CASS: Configurable, Adaptive, and Scalable Swarm of Aerial and Ground Robots for Collaborative Smart Agriculture

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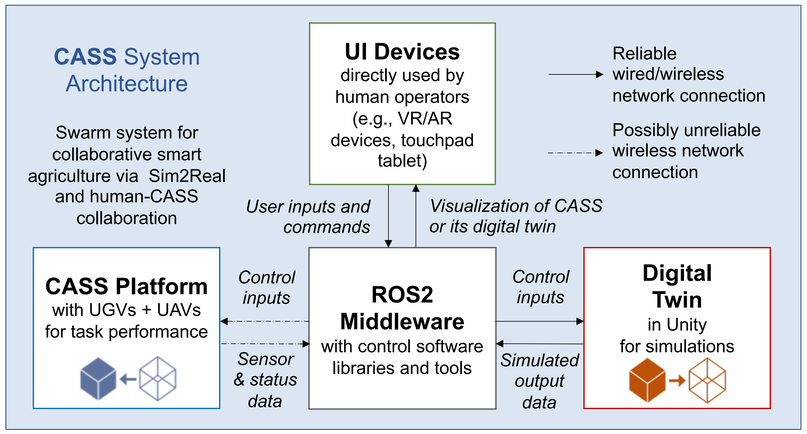
Challenges in Agriculture:

- High demand for increasing productivity in agriculture due to world population growth and increased living standards
- Difficulties addressing labor shortage, increasing climatic variability
- Large machinery-based modern agriculture in the U.S. causing reduced soil productivity and long-term negative environmental impacts

Scientific Impact:

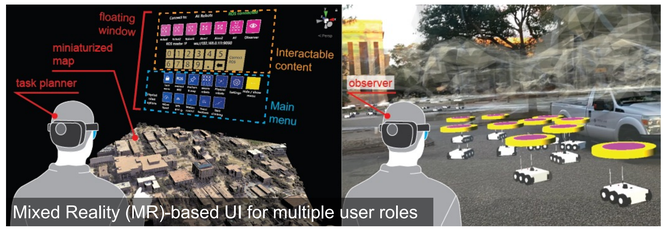
- Many low-cost, small robots that are configurable to fit the size and complexity of diverse agricultural tasks → offering flexible and adaptive solutions
- Integrated system architecture with hybrid swarm user interface (UI)
- Embedded swarm and individual robot control algorithms → broadly applicable to agricultural as well as other areas

Technical Approach:



*Integrated **CASS** system based on Robot Operating System (ROS) 2, combining **(1)** a scalable physical robotic platform with ground and aerial robotic agents, **(2)** a digital twin system (high-fidelity and low-fidelity simulations), and **(3)** user interface (UI) modalities.*

Key Innovations & Outcomes:



Mixed Reality (MR)-based UI for multiple user roles


CASS hardware platform with ground and aerial robots


3D visualization of a crop field and Unity simulation for digital twin development

Virtual-physical hybrid swarm simulator & adaptive UI

- *ROS 2-based distributed system architecture*
- *Hybrid swarm simulator supporting a swarm of virtual and physical robots to collaborate and interact with each other.*
- *MR-based UI for adaptive user roles and intuitive interaction*
- *Embedded swarm decision-making and navigation algorithms*

Development of physical CASS platform

- *UGVs: 8 ground vehicles for general monitoring purposes + 2 specialized ground units for agriculture-specific tasks*
- *UAVs: 1 testbed + several commercial units*
- *Working on increasing the number, equipping them with mesh network devices, and developing software*

Digital twins for 3D visualization and simulations

- *Ongoing data collection – RGB images from UAVs + RGB images, LiDAR data, and depth images from UGVs (April – October 2023)*
- *Unmanned Aerial System (UAS) hub for data management*
- *Aerial images collected from UAVs to create 3D visualization of crop fields – to be used to create a Unity simulation environment*

Societal Impact & Agricultural Benefits:

- Improving profitability of the producers
- Reduced waste, optimal use of water and fertilizer, and reduced use of pesticides
- Localized, adaptive monitoring, inspection, and intervention → long-term ecological and environmental benefits

Impact on Education and Outreach:

- Diversity and multidisciplinary research team
- Serving diverse on- and off-campus communities as a Hispanic Serving Institution (HSI)
- Participation of students with disabilities
- STEM summer camp for first-generation students and those with a low-income background

Research Team & Contact Info:

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2023 FRR & NRI Principal Investigators' Meeting
May 2-3, 2023

Award ID#: USDA-NIFA **2021-67021-35959**