Intelligent Resource Efficient Pond Aquaculture (IREPA): Cyber-Physical System to Improve the Fish Farms Productivity in the U.S.

PI: Bing Ouyang[1], Co-PIs: Paul Wills[1], Yufei Tang[1], Tsung-Chow Su[1] and James Garvey[2]

1. Florida Atlantic University; 2. Southern Illinois University

Challenges:

An alarming number: $14 billion/yr. – US trade deficit in seafood.

A dilemma: Limited advanced technology in aquaculture while the industry suffers from a **labor shortage**.

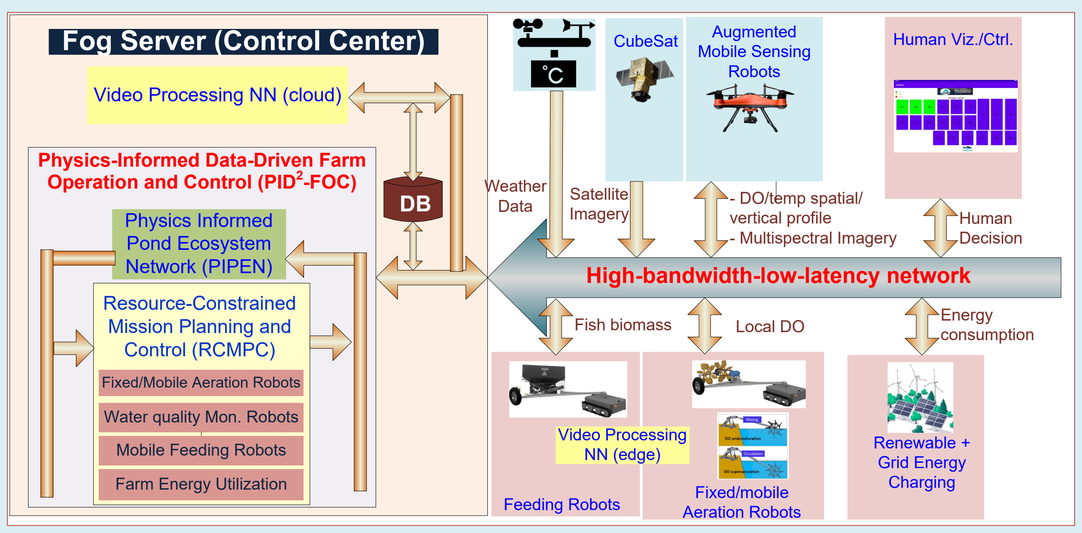
A Key Bottleneck: Current water quality management practice is "reactionary" and inefficient.

Scientific Impact:

- **Coastal zone environmental monitoring:**
  - Naval Air Warfare Command Aircraft Division (NAWCAD) Air Talent program: *Environmental Sensing Drone Launched from an Unmanned Surface Vessel (USV)*
- **Unified CPS solution for diverse aquaculture settings:**
  - *ARPA-E proposal: Seaweed Examination Autonomy using Hybrid Aerial Underwater Robotic System (SEA-HAUCS).*

Solution:

- Leveraging Hybrid Aerial Underwater RobotiC System (**HAUCS**) project funded by NIFA via NRI 2.0 - Developing robotic DO monitoring systems for pond farms.
- **IREPA**: A proactive feedforward CPS framework:
  - Physics-Informed Data-Driven Farm Operation and Control (PID^2-FOC) to support complex and diverse conditions on the fish farms.
  - Heterogeneous robotic systems to relieve the labor intensity of key operations on a pond fish farm.
  - High-bandwidth-low-latency network to accommodate farms with complex aquatic and terrestrial conditions.



The proposed IREPA framework

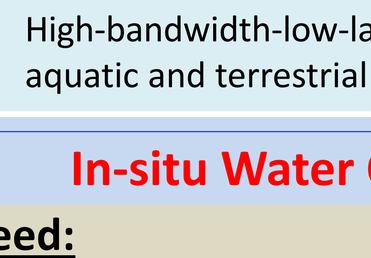
In-situ Water Quality Monitoring Capability

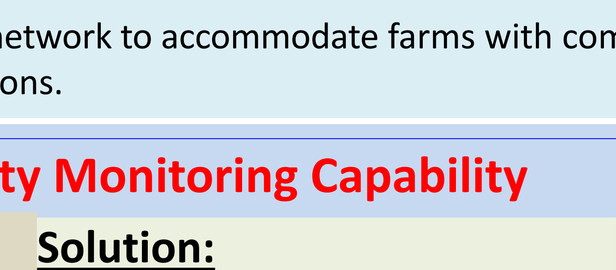
Need:

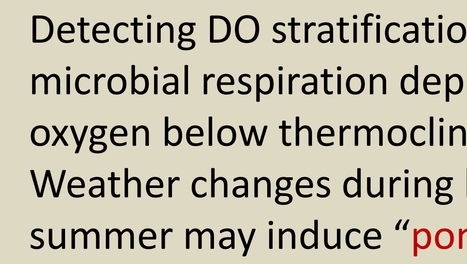
- Detecting DO stratification: microbial respiration depletes oxygen below thermocline.
- Weather changes during late summer may induce "pond mixing" – resulted in critically low DO in whole pond.

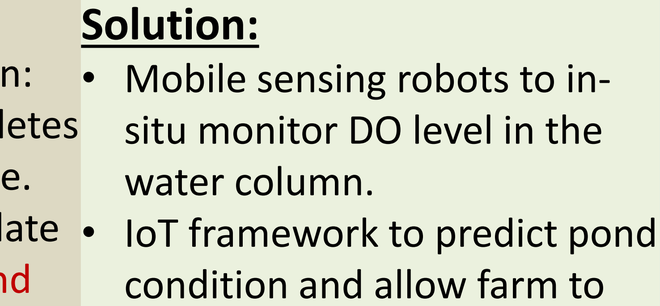
Solution:

- Mobile sensing robots to in-situ monitor DO level in the water column.
- IoT framework to predict pond condition and allow farm to make informed decisions

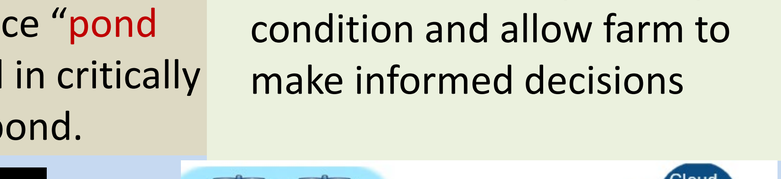








Stills from a video sequence show sensor testing with a winch in the lab



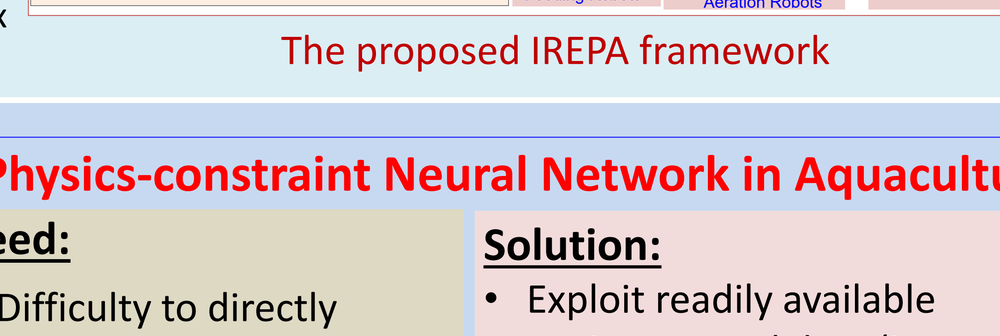
Physics-constraint Neural Network in Aquaculture

Need:

- Difficulty to directly measure farm conditions (i.e., DO, biomass);
- Robotic systems alleviate the problem but still expensive…

Solution:

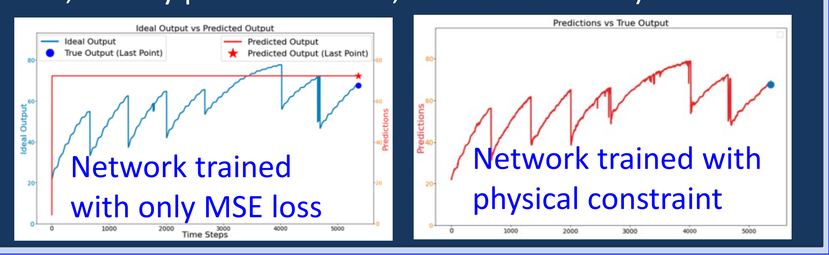
- Exploit readily available environmental data (i.e., weather)
- Using *Existing* models (i.e. pond ecology, algae growth) that using these data as inputs as the constraints in NN.



Case Study: prediction of seaweed biomass growth in recirculation aquaculture system.

Main challenge: Lack of continuous ground truth data: biomass is recorded only at discrete intervals (initial, weekly partial harvests, and final harvest)

Comparison of seaweed growth prediction results



Award: USDA 2024-67022-41580

Contact: bouyang@fau.edu