Smart Action

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Content:

- **Implementation of variable rate application**
  - Methods, Sensors and Implementation

- **Smart collaborative robotics and CPS for smart agriculture**
  - Background, Automation Methods and Technologies, Case Studies

Introduction

- The man- or horse-drawn equipment of the early 1900s made agricultural activities both time-consuming and restricted farmers to small-farm cultivation.

- The introduction of smart farming technologies into farm activities has enabled farmers to manage in-field variability and handle a lot of information efficiently.

Methods for variable rate application implementation

- There are three main methods for applying inputs at variable rates:
  - **traditional,**
  - **Sensor-based**
  - **and map-based.**

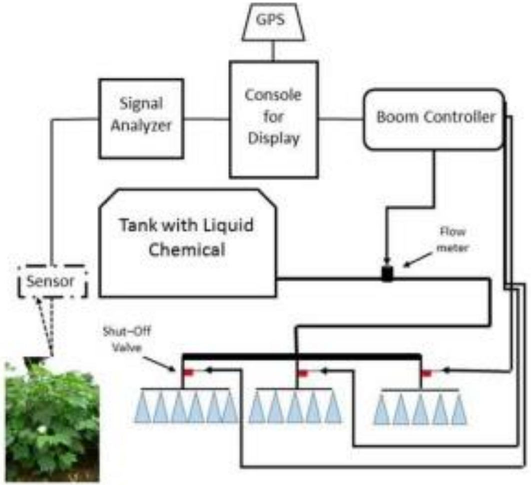
- **The choice of method is usually related to the agricultural task and farm budget**

Traditional variable rate application

- Since the 1990s, farmers have attempted to manage variability by applying varying amounts of agro-chemicals.
- Traditional VRA can be used by every farmer given its low cost and ease of use.
- The disadvantage of traditional VRA is that application success depends on the specific constraint and decision set of the farmer.

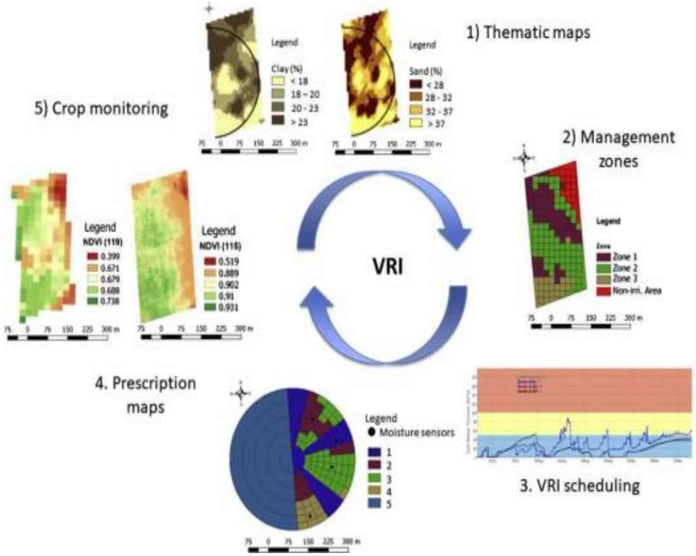
Sensor-based variable rate application

- Prior mapping and/or field property data collection is not required to determine the appropriate amounts of inputs for application.
- Ideal amount of input is determined online (on-the-go) from sensor outcomes while the tractor is moving.
- Sensor readings are then processed by a computer and the output is applied immediately by the variable rate controller. In one-point calibration, the reflectance is measured at a single location and an estimated nitrogen rate is associated to its reflectance index.
- The use of strips instead of a single spot can be more advantageous when applying sensor-based VRA because it allows us to identify more robust relations between reflectance and N input.



Map-based variable rate application

- Map-based and sensor-based VRAs are two approaches for managing variable minimum area (MZ) in the field.
- MZs are defined as parts of the field with homogenous properties that can be managed uniformly.
- Research suggests that a dynamic approach must be applied to address both intra- and inter-seasonal field variability.



Sensors and devices for variable rate application

- Either map- or sensor-based VRA requires several sensors and devices to apply inputs accurately.
- The most important sensors are:
  - Global positioning system
  - Soil moisture sensors
  - Controllers for variable rate application
  - Actuators for variable rate application

Implementing variable rate recommendations

- Input application at variable rates is often categorized according to type of input: seeds, dry chemicals, liquid chemicals and irrigation water.
- **Variable rate seeding -** Early planting dates and reduced seeding rates have been shown to increase profitability in soybean fields.
- **Dry chemicals variable rate application -** The application of dry inputs, such as fertilizers, requires high accuracy and speedy application. Spinner spreaders apply only one type of input at a time. Pneumatic applicators can apply one or more inputs simultaneously. Vital to the distribution of dry materials are the air stream and metering devices.

Implementing variable rate recommendations

- **Liquid chemical variable rate application -** The WeedSeeker is said to reduce the pesticide amounts by 20%, which can save farmers approximately $10 per hectare. Optical sensors detect weeds based on the reflectance of their canopies. The system has resulted in reductions to N fertilizer by as much as 86% while maintaining yield quantity and quality
- **Variable rate irrigation** - VRI can be adapted to support the delivery of liquid fertilizers (fertigation) and pesticides (chemigation). There are findings that VRI technology can reduce water used for irrigation by 45% compared with conventional irrigation, in a field of peanuts.

Practical examples of variable rate application

- **Nitrogen variable rate application in cotton -** Liakos et al. applied a side dress of nitrogen to cotton in Georgia, USA. Results showed that the farmer's profit increased at the VRA treatments by 6% while the fertilizer amount used was decreased by 12%. The N rates prescribed in the prescription map of the experiment were based on Oklahoma and Missouri recommendations.
- **Nitrogen variable rate application in durum wheat -** High N rates ensured high protein levels and enhanced the quality of gluten proteins, but increased environmental risks. Spatial variability of yield and protein content was mainly driven by soil texture and base fertilization in both years. Variable rate N fertilization partially mitigated 2011 weather impacts, but unusual weather conditions resulted in low N use efficiency.

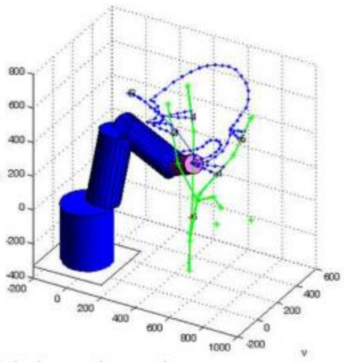
Smart collaborative robotics and CPS for smart agriculture

- Collaborative control theory (CCT) is applied at two system levels: CCP level e protocol and agent level, and CPS level e CPS and environmental level. The design and control goal is to deploy agents to tasks, address conflicts and allow better interactions between agents
- Agricultural plants cannot avoid growth fluctuation and variability in environmental conditions. Sensors can effectively monitor environmental conditions, such as temperature, humidity and water level. In most cases, sensors cannot monitor and analyze tasks without support from humans, computers and robots. A protocol is needed which collaborates all agents in the system to work in harmony..

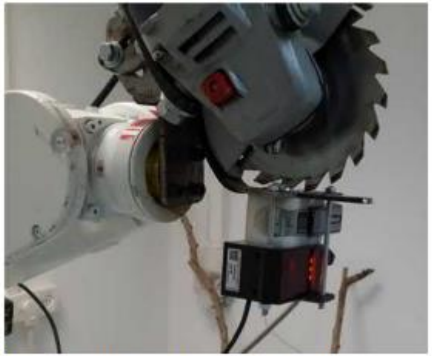
Automation and robotics solution approaches applied

- Automation has been used for helping workers in performing agricultural tasks for many decades.
- Greenhouse environment combines both the drawbacks of indoor and outdoor environments.
- Common tasks for greenhouse automation with PA objectives are climate control, seedling production, spraying and harvesting.
- The following section describes recent approaches for each task.

Climate control

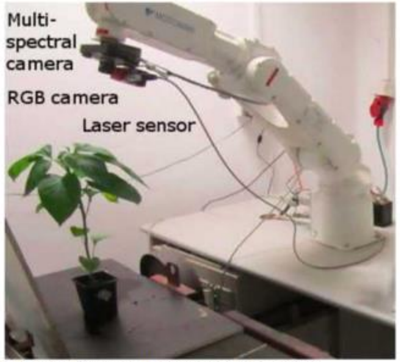


Calculation of optimal trajectory



Visual serving end-effector for pruning

Machine visualization, mapping and guidance of autonomous sprayer



Lab experiment of disease monitoring robot

- Autonomous sprayer for greenhouses:
  Relevant for PA for site- and location-specific spraying at the individual plant level.

Seedling production

- Seedling production is an important factor in developing a high-quality agricultural product.
- Machines and automation are utilized for seedling operation such as selecting seed, seeding, irrigation, transplanting, grafting, cutting and sticking.
- Emerging seedling production automation begins to rely on IoT in greenhouses.

Automatic sprayers

- To minimize exposure of farmers to chemical substances, automation or robots which can spray liquid chemicals is one of the solutions.
- Camera-guided selective and precision sprayers have also been developed.
- Alternative spraying methods and techniques, also useful for PA

Fruit harvesting robots

- Precision fruit and vegetable harvesting has been investigated extensively.
- Challenges include product diversity and variety of products' properties.
- As a result, fruit harvesting robots are not yet commonly used in industry and in commercial applications. Automation technologies for the kiwi industry are reviewed.
- Some of the main obstacles for their wider implementation of Fruit harvesting robots are the lack of:
  - Intelligence for overcoming expected and unexpected errors and conflicts in operation
  - Responsiveness under diverse requirements and interactions and
  - Operational predictability and knowledge-based response.

New and emerging cyber-augmented approaches

- **Cyber-physical system and precision agriculture robotics -** Sensors are widely used for monitoring processes in Pennsylvania. However, without human operators, sensors alone cannot successfully complete monitoring tasks.
- Therefore, robots are being considered to help humans and take over repetitive tasks.
- In addition, information gathered from plants such as humidity level can be analyzed better when sensed by sensors. Agricultural Cyber-augmented System (CPS) enables us with relatively better intelligence and real-time control to monitor greenhouse crops.
- CPS can help agents in the system such as humans, robots and sensors work together more harmoniously. Although CPS has various useful applications, the effective models in real situations are still challenging.

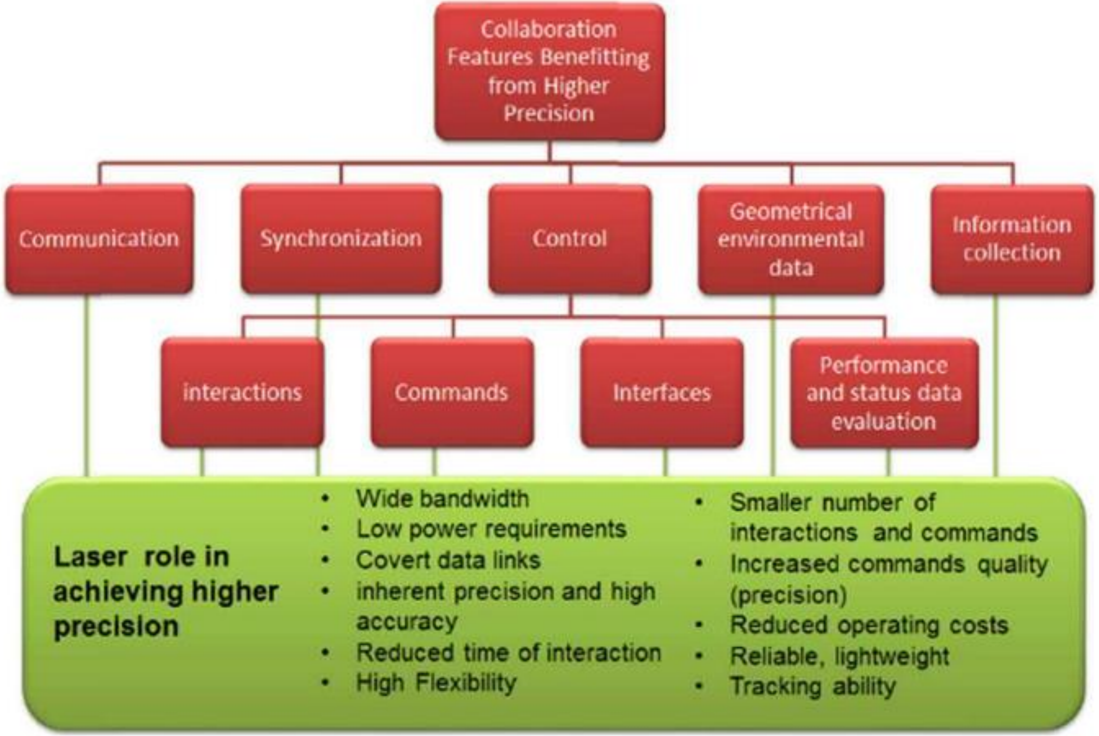
New and emerging cyber-augmented approaches

- **Collaborative control theory for designing complex system** Collaborative Control Technology (CCT) is a framework for designing effective complex systems.
- CCT-based middleware designed to resolve conflicts and detect errors has been developed and applied in industry.
- TAPs or collaborative workflow protocols and algorithm for conflict and error prevention and detection were developed and patented.
- Collaborative resource planning can be used to improve robotic performance in precision agricultural tasks.
- A CCT-based CPS platform for PA has been developed for detecting and localizing stress in crops. Smart collaborative robotics and CPS which include humans, robots and sensors can begin to be utilized in agriculture.

New and emerging cyber-augmented approaches

- **Precision collaboration -** Precision collaboration is considered as a useful feature for PA.
- Laser technology can be applied for achieving each of these functions alone and achieve all of them.
- It can do so through its unique ability to rapidly transfer signals, data, information and energy with no spatial or temporal residuals.
- A system that cannot prevent and resolve conflicts and errors will typically be inefficient and expensive to operate.

New and emerging cyber-augmented approaches



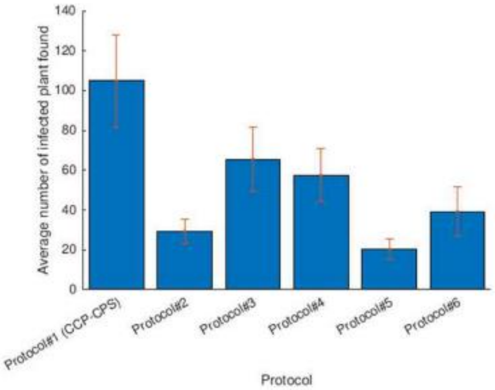
Collaboration support features and their precision requirements

Case studies

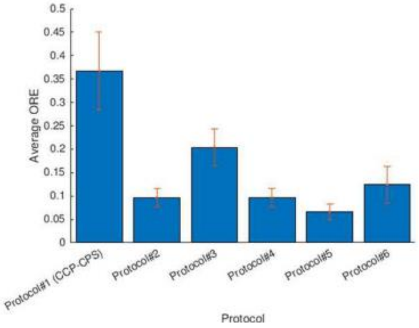
- Case study 1: collaborative control protocol with knowledge-based system for detecting stresses in greenhouse crops
- Case study 1 is used for demonstrating CCP-CPS concepts which are modified from the original CCP-ED
- The system includes humans, a mobile robot and sensors. Sensors such as electromagnetic and vision sensors mounted on the robot are used for inspecting current conditions of plants at each location. CPS will not only save time and cost to communicate but also effectively supports the agriculture system.

Case study 1 Conclusions

- In this case study, CCP-CPS is tested and compared relative to five other protocols. The objective of the protocol is to monitor conditions of plants under limited available time. Routing algorithm can save travelling time by creating a tour to smartly guide the direction of robot movements.



Number of stressed/infected plants detected under each protocol design



Overall robotic efficiency (ORE).

Case study 2

- Case study 2: CPS framework for monitoring plants conditions.
- In this case study, agricultural CPS framework is used and applied to the greenhouse.
- CCP-CPS needs two layers: CCP layer and CPS layer. The CPS layer comprises of four main parts:

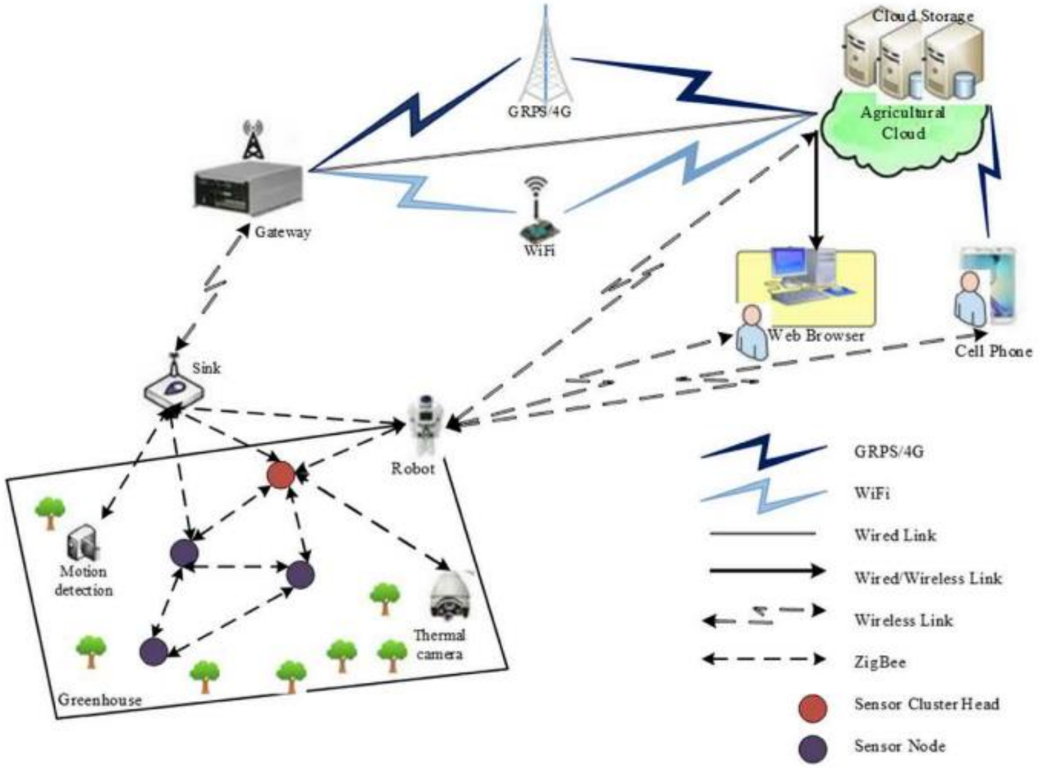
(1) WSN deployment,

(2) Cloud platform, IoT and IoS,

(3) transmission mode and

(4) agricultural robots and other actuators.

Case study 2



Monitoring, detecting and responding cyber-physical framework

Case study 2 Conclusions

- An agricultural CPS aims at collaborative monitoring, detection and responses to stresses at identified locations.
- Second case study demonstrates a framework, workflow and application of CCT and CPS in agricultural greenhouse setting.
- System can reduce total operational time for monitoring and detection, thanks to better communication among participating agents.

Session Q&A