8) *Human–robot collaboration:* The development of software architectures that enable human–robot collaboration can improve the safety and effectiveness of agricultural robots, as well as increase the acceptance and adoption of these robots in the industry.
9) *Data management:* With the increasing amount of data being generated by agricultural robots, effective data management strategies will be essential. This may include the development of data storage and retrieval systems, as well as data analytics and visualization tools to extract insights from the data.

Overall, the future directions for software architecture in agricultural robots will likely involve the integration of these emerging technologies and trends, enabling robots to become more intelligent, efficient, and effective in meeting the needs of farmers and other stakeholders in the agricultural industry.

VIII. Conclusion

The development of agricultural robots is a promising and challenging field with immense potential to transform the agriculture industry. The design and implementation of software architecture for such robots are critical factors that determine their overall performance and success. The perception, world modeling subsystem, planning and control, and gripping and manipulation subsystems were identified as critical components of the software architecture for agricultural robots highlighting the need for robustness, adaptability, and real-time capabilities. This article begins by examining the unique characteristics of the agricultural environment, highlighting its complexity and the need for specialized robotic systems. It identifies different types of agricultural robots, ranging from harvesting robots to food processing and packaging robots. Several challenges in developing agricultural robot software architecture are identified, such as dealing with unpredictable environmental conditions, ensuring efficient data processing, and integrating multiple sensors and actuators. The application of software architecture patterns specifically tailored for agricultural robots is explored, aiming to address these challenges effectively.

This article presents case studies of harvesting robots, food processing robots, and food packaging robots, showcasing how software architecture plays a crucial role in their design and operation. Various software architecture patterns and principles are employed to enhance functionality, performance, and safety in these applications. Limitations of current agricultural robotic architectures are discussed, acknowledging areas where improvements can be made. This article concludes by outlining potential future directions for agricultural robot software architecture, including the integration of advanced AI and ML techniques, enhanced autonomy, improved human–robot interaction including ethical perspective. The ethical architecture for robots is a source of concern, since robots are expected to collaborate with humans. The software architecture must adapt to these technologies to meet the changing demands of the agriculture industry. Although bringing ethical intelligence into robot is still a concept, and much work is needed to integrate ethics into architectural patterns that would work in real life. Overall, this research article contributes to the understanding of software architecture's importance in agricultural robot development. By addressing the specific requirements and challenges of agricultural environments, it provides valuable insights into designing efficient and robust software systems for agricultural robotics. The case studies presented demonstrate the practical application of software architecture principles, while the identified limitations and future perspectives offer a roadmap for further advancements in the field.

Acknowledgment

The author extends sincere thanks to all members of the FlexCRAFT project for engaging in discussions, which were instrumental in generating innovative ideas and shaping the direction of the work.

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