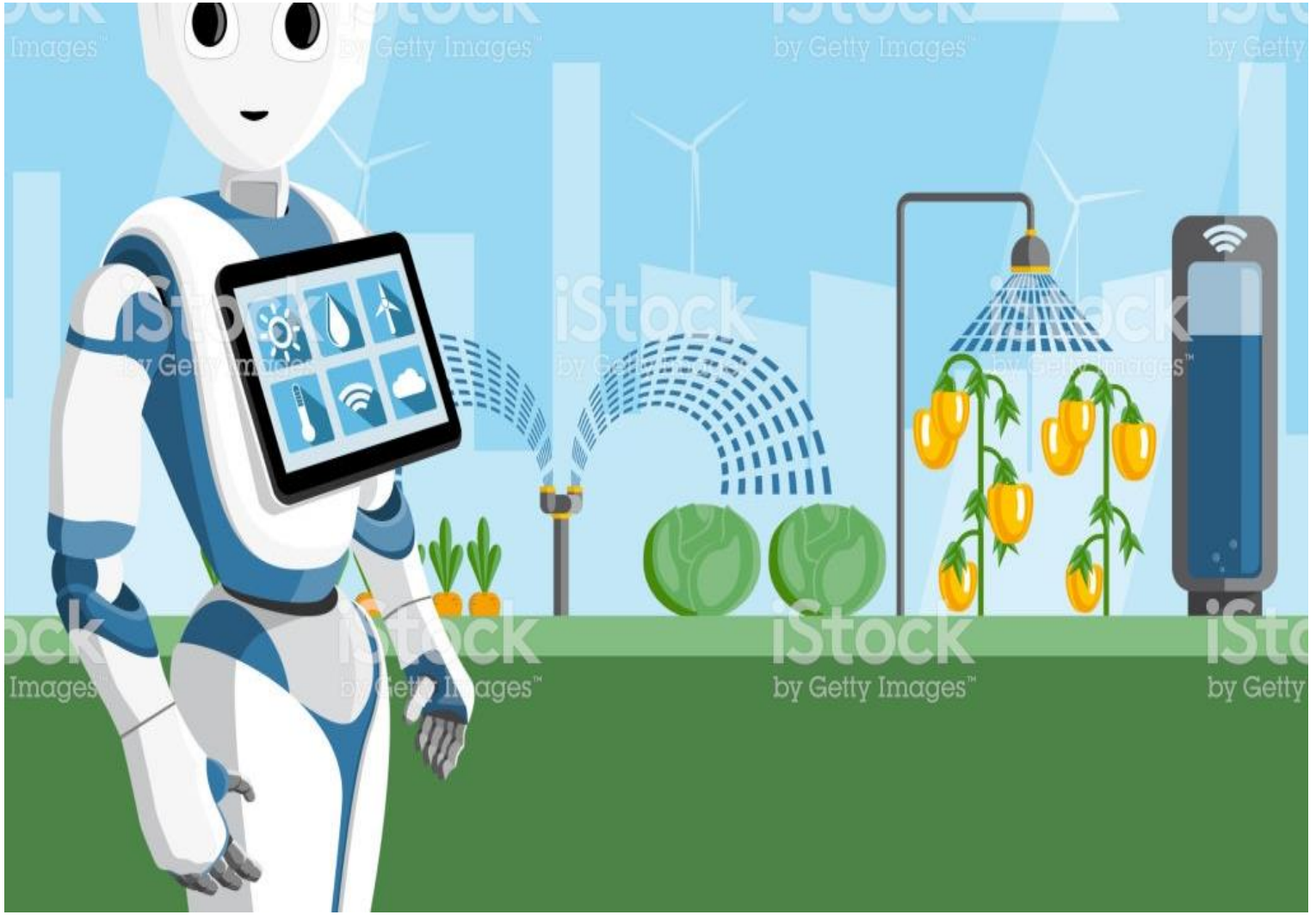

WISDOM: Watering Intelligently at Scale with Distributed Optimization and Modeling

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Introduction

United States Environmental Protection Agency (EPA) estimates - 30% fresh water goes to the irrigation of residential landscaping

Distributed actuation systems allow the irrigation system to apply water completely independently across the field allowing flexibility of control

Geological Survey estimates that lawn irrigation systems consume 7 billion gallons of fresh water each day in North America alone

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It is estimated that only about 1% of Earth's surface water is fresh

University of California's goals to reduce overall water consumption by 20% by 2020 and 36% by 2025

Responsibility of System

- The responsibility of these systems is to apply the correct amount of moisture to the area
- Soil moisture levels that are too low will cause the plant to wilt and die
- Levels that are too high can cause the plant roots to rot, soil erosion, and in extreme cases transport fertilizer chemicals into nearby drinking water supplies
- The same has occurred in California's Salinas Valley

Problems with the current system:

- The proposed systems are designed with centralized architectures that introduce single points of failure due to the growth of the global models used at scale
- Computational bottlenecks in data processing
- Significant network energy for data forwarding used by the centralized data driven modeling strategies.
- Additional requirement of periodic batterychangesinthesesystems

The solution: WISDOM

- Optimization techniques for use in localized neighborhoods, and introduce a processing pipeline for distributed irrigation decision making on the edge devices themselves.
- It uses a low-power embedded device with a relatively high-performance co-processor to meet these requirements.
- With power duty-cycling by the low-power “master” device, the coprocessor vastly improves storage, memory, and processing power, while incurring are latively small energy penalty during operation.
- WISDOM is the first system to utilize a co-processor architecture for distributed computation in data-driven modeling and control.

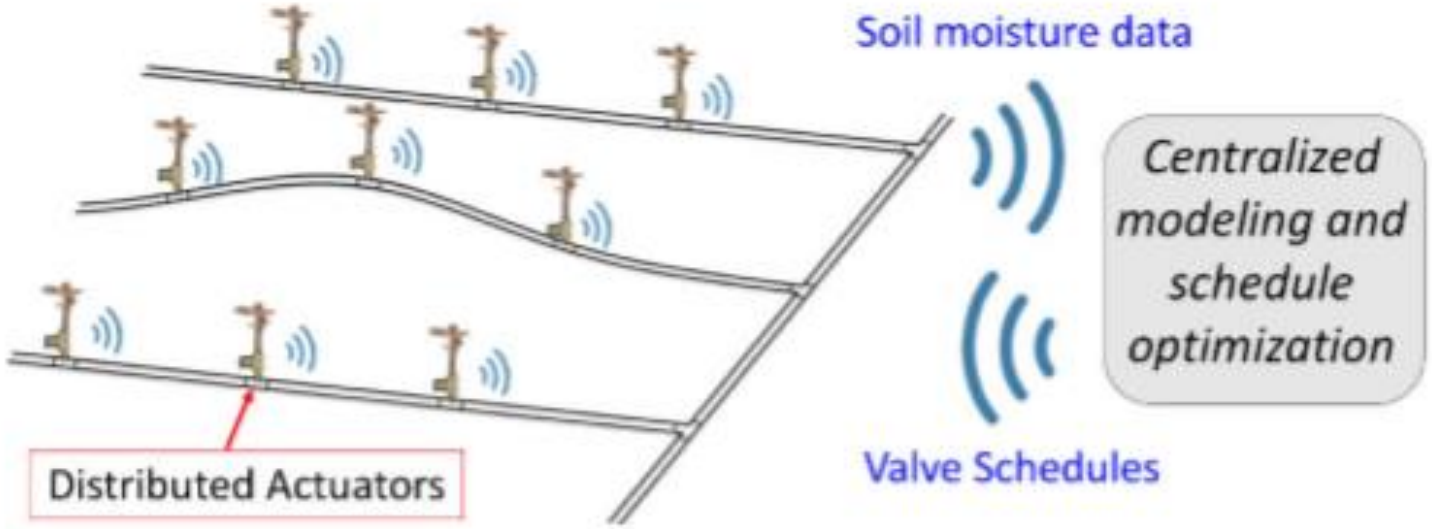
The solution: WISDOM

WISDOM is the first system to utilize a co-processor architecture for distributed computation in data-driven modeling and control.

Devices are collocated with sprinklers throughout the space.

Small water turbines1 installed underground that allow us to harvest energy for battery recharge during irrigation.

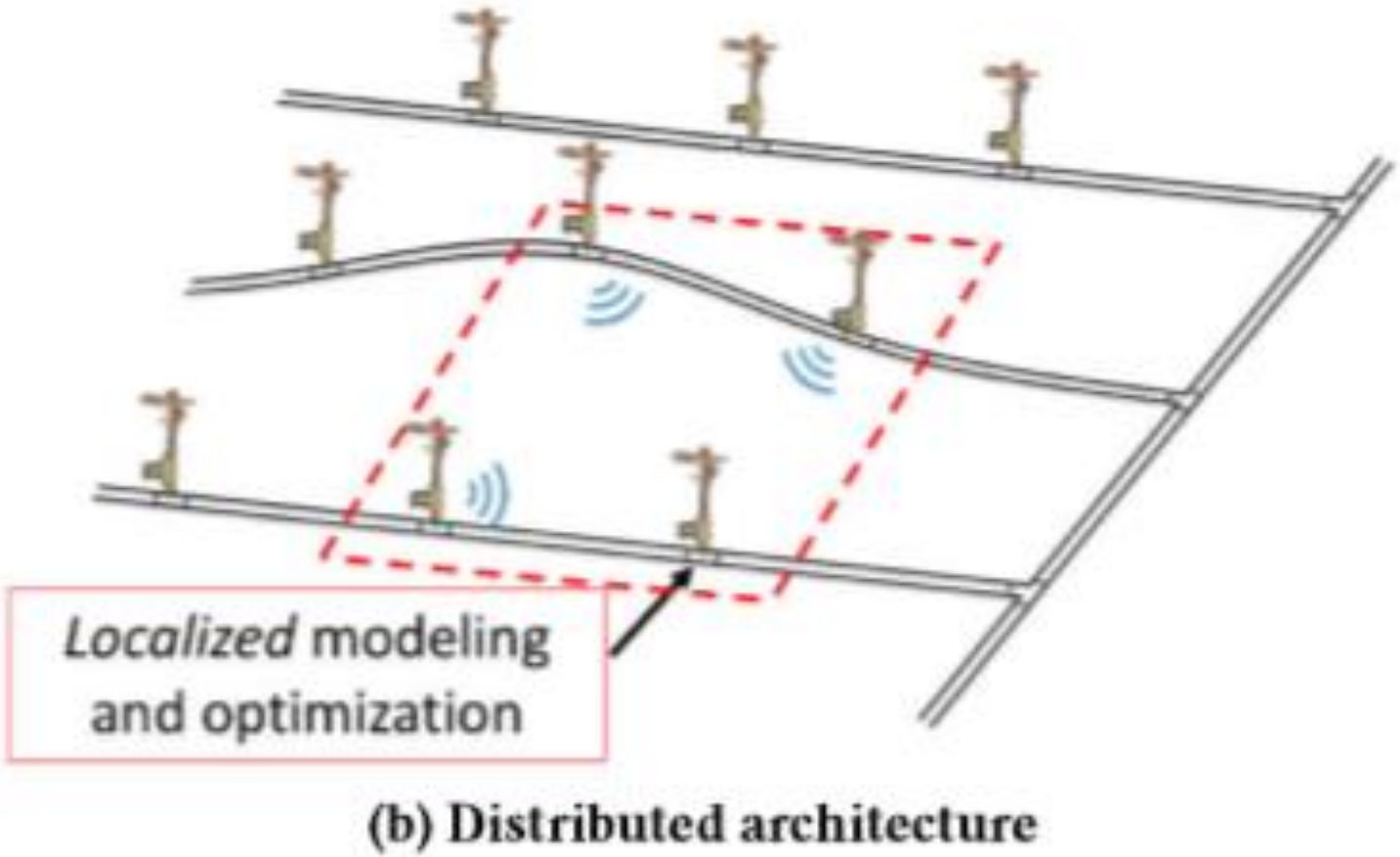
In the wireless sensor network domain, WISDOM is the first to utilize sprinkler water source for energy harvesting.



(a) Centralized architecture

Centralized Architecture

In the Figure each device in the PICS system transmits its data to a centralized controller for processing. The controller trains a global water movement model, which is then used to optimize valve schedules. These schedules are then re-distributed to the devices for actuation. With a large irrigation system, the global water movement model makes schedule optimization time too slow, increasing network traffic causes forwarding nodes to consume more energy, and any lapse in communication with the controller can cripple the system.



(b) Distributed architecture

Distributed Architecture

The WISDOM system is fully distributed and controlled locally using the solenoids devices.

These models, trained by the co-processor, are then used by the co-processor in optimization to find schedules that minimize system water consumption while maintaining adequate moisture levels everywhere in the system, our two primary goals.

How WISDOM works?

- As the WISDOM system runs, its installed devices periodically measure and log the state of moisture in the space, as well as the on/off status of the solenoids.
- Each device shares this information with all devices in its local neighborhood (within radio range)
- Over time, using these collected data traces, each device learns localized models that describe the effect of actuation by all nodes within the neighborhood on the soil moisture distribution across the neighborhood.
- Likewise each device learns how its own local soil moisture will degrade over time after irrigation has ended

How WISDOM works?

- By performing these tasks in a distributed way, we enable a system that can robustly scale to control an irrigation system of any size, without sacrificing system efficiency or quality of service
- Each day, all master devices in the network wake up and distribute all buffered data to the surrounding nodes within the local neighborhood.
- Once all data is received, the master device will use the current moisture distribution in the neighborhood to make a decision whether or not irrigation is necessary on this day, returning to low power if it is not necessary.

Water Consumption Bar Graphs

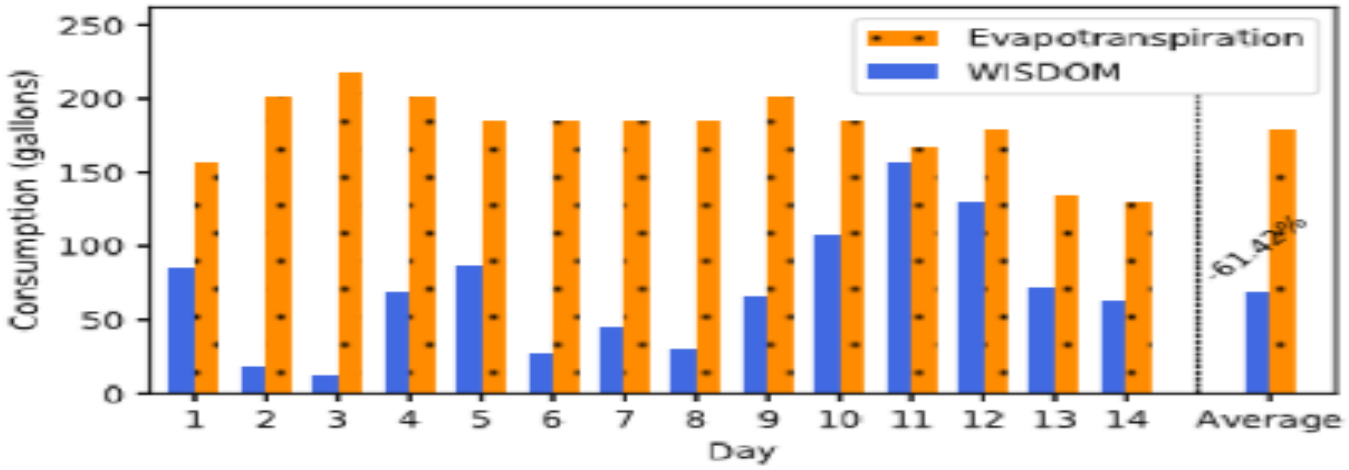


Figure 7: Water consumption of ET vs WISDOM

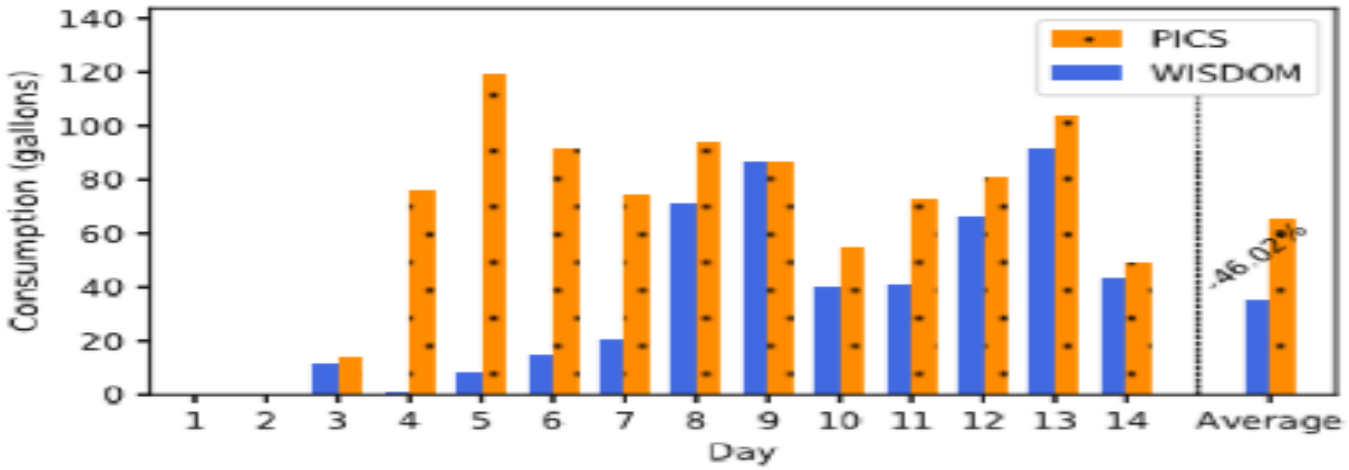


Figure 8: Water consumption of PICS vs WISDOM

Conclusion

WISDOM, a distributed system for control of irrigation systems at any scale that utilizes energy harvesting to allow a perpetual system lifetime.

Across 4 weeks of live system deployment, it is found that up to 32.9% water savings is possible in comparison to industry-standard controllers, and demonstrate through extensive comparison in simulation that the proposed distributed system can provide all of the efficiency and quality of service benefits of the centralized one, while allowing energy independence and the robust control of irrigation systems of any size.