Expanding Distributed Artificial Intelligence Research Infrastructure: A Case for Container Farms

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Center of Excellence in Sustainable Food and Agricultural Systems

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Introduction

New Mexico State University aims to establish itself as a leading institution in innovative research and development while fostering a highly capable workforce. In today's increasingly artificial-intelligence-driven world, critical gaps have emerged between AI innovations and the workforce needed to implement them effectively, the high level of expertise required to develop and maintain these systems is the dominant barrier. Bridging that gap is a critical step towards solving key challenges in the Food, Energy, and Tech sectors. This project presents a case for Container Farms(CF) to address this gap while promoting transdisciplinary R&D in the State. NMSU's research strengths, statewide agriculture science centers, and the unique environmental composition of the state provide the foundation for a network of CFs to develop a workforce in applied AI systems while benefiting from its existing expertise in agriculture systems.

Research & Strategic Alignment

Primary Research Topics

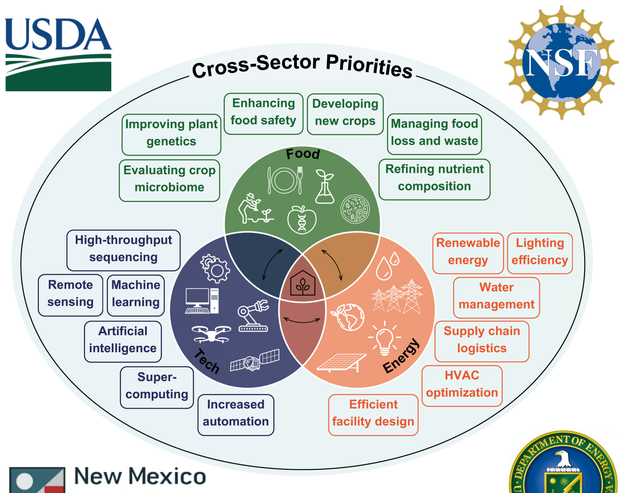
- Plant Physiology in Artificial Environments
- CEA Systems Design, Parameters, & Operational Dynamics
- Heating, Ventilation, Air Conditioning, and Dehumidification (HVACD), Lighting, Nutrient Delivery
- Internet of Things (IoT) and Distributed Information Systems
- Secure, Scalable, and Feasible AI, ML, and DRL Systems.

Strategic Plan of the NMSU VPR

1. Strategic investments that nurture interdisciplinary collaborations.
2. Build Capacity in comprehensive capture management.
3. Lead an integrated research communication strategy.
4. Develop state-of-the-art workflows to support the research enterprise.

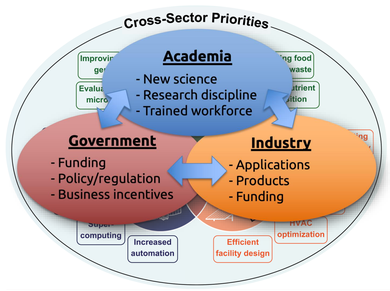
Institutional Strengths

1. Artificial Intelligence and Machine Learning
2. Energy, Environment, and Water
3. Food Production, Safety, Science, and Security
4. Biomedical Science
5. Transforming STEM Education

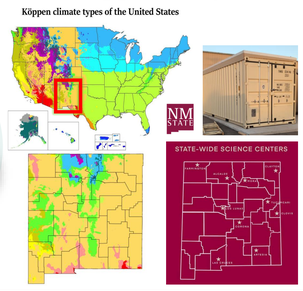


Overview

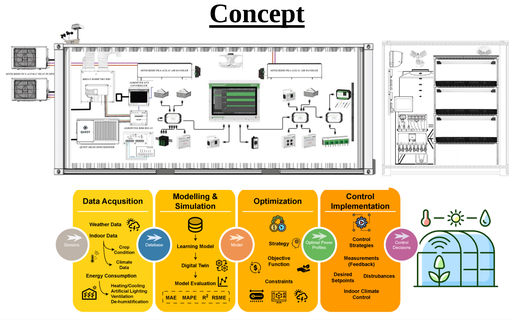
Motivation



Opportunity

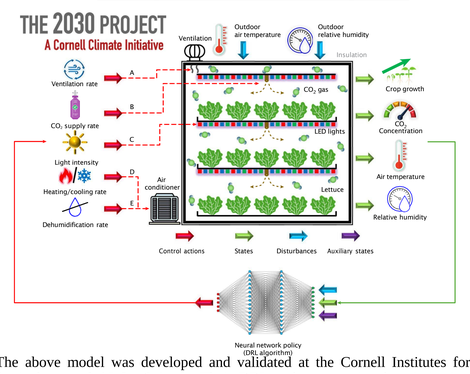


Concept



Theoretical Framework: Referencing Converging Capabilities & Infrastructure

CF Deep Reinforcement Learning Model

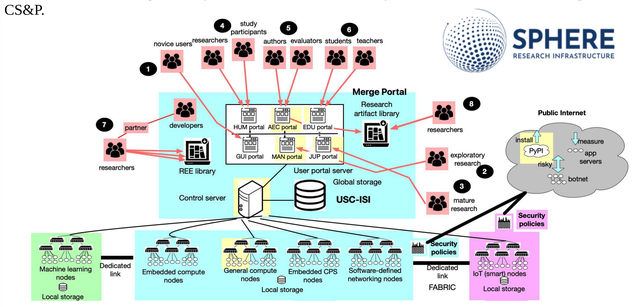


The above model was developed and validated at the Cornell Institutes for Digital Agriculture and AI for Science. Their DRL and computational optimization models were validated by analyzing indoor lettuce production at facilities located across a diverse range of climates, effectively reducing energy use by optimizing lighting and climate regulation systems. Their research found that, in arid southern U.S. climates, AI reduced energy usage more than 30% on average. Low ventilation during light periods and high ventilation during dark periods provided an energy-efficient solution for optimal indoor carbon dioxide levels for photosynthesis, confirming our concept phase conclusion that energy can be conserved using ventilation while minimizing carbon dioxide waste and maintaining ideal growing conditions, a method that was widely considered infeasible within the indoor agriculture community until recently.

SPHERE

Security and Privacy Heterogeneous Environment for Reproducible Experimentation

"SPHERE's novel offering of diverse, rich hardware infrastructure, configurable network substrate and safe network policies will support novel CS&P research in emerging areas, such as IoT, cyber-physical systems, programmable networks, edge computing, Internet measurement and human-centric CS&P. SPHERE's novel user portals will democratize access to CS&P research, and will facilitate practical CS&P education of broad student populations. SPHERE's novel support for representative experimentation and reproducibility, tight collaboration with researchers and close alliances with artifact evaluation committees, will enable vertical progress in the science of CS&P. The SPHERE research infrastructure will transform CS&P research, from piecemeal and opportunistic to highly integrated, by unifying the community's experimentation efforts on a common, rich, highly usable infrastructure. Integrated research efforts will increase the pace of innovation and improve the success and sophistication of CS&P research products. Thus, SPHERE will significantly advance scientific discovery and the Nation's research capabilities in CS&P.



NMSU AI Assets for Follow On Development

Knowledge Representation, Logic, and Advanced Programming (KLAP) Lab

The Knowledge Representation, Logic, and Advanced Programming (KLAP) lab was created in 1994 to support research in the areas of logic and constraint programming, knowledge representation, and parallel processing. The mission of the KLAP lab is to conduct cutting edge research in the above areas, with emphasis on practical application of research outcomes in a local and inter-disciplinary context. The laboratory is also dedicated to the active involvement of undergraduate and graduate students in research activities, with particular attention to the training of students belonging to traditionally under-represented groups.

Directors: Enrico Pontelli and Son Tran
URL: https://www.cs.nmsu.edu/klap/

Private, Resilient, and Secure Machinery (PRISM) Research Lab

The PRISM Research Lab, part of the Department of Computer Science at New Mexico State University, conducts research in security, privacy, and resilience in networks and distributed systems. The lab focuses on enhancing trust, security, and privacy in cyber-physical systems and edge computing systems, covering domains such as smart grids, embedded systems, mobile computing, wireless sensor networks, and applications ir blockchain and decentralized finance.

Director: Gaurav Panwar

Bioinformatics Research Lab

The bioinformatics research lab develops efficient computational and statistical methods to model mechanisms of complex biological systems. They rigorously evaluate both theoretical and practical effectiveness of computational methods for characterizing molecular interactions from high-throughput measurements such as next generation sequencing data. The lab's long term goal is to invent advanced computational technology to expedite quantitative understanding of the complexity of life processes.

Director: Joe Song
URL: https://www.cs.nmsu.edu/~joemsong/group.shtml

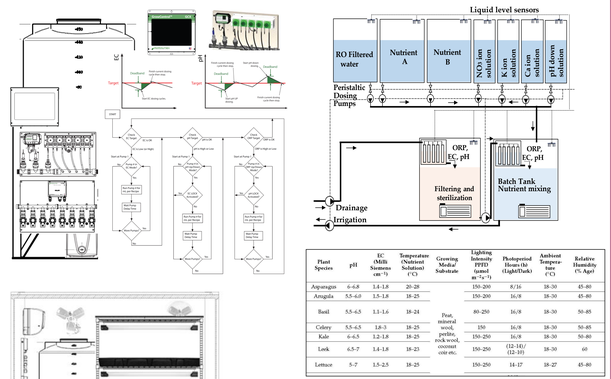
Prototype Design Objectives

Design, develop, and deliver a turnkey Controlled Environment Agriculture (CEA) research facility to:

- Support the development of an agricultural and biosystems engineering research pipeline at NMSU
- Explore solutions to bridge the gap between profitability and sustainability in CEA
- Expand external partnerships and research impact
- Enable transdisciplinary research in applied artificial intelligence (AI) and biosystems engineering.

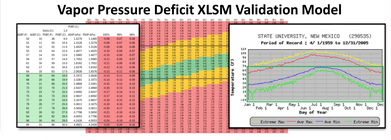
Prototype Design Overview

Mobile Controls and Irrigation Skid For Transfer from Training Lab to Field Site

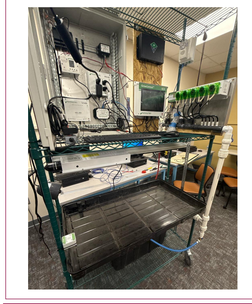


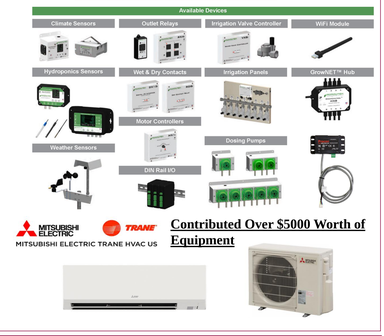
Plant Species	pH	EC (Milli Siemens cm⁻¹)	Temperature (Nutrient Solution) (°C)	Growing Media/ Substrate	Lighting Intensity PPFD (µmol m⁻²s⁻¹)	Photoperiod Hours (h) (Light/Dark)	Ambient Temperature (°C)	Relative Humidity (% Age)
Asparagus	6-6.8	1.4-1.8	20-28		150-200	8/16	18-30	45-80
Arugula	5.5-6.0	1.5-1.8	18-25		150-200	16/8	18-30	45-80
Basil	5.5-6.5	1.1-1.6	18-24	Peat, mineral wool, perlite, rock wool, coconut coir etc.	80-250	16/8	18-30	50-85
Celery	5.5-6.5	1.8-3	18-25		150	16/8	18-30	50-85
Kale	6-6.5	1.2-1.8	18-25		150-250	16/8	18-30	50-80
Leek	6.5-7	1.4-1.8	18-23		150-250	(12-16)/ (12-10)	18-30	60
Lettuce	5-7	1.5-2.5	18-25		150-250	14-17	18-27	45-80

Vapor Pressure Deficit XLSM Validation Model



Bench Test Prototype





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Contributed Over $5000 Worth of Equipment

References

Project Reference Literature