresolved problems in the field, this article addresses potential challenges and areas requiring further investigation. It opens avenues for future research aimed at enhancing the efficiency and effectiveness of future robot architectures in agricultural robotics.

Overall, this research article serves as a valuable resource in the field of agricultural robotics, offering an in-depth analysis of software architectural patterns.

II. Agricultural Environment and Robotic Systems

The field of agricultural robotics has emerged as a promising area for the application of advanced robotic technologies to increase efficiency, reduce labor costs, and improve overall productivity in agriculture. This section will provide an overview of agricultural robot systems, including their applications, types, and components. It will also discuss the importance of software architecture in the development of effective agricultural robot systems.

A. Agricultural Environment

It is essential to understand the agricultural environment in order to establish a robot architecture for agricultural applications. Agricultural application domain can be broadly categorized into three categories as follows.

1) Arable farming, horticulture, and animal husbandry are the three broad categories of agricultural production [5]. Arable farming is the large-scale cultivation of plants, such as wheat, potatoes, oilseeds, and fiber crops that are harvested at the same time.
2) Horticultural production on a small scale involves the production of fruits, vegetables, and ornamental plants, such as tomatoes, apples, cucumbers, and cabbage, which require selective harvesting.
3) Animal husbandry is the practice of breeding, feeding, and caring for animals, such as livestock, poultry, and fish. Examples of animal husbandry activities include watering, and milking of dairy animals, as well as shearing and processing wool.

The agricultural production cycle includes several stages, such as soil preparation, seeding, transplanting, transporting seeds, planting, fertilizing, pest control, weed control, irrigation, crop monitoring, harvesting, sorting, grading, packing, and cleaning.

Many of these activities have already implemented automated technologies, however, are engineering solutions. This is due to the inability to create a fully autonomous system due to limitations in sensing, vision, decision-making, learning, and safety capabilities to deal with uncertainty exist in the agriculture environment which would be included in the overall system architecture. Some key uncertainties are listed as follows.

1) *Environmental factors:* Agriculture is heavily influenced by environmental factors, such as weather, soil conditions, and other external factors. These uncertainties make it difficult for robots to predict and adapt to changes.
2) *Crop variability:* Each crop is unique and has different characteristics that can make it difficult for robots to handle them. Crop variability can include differences in size, shape, and texture, which can impact the robot's ability to identify and pick crops.
3) *Obstacles and terrain:* Agricultural fields can have various obstacles and terrains, such as rocks, trees, and uneven ground. These uncertainties make it difficult for robots to navigate and avoid obstacles.
4) *Sensor and hardware limitations:* Robotic systems require sensors and hardware to operate effectively. However, these components can have limitations in terms of accuracy, precision, and range. These uncertainties can impact the overall performance of the robot.
5) *Data quality and quantity:* Agricultural data can be difficult to collect and may vary in quality and quantity. This uncertainty can impact the robot's ability to make informed decisions.
6) *Regulatory challenges:* Agricultural robots must comply with various regulations and standards set by governments and other regulatory bodies. These regulations can vary by region and can create uncertainties for robot developers and manufacturers.

The design of architecture not only depends on environment but also depends on the type of robots used in the environment.

B. Types of Agricultural Robots

Depending on the task and environment robots can be categorized into following classes.

1) *Autonomous ground vehicle (AGV):* These robots operate on the ground and are typically used in various applications, including planting, spraying, and harvesting crops.
2) *Autonomous aerial vehicle (AAV):* These robots operate in the air and are typically used for tasks, such as crop monitoring, spraying, mapping, and surveying. AAVs are equipped with advanced sensors and cameras that can capture high-resolution images and provide real-time data on crop health, growth, and yield. AAVs are particularly useful for large farms and fields where manual monitoring and inspection can be time-consuming and labor-intensive.
3) *Autonomous underwater robot (AUR):* These robots are a type of agricultural robot designed to operate underwater, performing tasks, such as monitoring water quality, inspecting aquaculture facilities, and conducting oceanographic research.
4) *Autonomous arm robot (AAR):* An AAR for agriculture is a type of robotic system used in agricultural operations, such as planting, harvesting, pruning, and spraying. The arm can be mounted on a ground vehicle or mobile base or ariel vehicle that can navigate across fields and orchards.