NSF CAREER Awardees

Moderated by:
Dr. Frank A. Gomez
Executive Director, STEM-NET
Office of the Chancellor

STEM-NET

https://www2.calstate.edu/impact-of-the-csu/research/stem-net

Speakers

George Youssef, San Diego State
Light-matter Interactions for Mechanics of Nontraditional Materials

Ava Hedayatipour, Cal State Long Beach
CISE-MSI: Towards Efficient, Reliable, and Secure Chaotic Communications in Wearable Devices

Yu Yang, Cal State Long Beach
Global Optimization of Chance-Constrained Programming for Reliable Process Design

Wencen Wu, San Jose State
Multi-Robot Exploration of Spatial-Varying Fields

Long Wang, Cal Poly San Luis Obispo
Characterization and Detection of Corrosion Damage

SDSU

Experimental Mechanics Laboratory

Light-matter Interactions for Mechanics of Nontraditional Materials

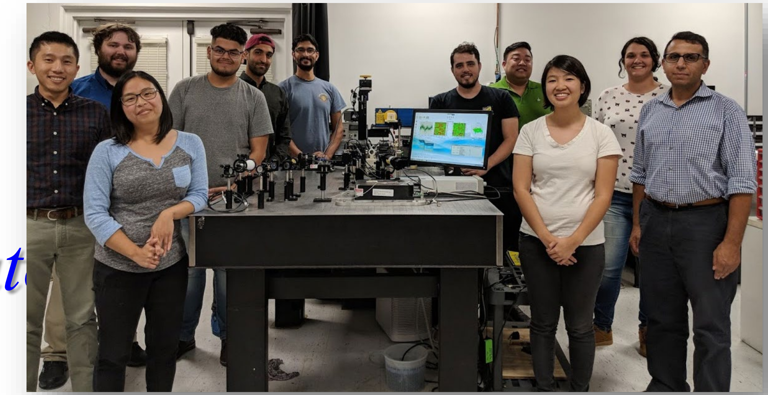
George Youssef, *Ph.D., P.E.*

Experimental Mechanics Laboratory, *Principal Investigator*
Mechanical Engineering, *Professor*
San Diego State University, CA, U.S.A.

CSU Exemplars in Engineering Webcast – October 4th, 2023

Experimental Mechanics Laboratory

Mechanics of Nontraditional Mat



Advancing Mechanics

and

Broadening Participation in Engineering

Underrepresented minorities and women

PPG Aerospace
ARMORCAST
JPL Jet Propulsion Laboratory
NSF
Department of Defense, United States of America
Department of Education, State of California
W.M. KECK FOUNDATION
The San Diego Foundation
Continuous Composites

Experimental Mechanics Laboratory

Polymers

Response of dense and foam polymers to extreme loading scenarios in harsh operating conditions

Physical
Mechanical
Thermal
Dynamic

Composites

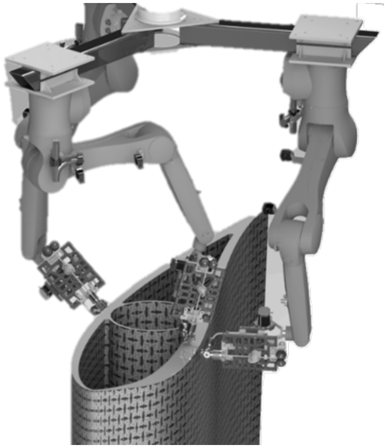
Advanced manufacturing and nondestructive evaluation of continuous fiber reinforced polymer matrix composites

Robotic 3D printing
Terahertz NDE
Data-driven detection

Multifunctional

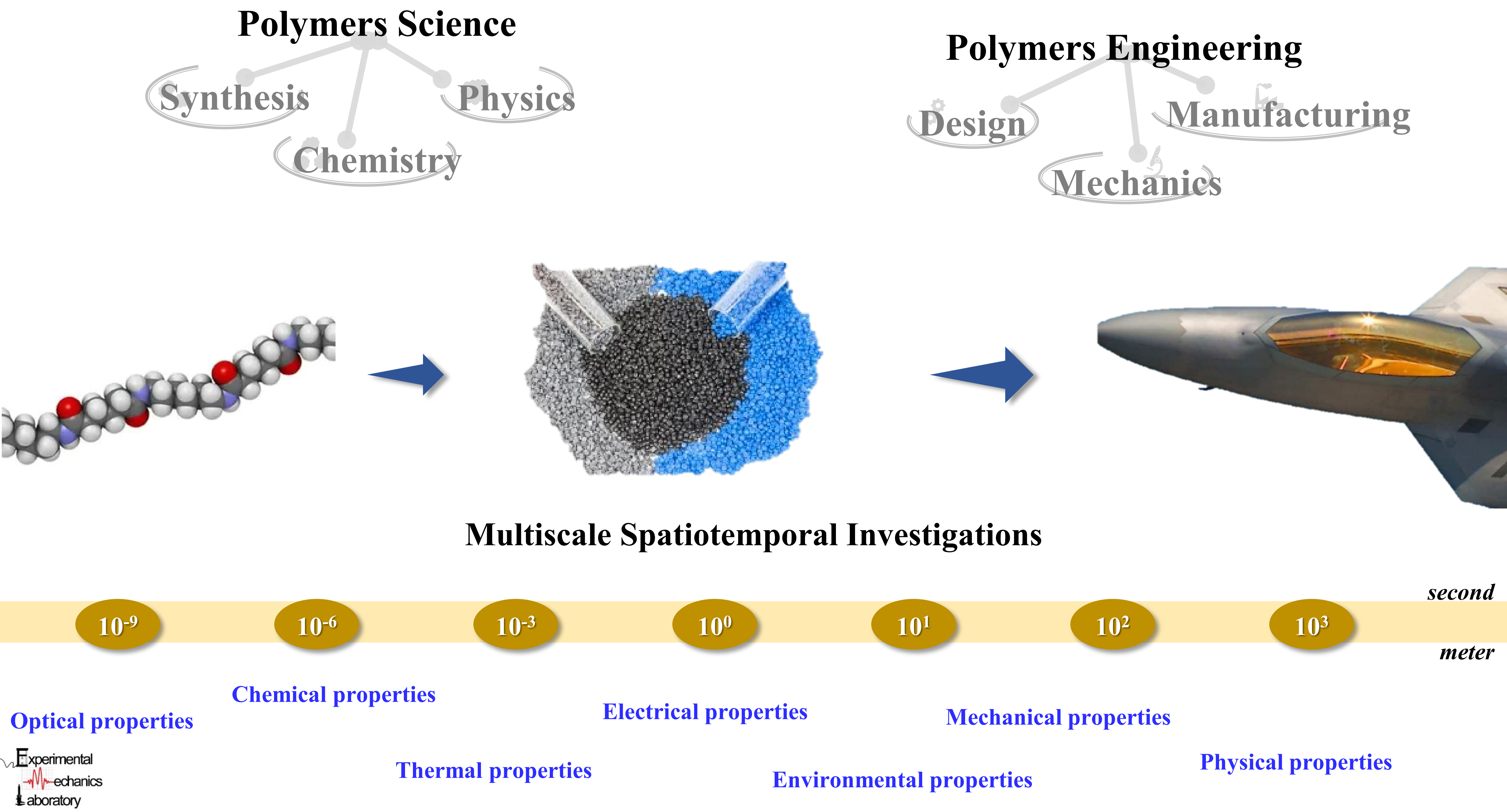
Strategically leverage solid and structural mechanics to inspire multi-functionality

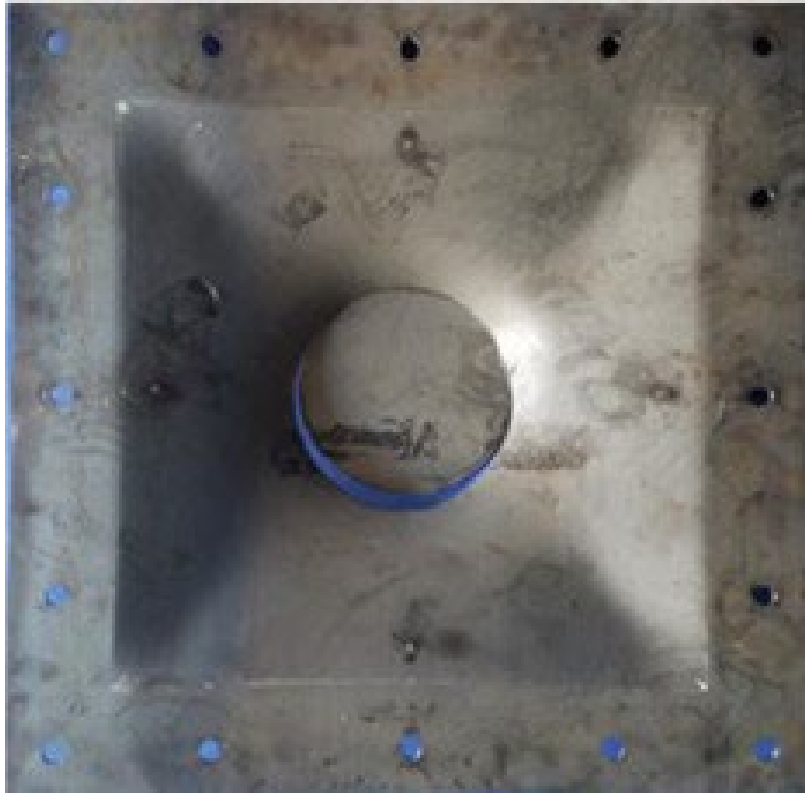
Load Management
Heat Management
Fluid Management
Electrical Management



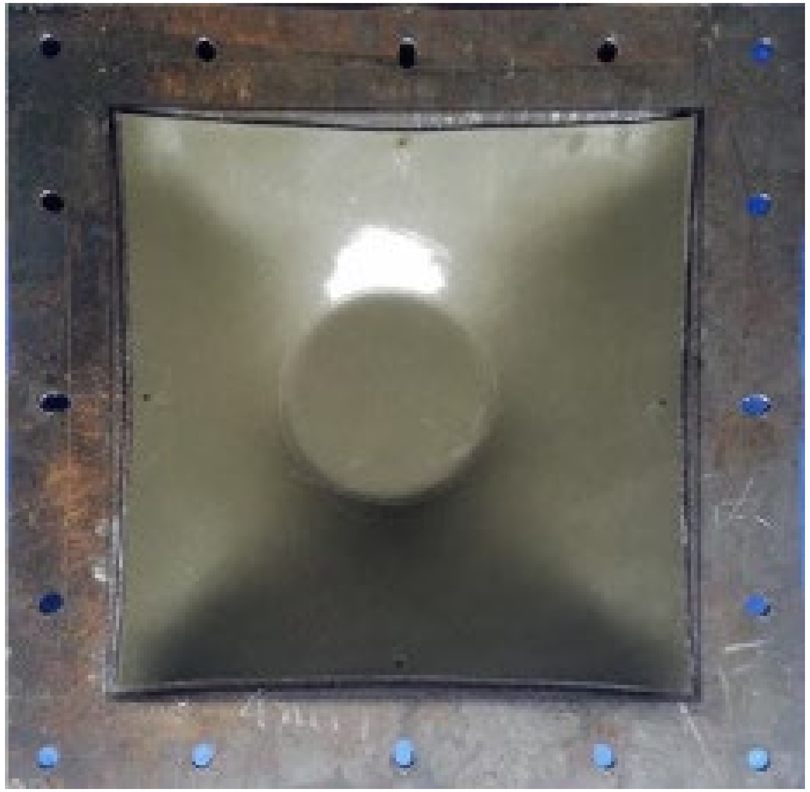
Experimental Mechanics Laboratory

EML focuses on lightweight and multifunctional materials


Polymers Science
Synthesis
Physics
Chemistry
Polymers Engineering
Design
Manufacturing
Mechanics
Multiscale Spatiotemporal Investigations
second
10-9
10-6
10-3
100
101
102
103
meter
Optical properties
Chemical properties
Thermal properties
Electrical properties
Environmental properties
Mechanical properties
Physical properties
Experimental
echanics
aboratory

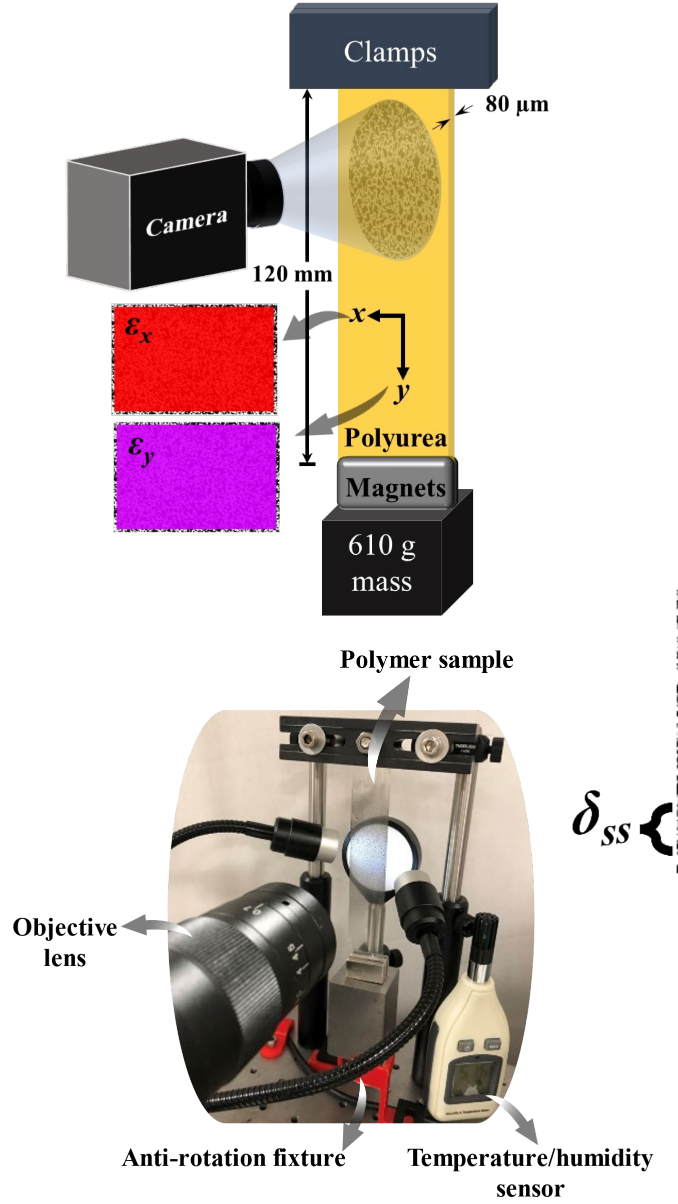


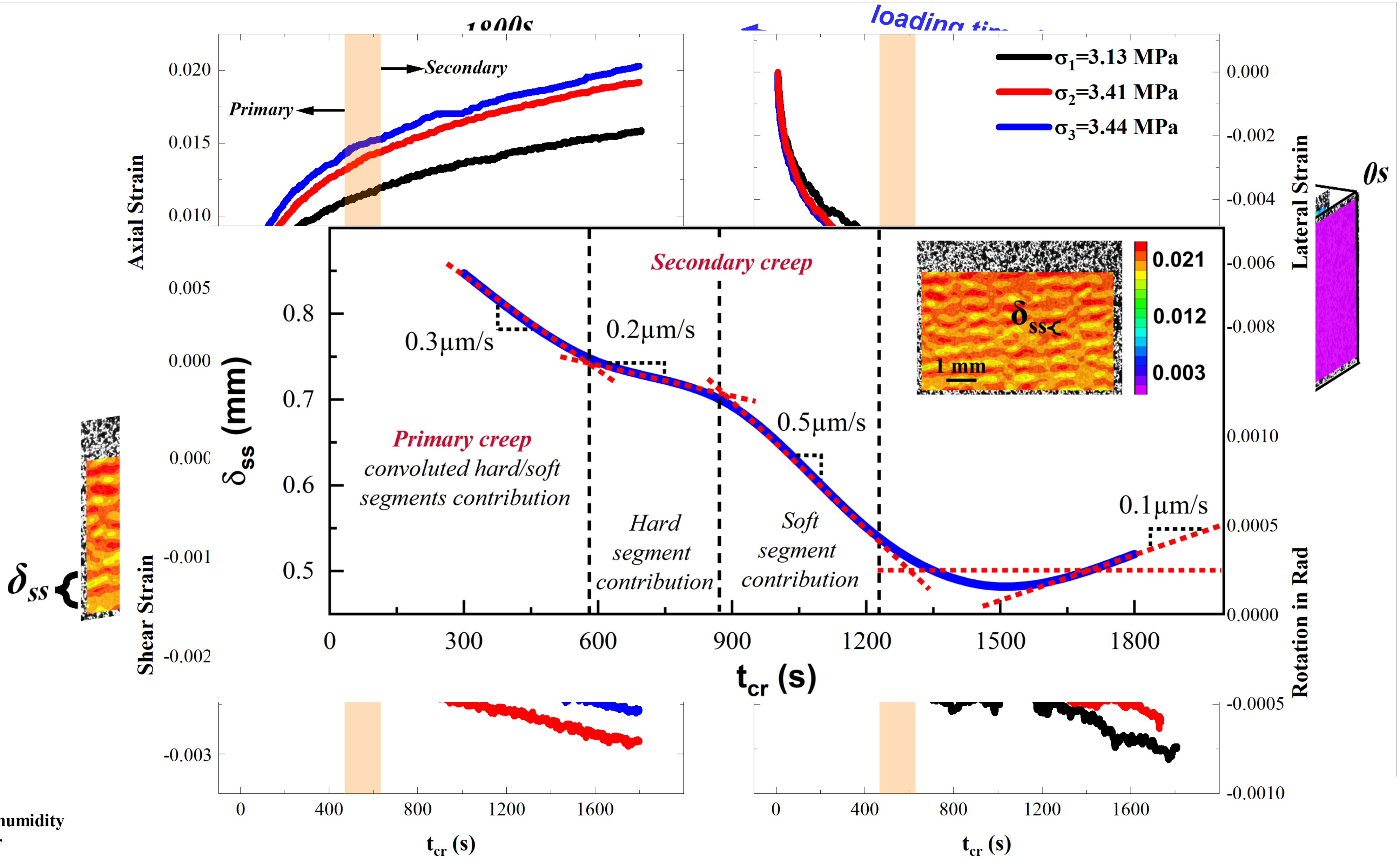
Steel armor plate without protective coating



Steel armor plate with polyurea protective coating

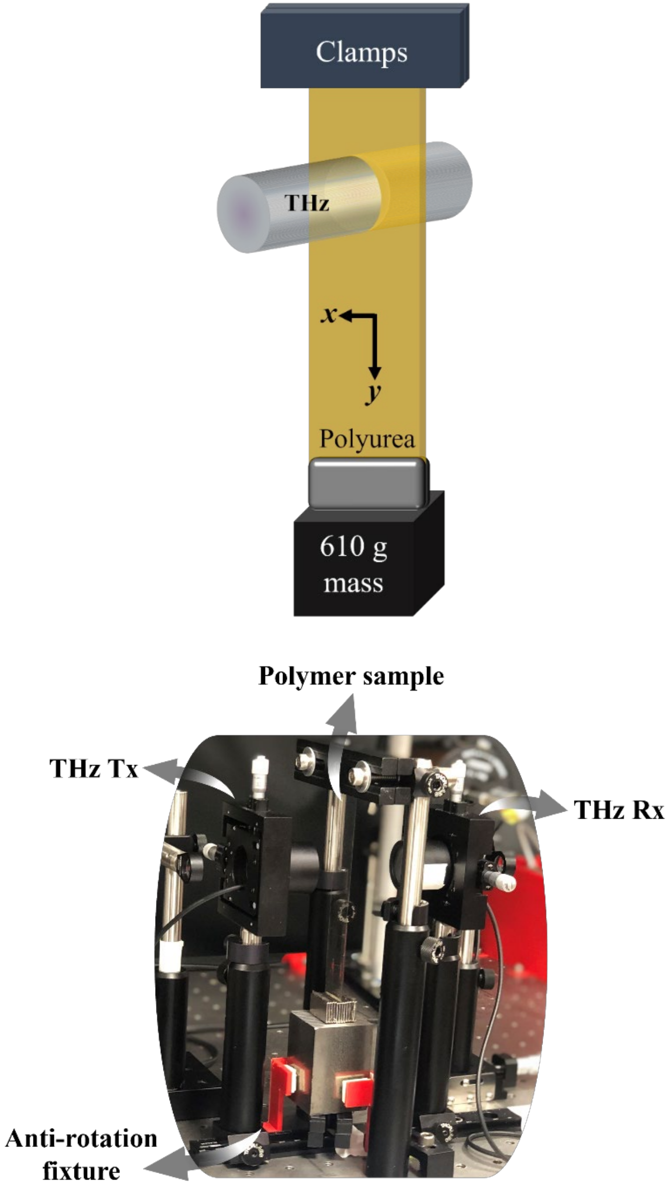
Full-field Creep Results

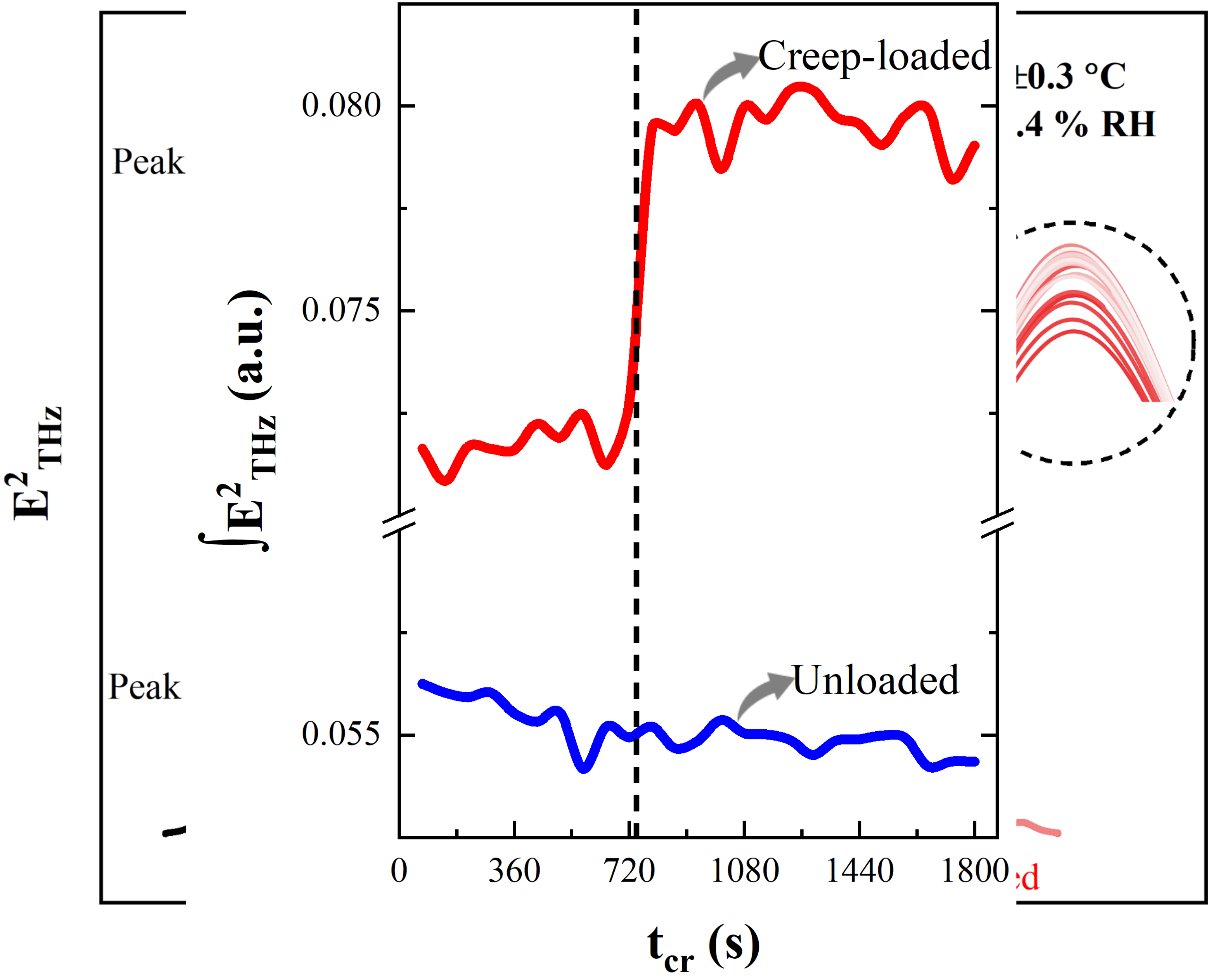




Huynh, et al., *J .Mech. Tim-Depend Mats* (2022)
Huynh et al., *Macromolecular Rapid Communications* (2023)

THz-TDS Results – Time Domain





Experimental Mechanics Laboratory

Huynh, et al., *J .Mech. Tim-Depend Mats* (2022)
Huynh et al., *Macromolecular Rapid Communications* (2023)

Experimental Mechanics Laboratory

Advancing Mechanics
and
Broadening Participation in Engineering

gyoussef@sdsu.edu

PPG Aerospace

ARMORCAST

JPL Jet Propulsion Laboratory

NSF

W.M. KECK FOUNDATION

The San Diego Foundation

Continuous Composites

CISE-MSI: Towards Efficient, Reliable, and Secure Chaotic Communications In Wearable Devices

Ava Hedayatipour–
Department of Electrical Engineering (EE),
California State University Long Beach

Collaborators:
Dr. Amin Rezaei, Dr. Hossein Sayadi, Dr. Mehrdad Aliasgari,
Department of Computer Engineering & Computer Science (CECS)
California State University Long Beach

Ava Hedayatipour, Assistant Professor

Campus, Department of *Electrical Engineering*

Email: ava.hedayatipour@csulb.edu

CISE-MSI: Towards Efficient, Reliable, and Secure Chaotic Communications In Wearable Devices

Project Overview

Convenience or Complexity?

Sleep Tracker

Smart Coffee Maker

Smart Refrigerator

Video Conference Rooms

Cloud Storages

Fitness Tracker

Smart Phones/Watches

Autonomous Cars

Smart Home Appliances

These are the bulk images taken from google, no copyrights on any of the images.

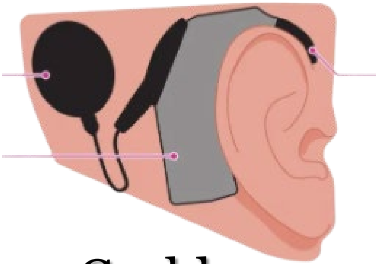
CISE-MSI: Towards Efficient, Reliable, and Secure Chaotic Communications In Wearable Devices

Project Overview

Internet of Medical Things (IoMT)


Cove


Mudra Band


Cochlear Implant


Smart Shoes


Ingestible Sensors


Think Reality A3


JBud Frame


Heart Rate Monitor watch


Pacemakers

Smart Band


NFC Ring


Insulin Pumps


Connected Inhalers

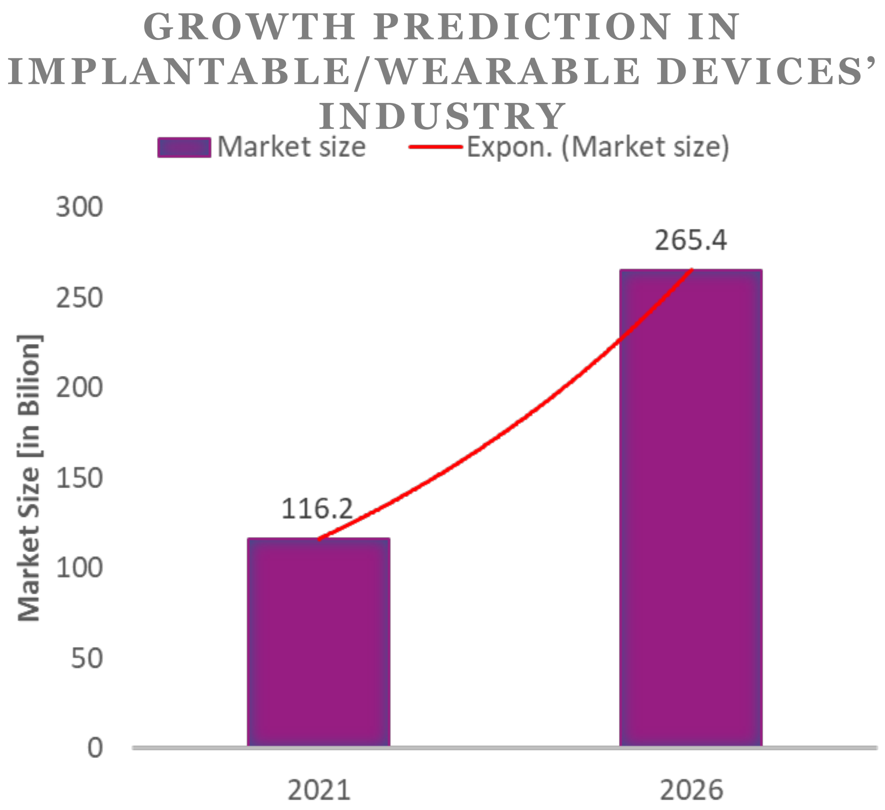

Bioheart

R. S. Bisht, S. Jain, and N. Tewari, "Study of wearable IoT devices in 2021: Analysis amp; future prospects," in *2021 2nd International Conference on Intelligent Engineering and Management (ICIEM)*

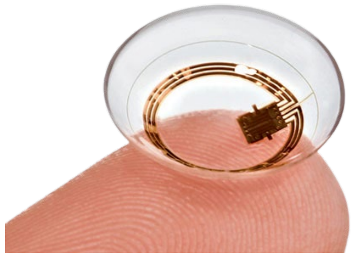
CISE-MSI: Towards Efficient, Reliable, and Secure Chaotic Communications In Wearable Devices

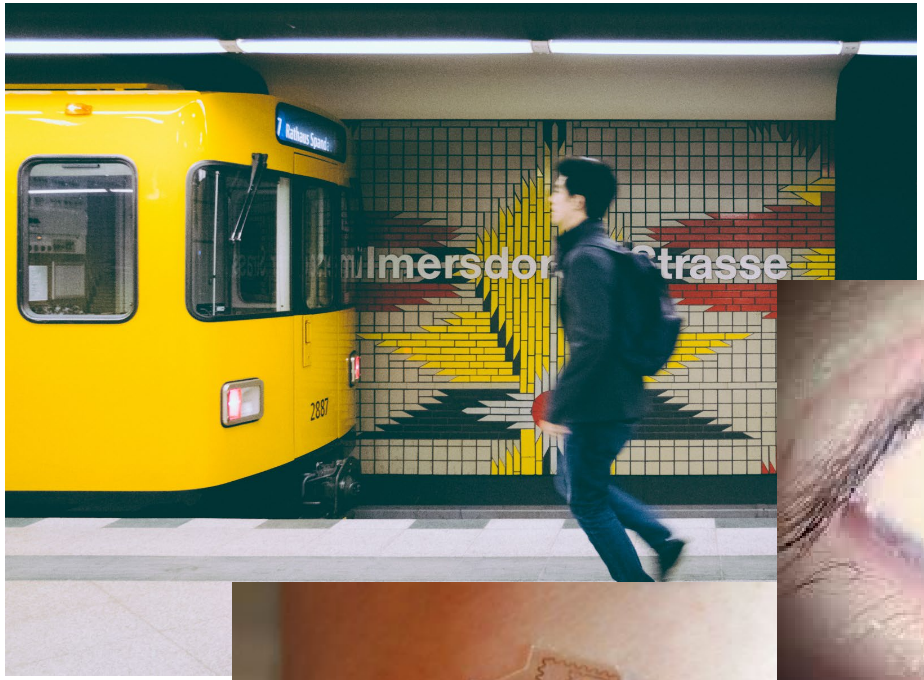
Project Overview

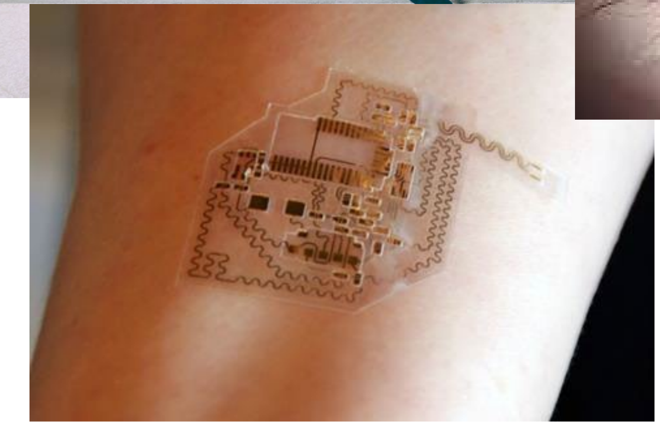
Glance to the Future



https://www.marketsandmarkets.com/Market-Reports/wearable-electronicsmarket-983.html, Apr 2021.







Project Overview

Encryption Algo

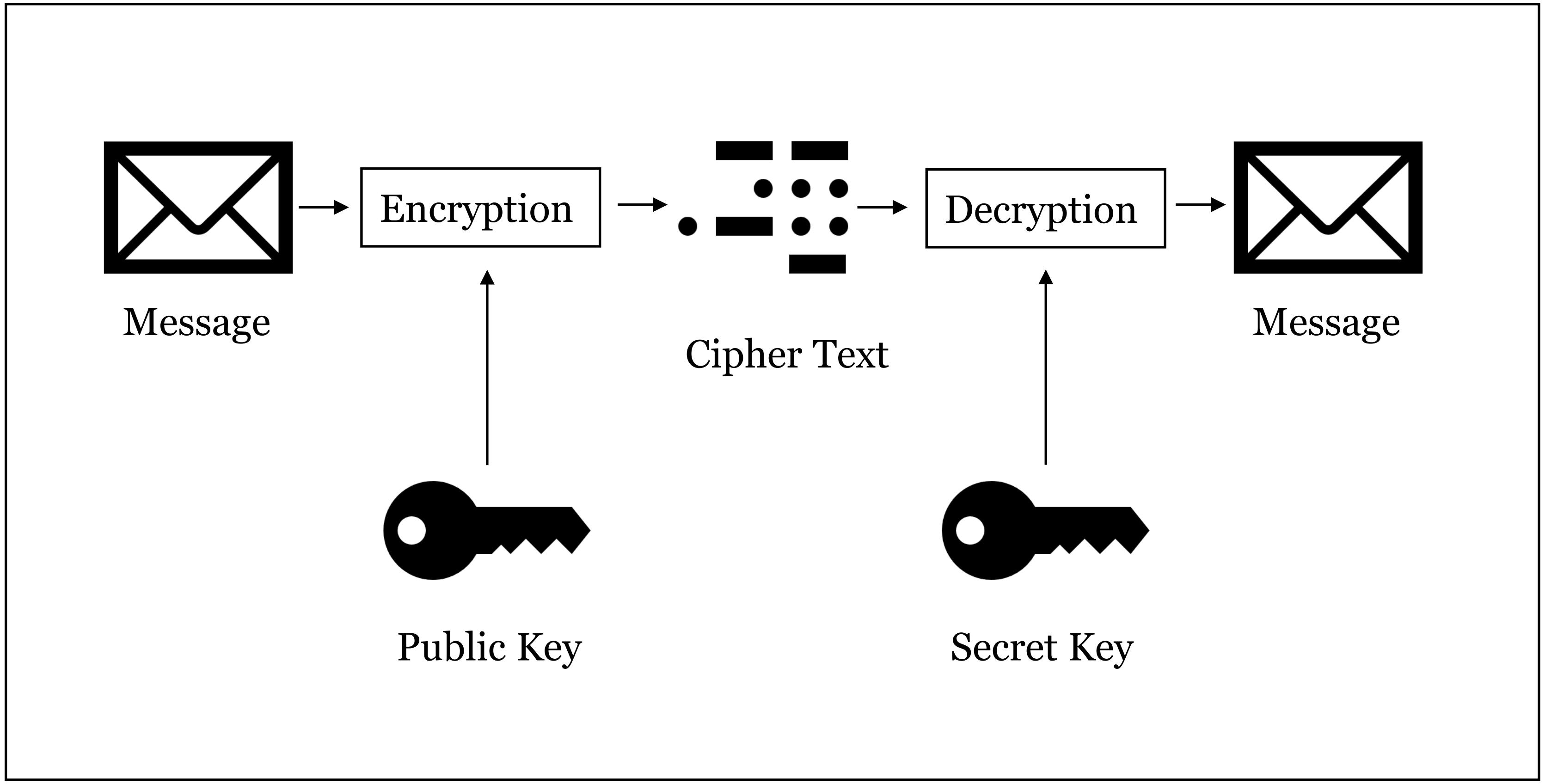
- **Symmetric Encryption:**
  - * The shared private key between sender and receiver.
  - * Fast, less computing, but not considered reliable communication.
    Example:
    Advanced Encryption Standard (AES)

Algorithm	Purpose
Advanced encryption standard (AES)	Confidentiality
Rivest Shamir Adelman (RSA)/ Elliptic Curve Cryptography (ECC)	Digital signatures key transport
Diffie-Hellman (DH)	Key agreement
SHA-1/SHA-256	Integrality

- **Asymmetric Encryption:**
  - * The sender provides the public information and the receiver decrypts that with the private information
  - * Higher computational requirements and factorization complexity
  - * Example: Rivest Shamir Adelman (RSA) and the Diffie-Hellman (DH)

CISE-MSI: Towards Efficient, Reliable, and Secure Chaotic Communications In Wearable Devices

Project Overview



Asymmetric cryptography

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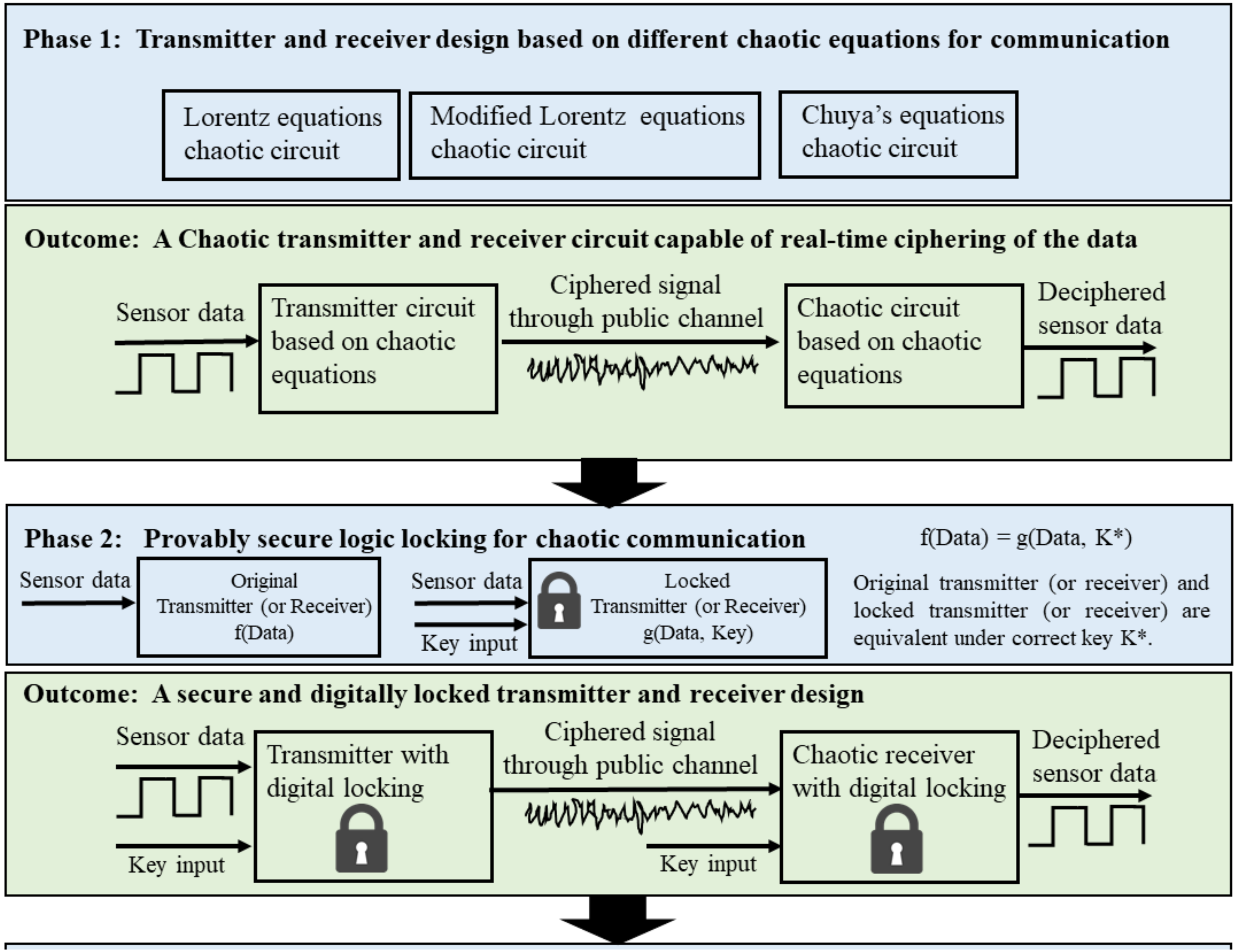
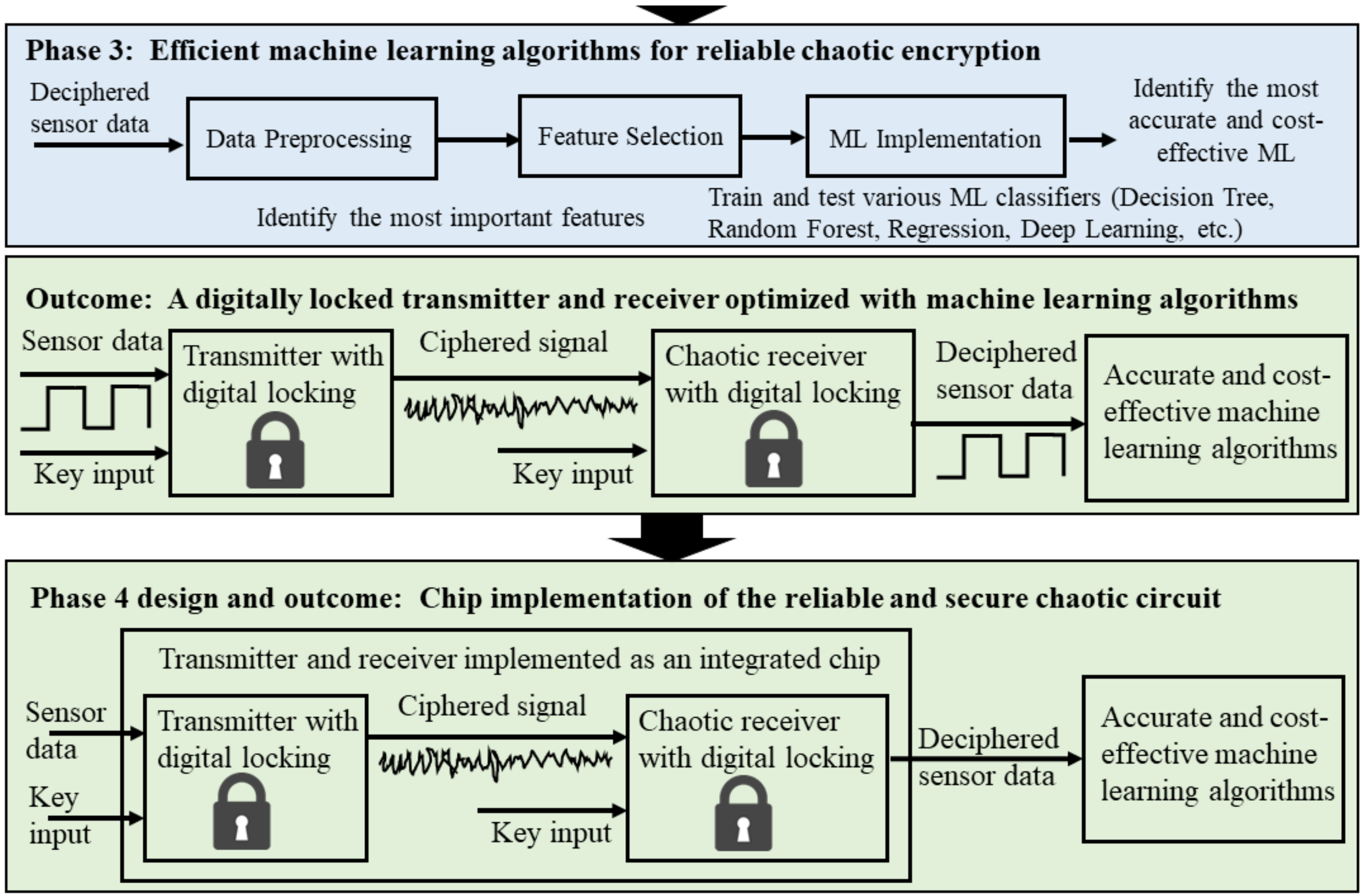
Project Overview



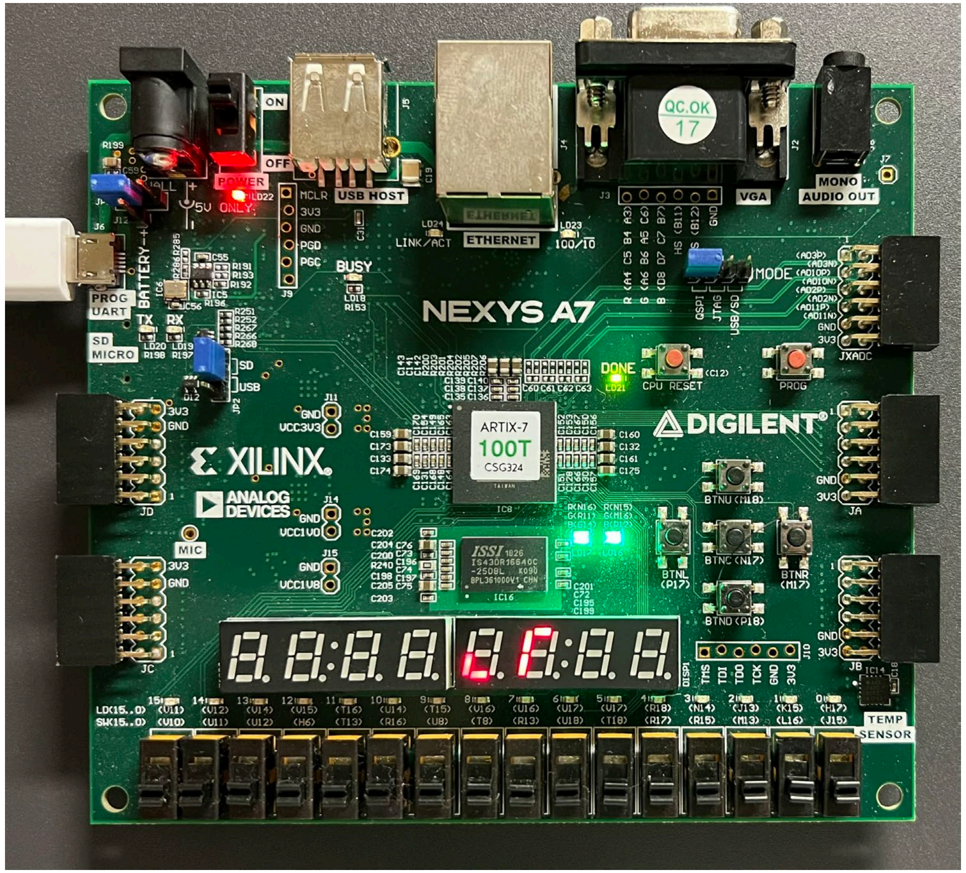
CISE-MSI: Towards Efficient, Reliable, and Secure Chaotic Communications In Wearable Devices

Project Overview



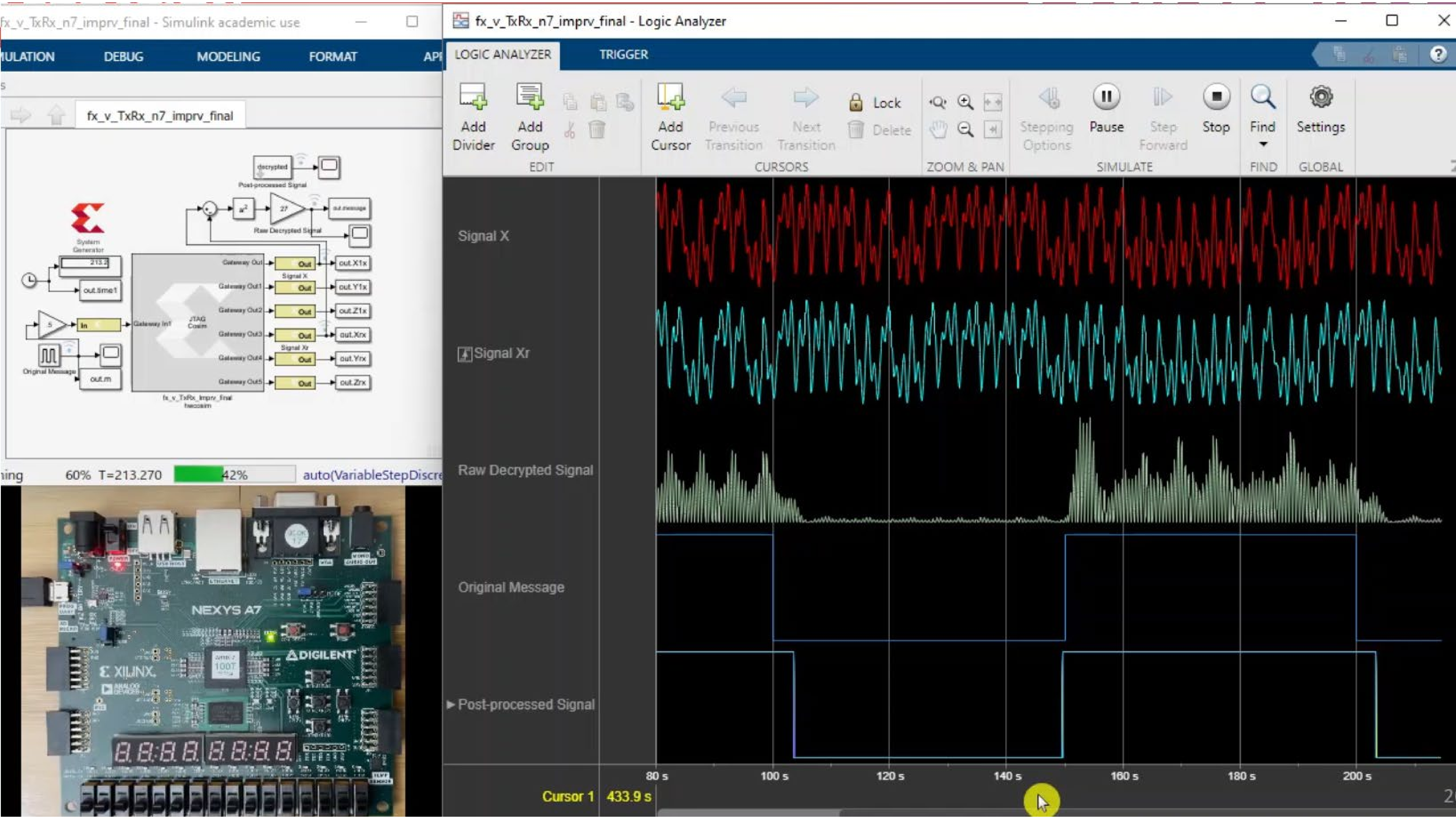
Results

- Demonstration of encryption architecture on Xilinx's Digilent Artix7Nexys7 FPGA board.
- The JTAG port has been used to deliver the computation to the board and bring back the results.



Xilinx FPGA Board- NEXYS A7

19



fx_v_TxRx_n7_imprv_final - Simulink academic use
fx_v_TxRx_n7_imprv_final - Logic Analyzer
LOGIC ANALYZER
TRIGGER
Add Divider
Add Group
EDIT
Add Cursor
Previous Transition
Next Transition
Lock
Delete
CURSORS
ZOOM & PAN
Stepping Options
Pause
Step Forward
Stop
SIMULATE
Find
FIND
Settings
GLOBAL
DEBUG
MODELING
FORMAT
fx_v_TxRx_n7_imprv_final
Signal X
Signal Xr
Raw Decrypted Signal
Original Message
Post-processed Signal
80 s
100 s
120 s
140 s
160 s
180 s
200 s
Cursor 1
433.9 s
60% T=213.270
42%
auto(VariableStepDiscre
NEXYS A7
DIGILENT
XILINX

Results

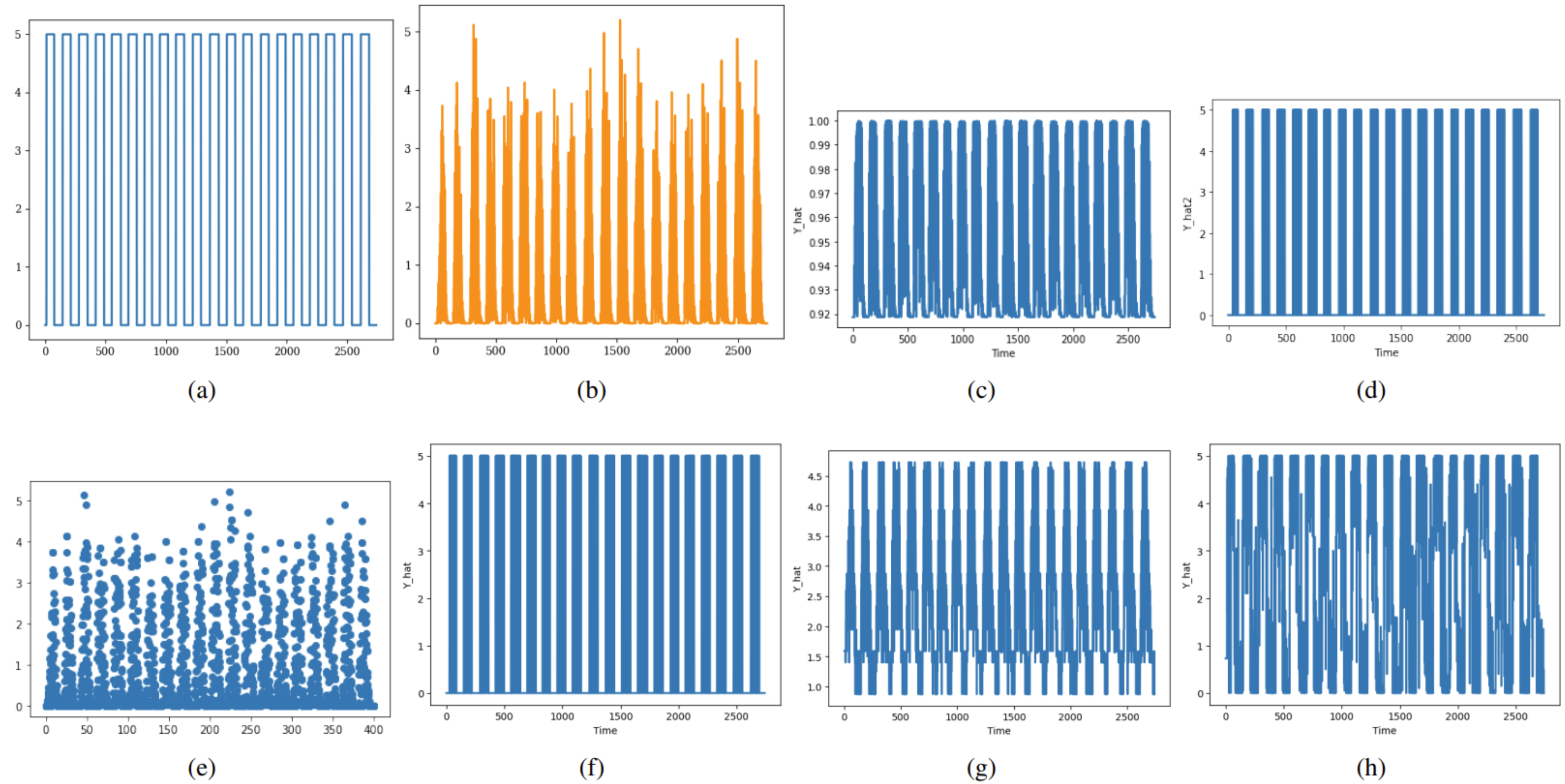


FIGURE 5. Different machine learning algorithms used in signal synchronization (a) Original message (b) Decoded message (MSR: 13.00) (c) LSTM synchronization (d) K-means synchronization (MSR: 6.96) (e) DBSCAN synchronization (MSR: 12.56) (f) SVM synchronization (g) AdaBoost synchronization (MSR: 3.52) (h) RF synchronization (MSR: 4.00)

Lessons Learned

- If you are the main PI be ready to PUSH.
- Things **rarely** move forward without follow-ups.
- Have alternative planning in line.
- The program director is a friend, not a foe.

Next Steps/Long-Term Plans

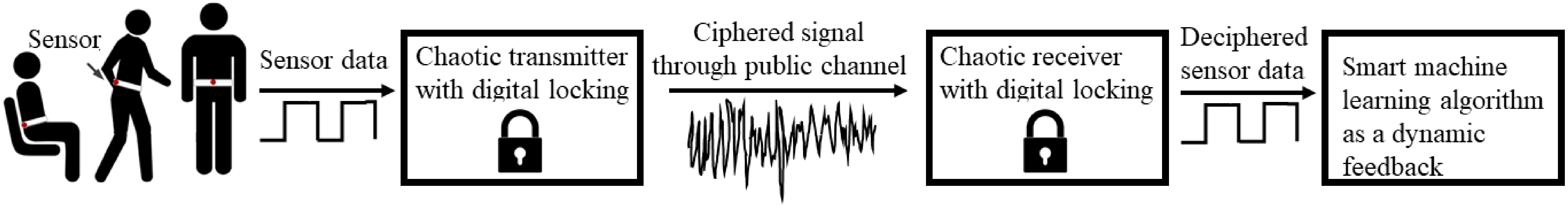
- To expand the scope of the design and get experimental data for real-world bio-medical signals, i.e, ECG.
- To achieve the initial goal with which this research began, implement the efficient and low-power chaotic encryption circuit on-chip
- To make the design robust and eliminate the flaws, carry out the testing/validation against attacks.

Acknowledgment

This material is based upon work supported by the National Science Foundation under Grant No. 2131156.
The work presented is the work of my brilliant students.

CISE-MSI: Towards Efficient, Reliable, and Secure Chaotic Communications In Wearable Devices

Summary



Questions?

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Phone #: 562.985.8034

Email: ava.hedayatipour@csulb.edu

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College of Engineering

Global Optimization of Chance-Constrained Programming for Reliable Process Design

Dr. Yu Yang California State University Long Beach

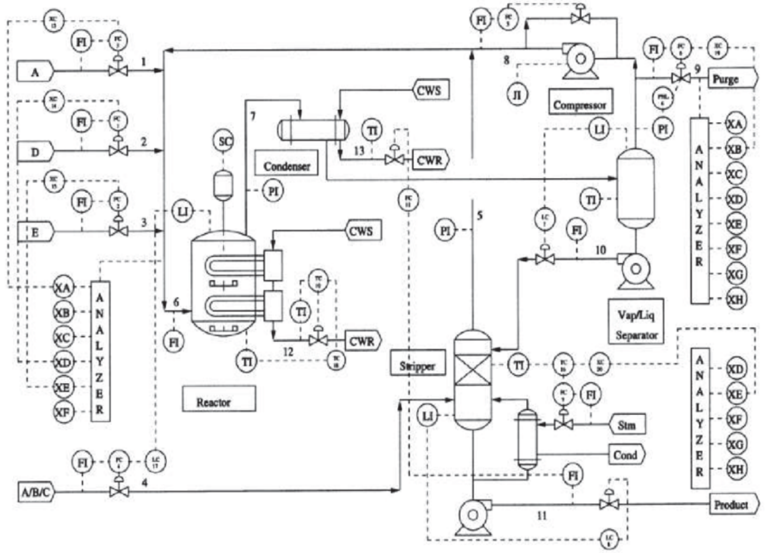
Dr. Yu Yang, Associate Professor

CSULB, Department of Chemical Engineering

yu.yang@csulb.edu

Motivation

- Incomplete knowledge of mathematical models used for the optimization-based design of chemical processes can lead to degraded quality of fuels, vaccines, manufactured foods, and other chemical products, giving rise to economic, safety, health, and environmental issues.



Project Overview

- Chance-constrained Programming (CCP)

$$\min_{x,y} c^{\mathrm{T}} x$$
$$\text{s.t. } F(x,y) \leq d,$$
$$\mathbb{P}(\theta^T x \leq b) \geq 0.95$$
$$x \in \Re, y \in \{0,1\}.$$

Uncertainty

Random Algorithm: Scenario Approximation,
Scenario Tree

Analytical Approach: Distribution-based
(Only applicable for Gaussian distribution)

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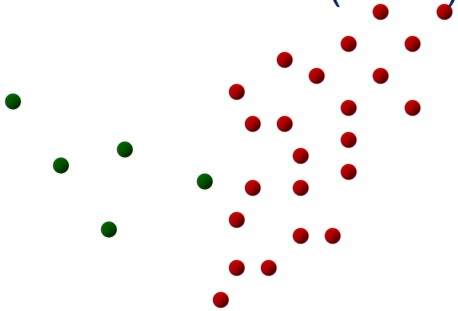
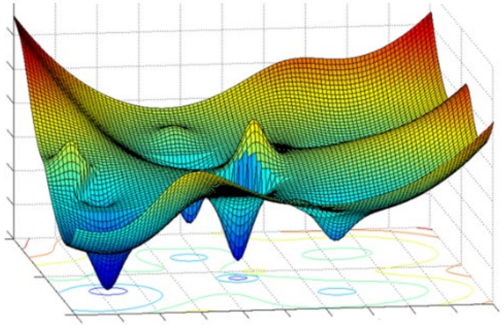
Project Overview

- Data-Driven Modeling and Global Optimization

Gaussian Mixture Model (GMM)



Global Optimization



- Convex relaxation>>Second-order cone relaxation
- Branch-and-Bound
- Bound tightening
- Reformulation linearization technology
- Piecewise linear decision-rule

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Project Overview

- Theoretical and Experimental Research

Develop GMM-based CCP → Oil blending modeling and optimization

Oil Blending Experiment → Generate an edible oil blending dataset

Two-stage CCP with line decision rule → Refinery optimization

Two-stage CCP with piecewise decision rule → Refinery optimization

Collaboration & new proposal submission → Target: NSF, DOE

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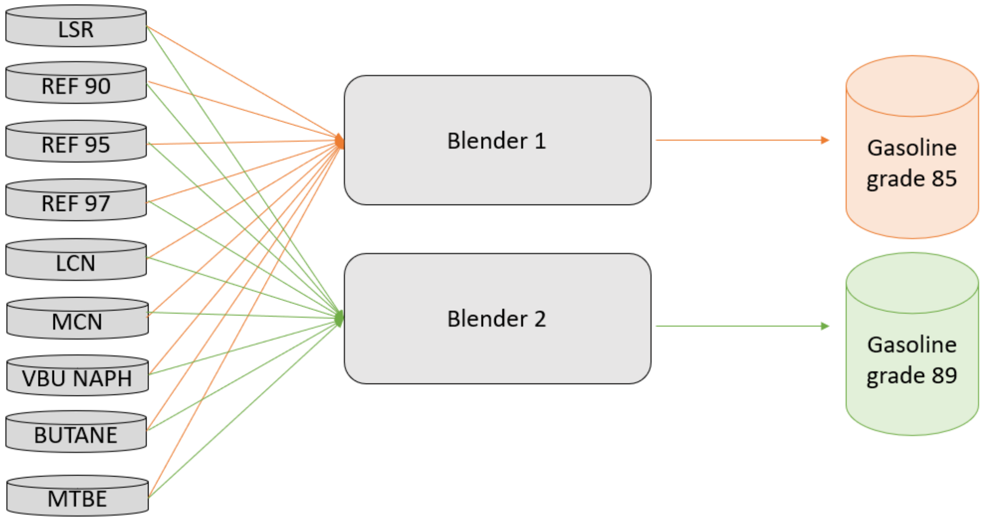
Activities (Single Stage GMM-CCP)

- Oil Blending (Linear Programming)



Objective: Determine the blending receipt such that the profit is maximized, and quality specifications are met with high chance (>95%)

	GMM-CCP	Scenario Average (SA)
Profit:	$378.49	$354.60
Solution time:	6,668 s	101 s
Conclusion:	Slow but guaranteed optimality	Fast but needs significant tuning

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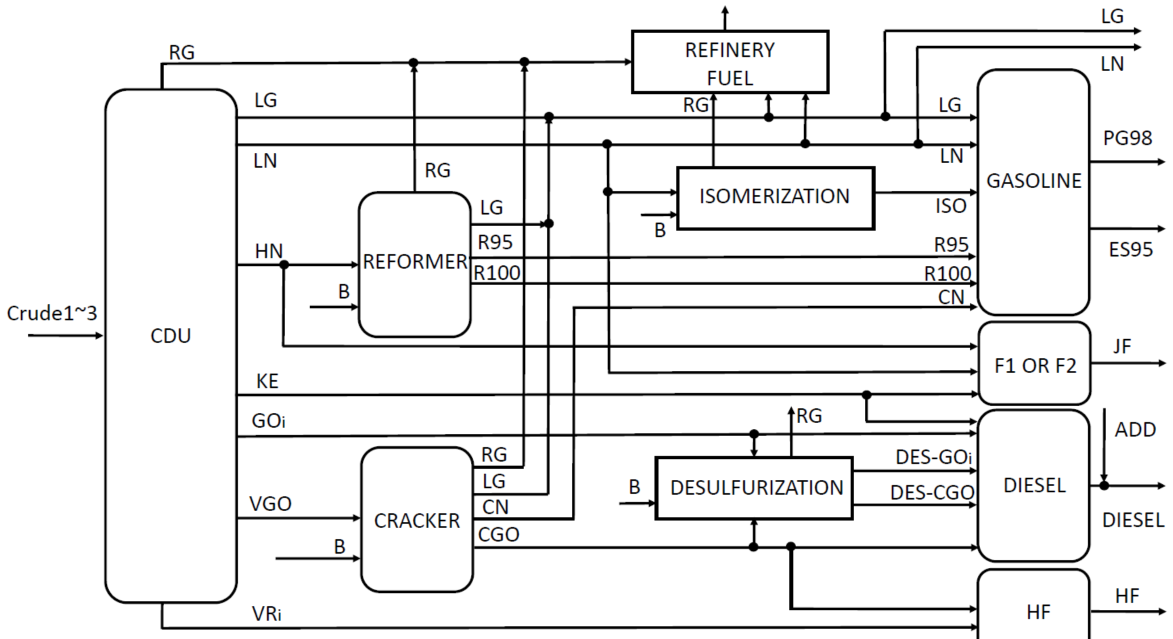
Activities (Two-Stage GMM-CCP)

- Refinery Optimization (Mixed-integer linear programming)



Objective: Determine the crude oil procurement (State-I) and refinery operations (Stage-II) to maximize the profit and meet the quality specification with high chance.

	GMM-CCP + Decision-Rule	Scenario Tree
Profit:	$102,467,704	$101,282,597
Solution time:	4709 s	7224 s
Risk:	2.4%<5%	2%<5%
Conclusion:	Faster, Scalable, More profitable	Slower, Non-scalable

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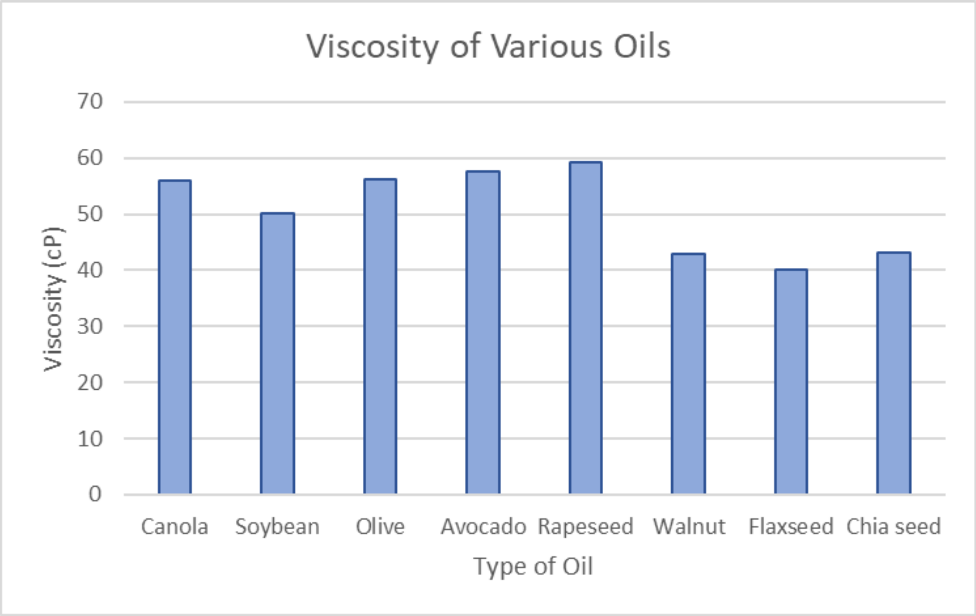
Activities

- Student Project: Optimization of Blended Vegetable Oil with Viscosity Constraint



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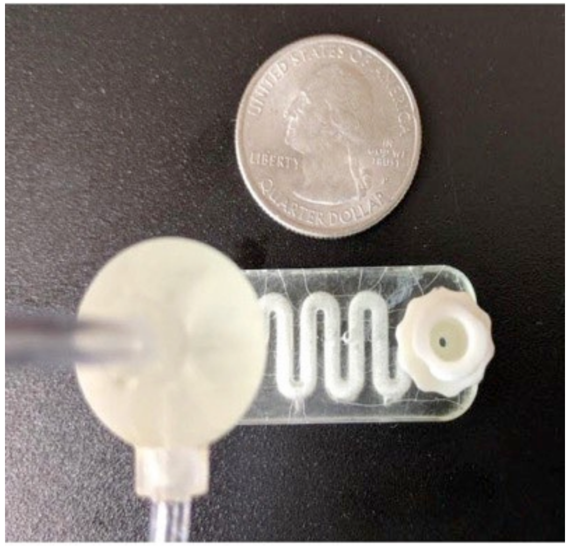
Lessons Learned

- Pre-award: Preliminary data and publication are important to the NSF grant application.
  - Yang, Y. (2019). Improved Benders decomposition and feasibility validation for two-stage chance-constrained programs in process optimization. *Industrial & Engineering Chemistry Research,* 58, 4853-4865.
  - Yang, Y., dela Rosa, L., Chow, T. (2020). Non-convex chance-constrained optimization for blending recipe design under uncertainties. *Computers & Chemical Engineering,* 139*,* 106868.
  - Yang, Y. and Sutanto, C. (2019). Chance-constrained optimization for nonconvex programs using scenario-based methods. *ISA Transactions*, 90, 157-168.
  - Yang, Y., Vayanos, P., Barton, P. (2017). Chance-constrained optimization for refinery blend planning under uncertainty. *Industrial & Engineering Chemistry Research,* 56, 12139-12150.
  - Yang, Y. (2019). Improved Benders decomposition and feasibility validation for two-stage chance-constrained programs in process optimization. *Industrial & Engineering Chemistry Research,* 58, 4853-4865.

- Post-award: Integrate the education with research (CHE 440/450 Chemical Engineering Laboratory)

Next Steps/Long-Term Plans

- Seek collaborations in the microfluidics and renewable energy



A. Boyano et al. / Energy 36 (2011) 2202–2214 2205

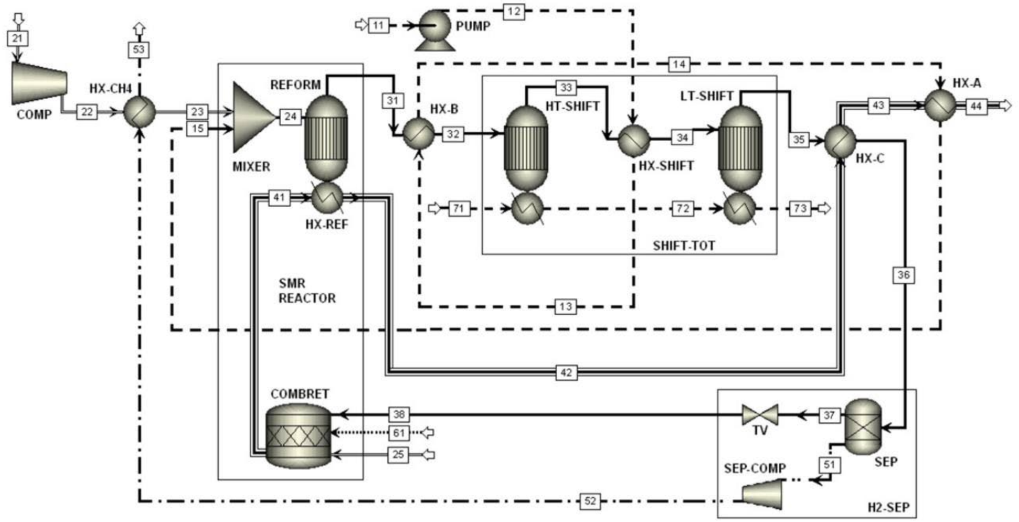


Fig. 1. Schematic of a Steam methane reforming (SMR) plant for hydrogen production: ▪▪▪▪▪, air; ═══, CH_4; —·—·—H_2; ▬▬, exhaust gases; —, syngas; – – –, water.

** Lo Lab @ CSULB **
https://www.csulb.edu/college-of-engineering/dr-roger-c-lo
http://www.microfluidics-at-the-beach.net

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College of Engineering

Questions?

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Campus/Department: California State University Long Beach, Department of Chemical Engineering
Website: https://sites.google.com/view/yuyang
Email: yu.yang@csulb.edu

Multi-robot Exploration of Spatial-temporal Varying Fields

Wencen Wu – San Jose State University

Wencen Wu, Associate Professor
San Jose State University, Computer Engineering Department
wencen.wu@sjsu.edu

SJSU SAN JOSÉ STATE UNIVERSITY

Environmental Disasters

Forest fires

Gas leak

Air crash

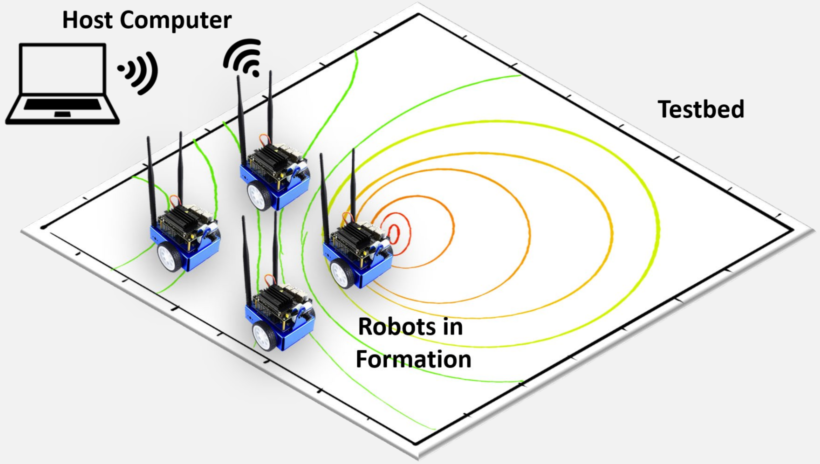
Difficult and **dangerous** for people to search and rescue

How to explore fields and events in an unknown space?

Problem Formulation

Employ multi-robot systems to perform exploration tasks for safety and efficiency

- Source seeking
- Boundary tracking
- Environment mapping
- …

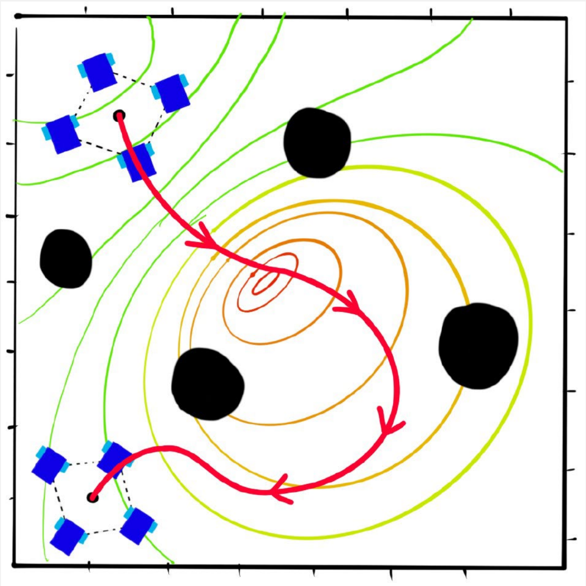


Consider a concentration field $z(r)$.

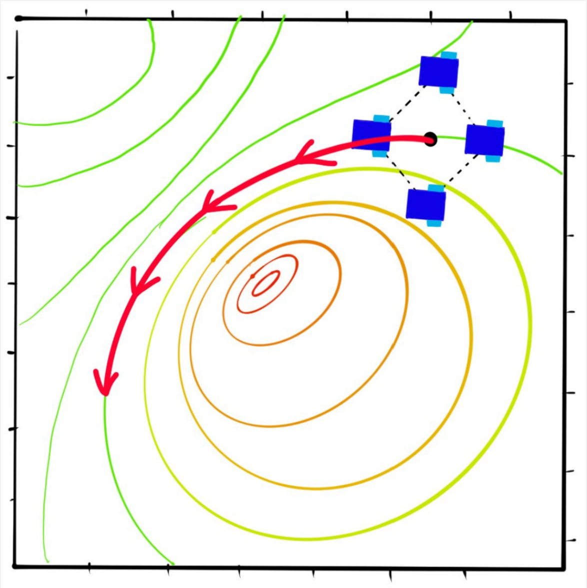
Employ a group of mobile sensors in this field with noisy discrete measurements

$$p(r_{i,k}, k) = z(r_{i,k}, k) + n_i$$

at time step t_k for agent i at $r_{i,k}$, $i = 1, \dots, N$

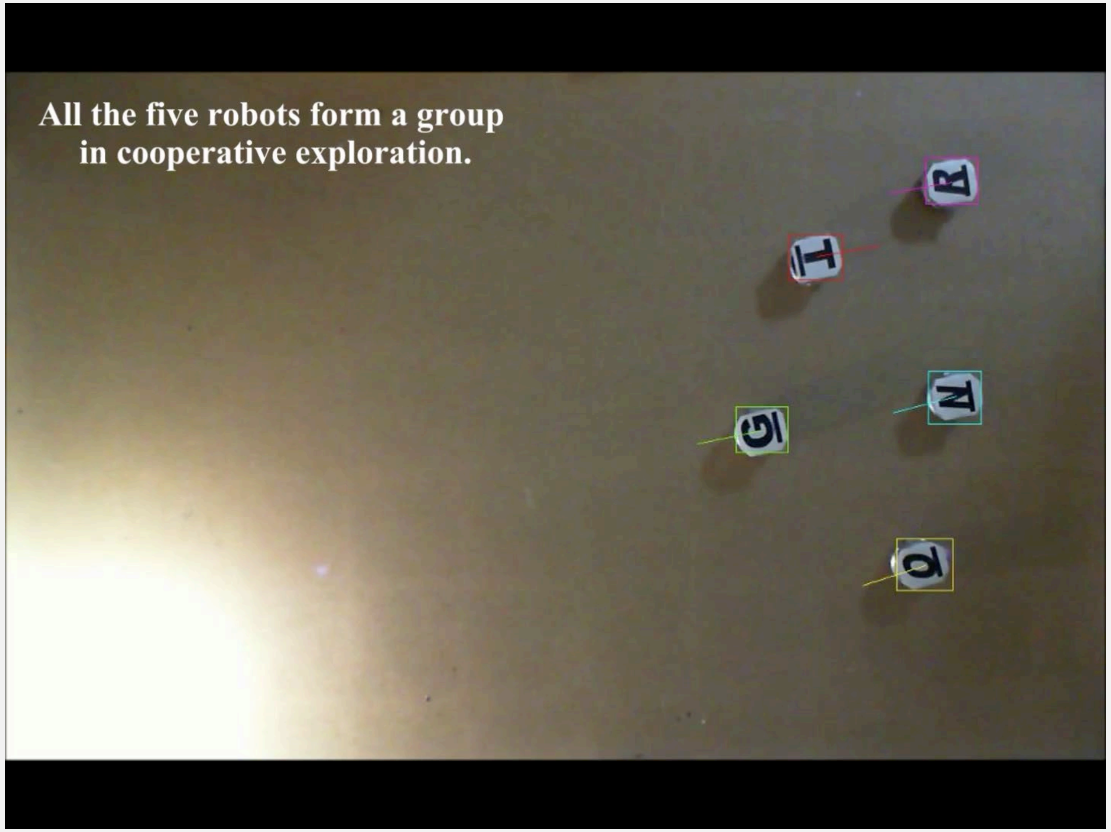


Source seeking

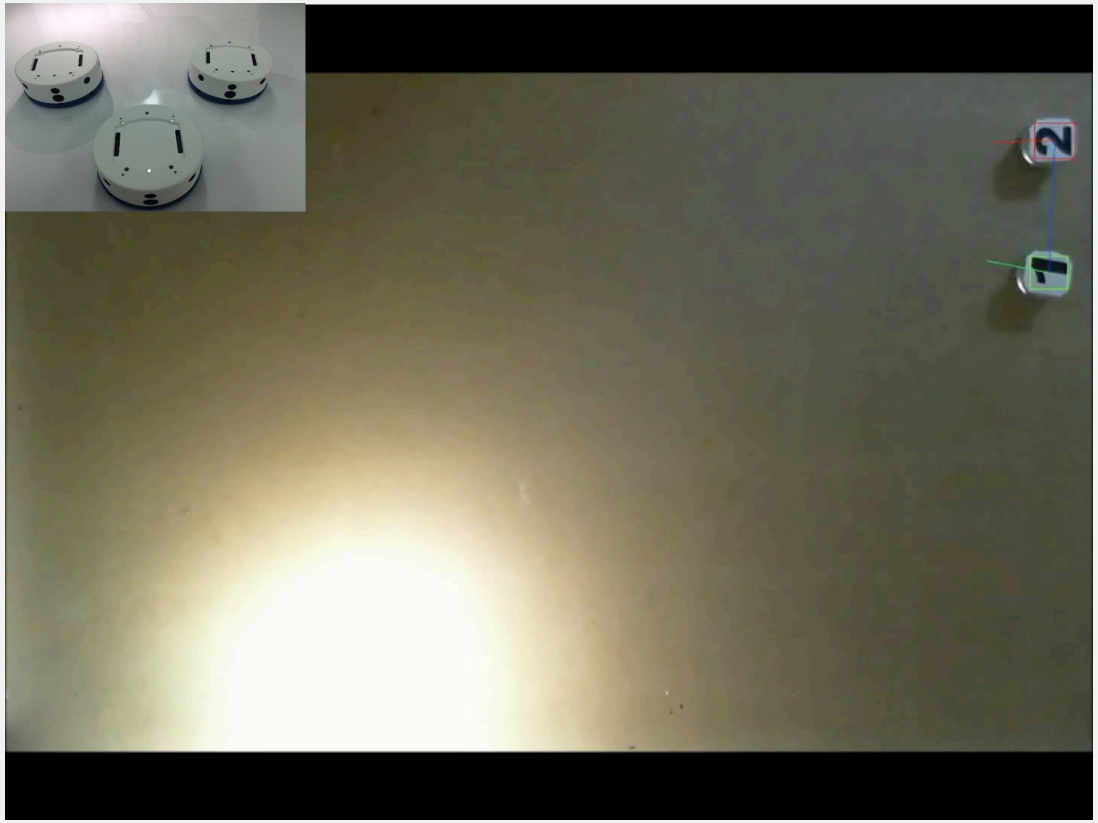


Boundary tracking

Gradient-based vs. Gradient-free Source Seeking



Estimate $\nabla z(r)$ first, then use the estimated $\widehat{\nabla} z(r)$ in the motion control



No explicit gradient estimation needed

Exploring Spatial-Temporal Varying Fields

Challenges

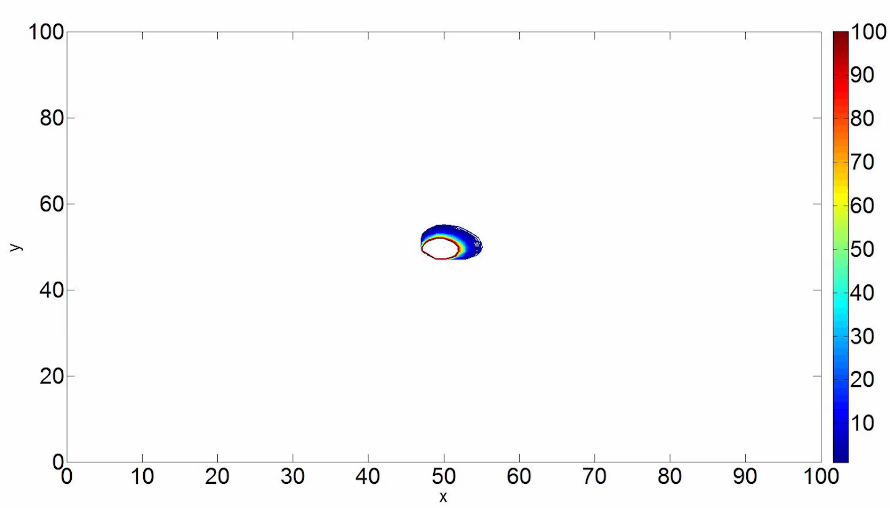
- Unknown distributed parameters
- Spatial-temporal varying state

$$\frac{\partial z(r,t)}{\partial t} = \sum_{i=1}^{M} \theta_i(t)\psi_i(z(r,t), \nabla z(r,t), \nabla^2 z(r,t)), \; r \in \mathbb{R}^d, t \in \mathbb{R}_+$$

θ_i to be estimated

Goal: using a mobile sensor network to achieve

- state estimation
- parameter identification
- map reconstruction



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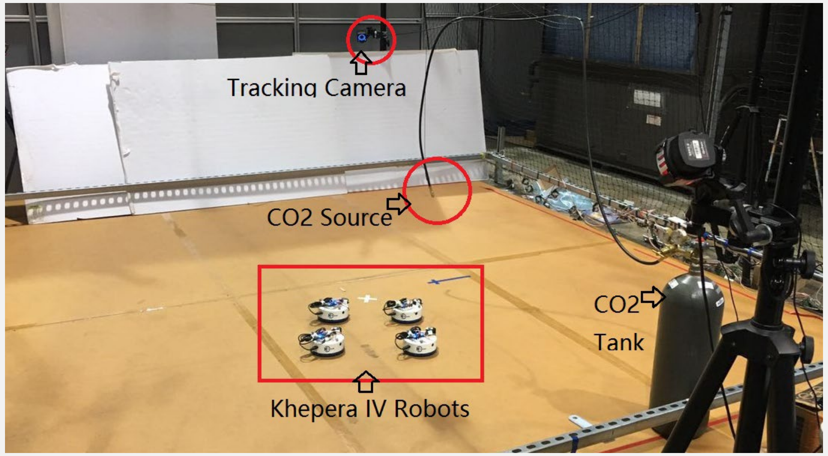
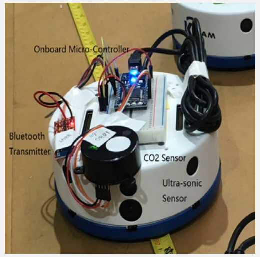
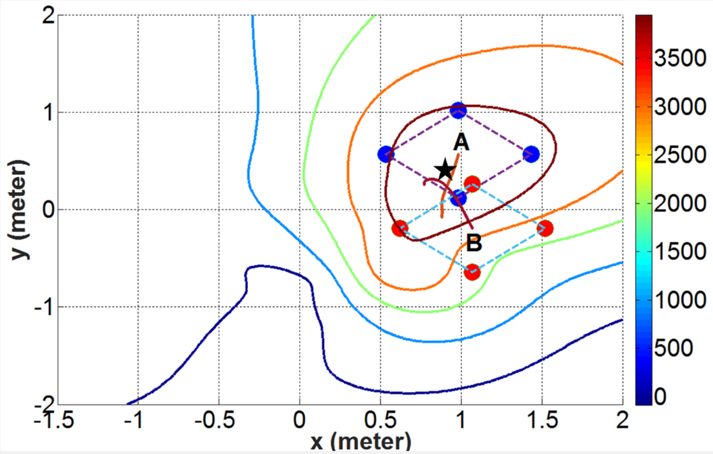
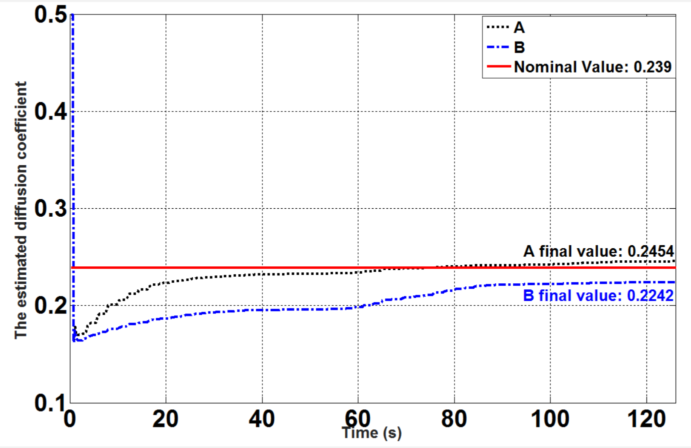
Experimental Results: On-line Parameter Identification







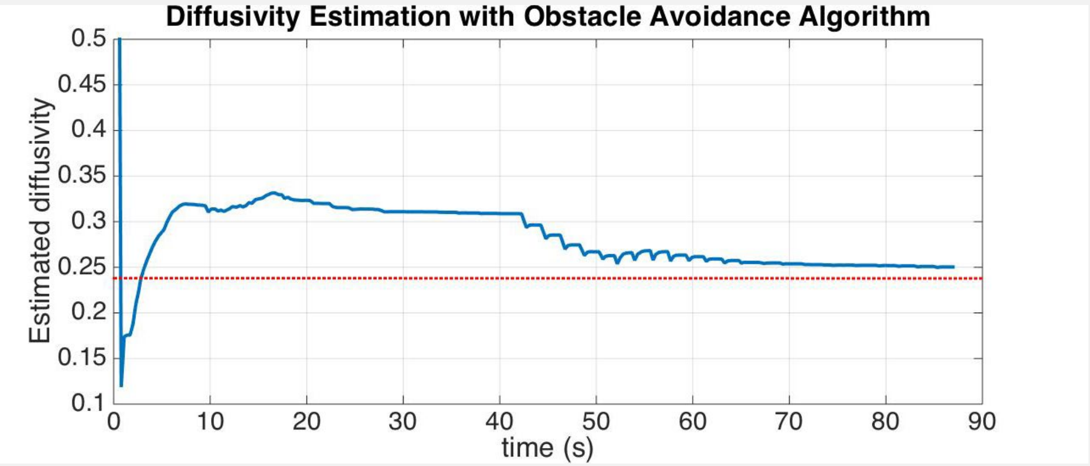


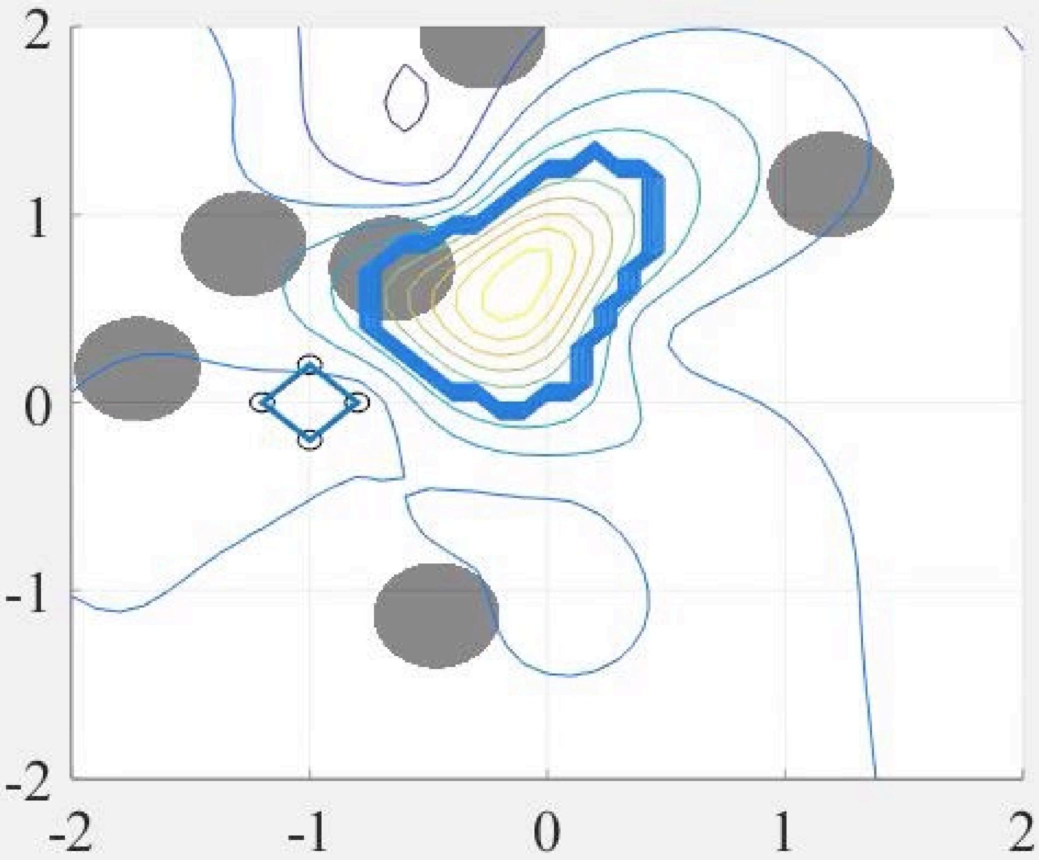
Simulation Study

- Consider the field contains
  - Obstacles
  - Hazard zones
- Online parameter identification

  + state estimation

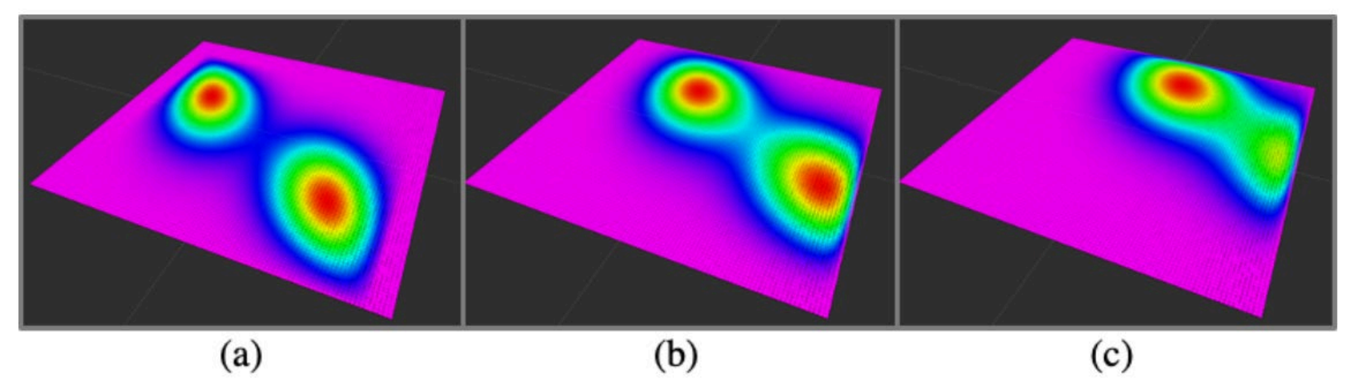
  + source seeking





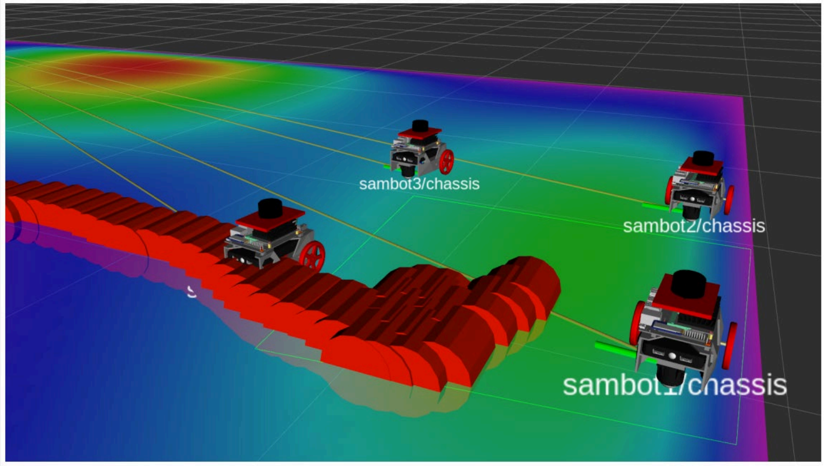
Multi-robot Exploration of Spatial-temporal Varying Fields

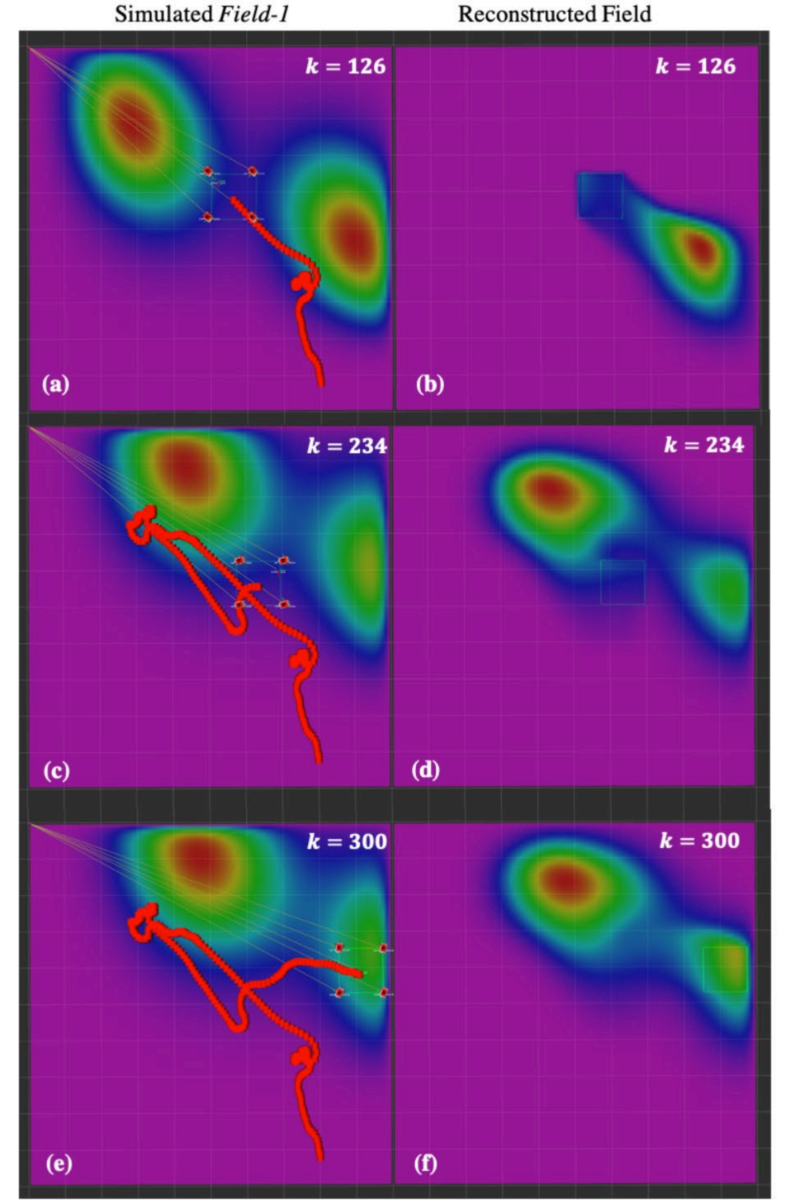
RL Based Path Planning and Field Reconstruction



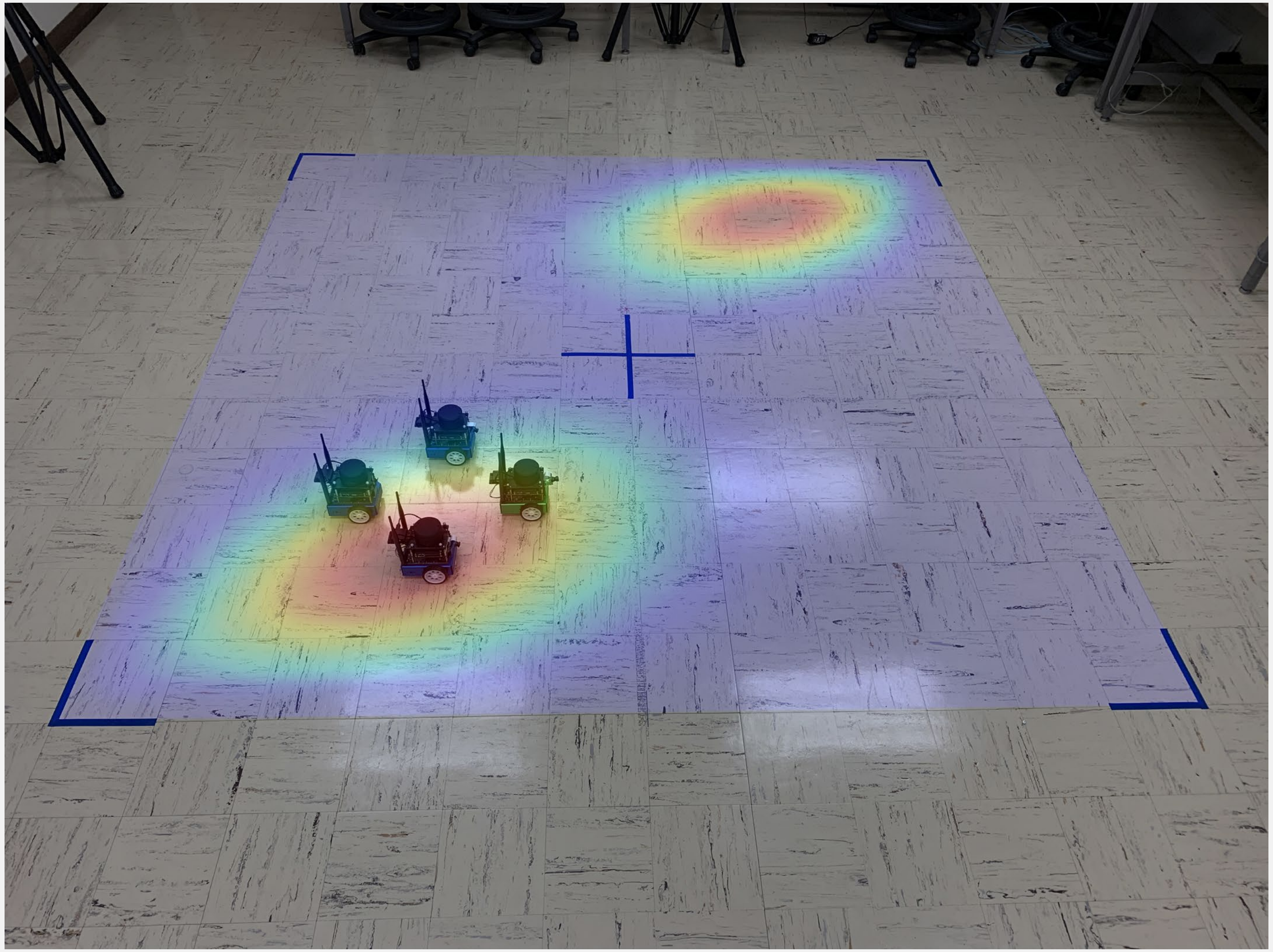
Representation of an advection-diffusion field grid map in Rviz at 3 time steps.

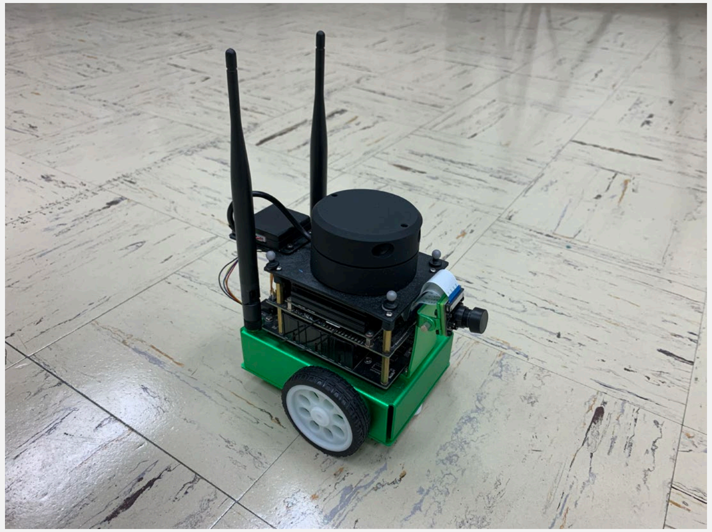
Snapshot of the mobile robot formation moving in the simulated advection-diffusion field

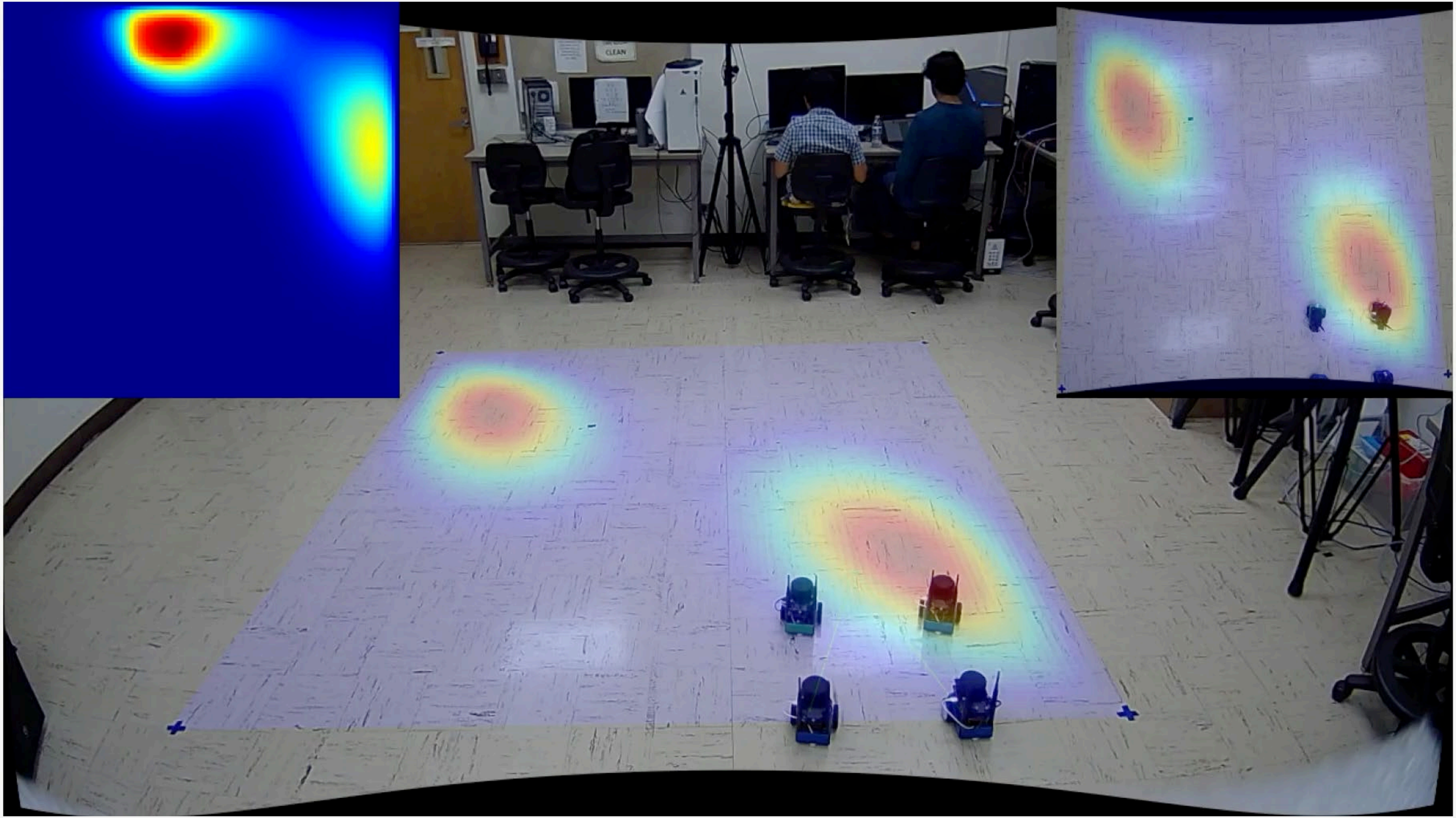




Experimental Study



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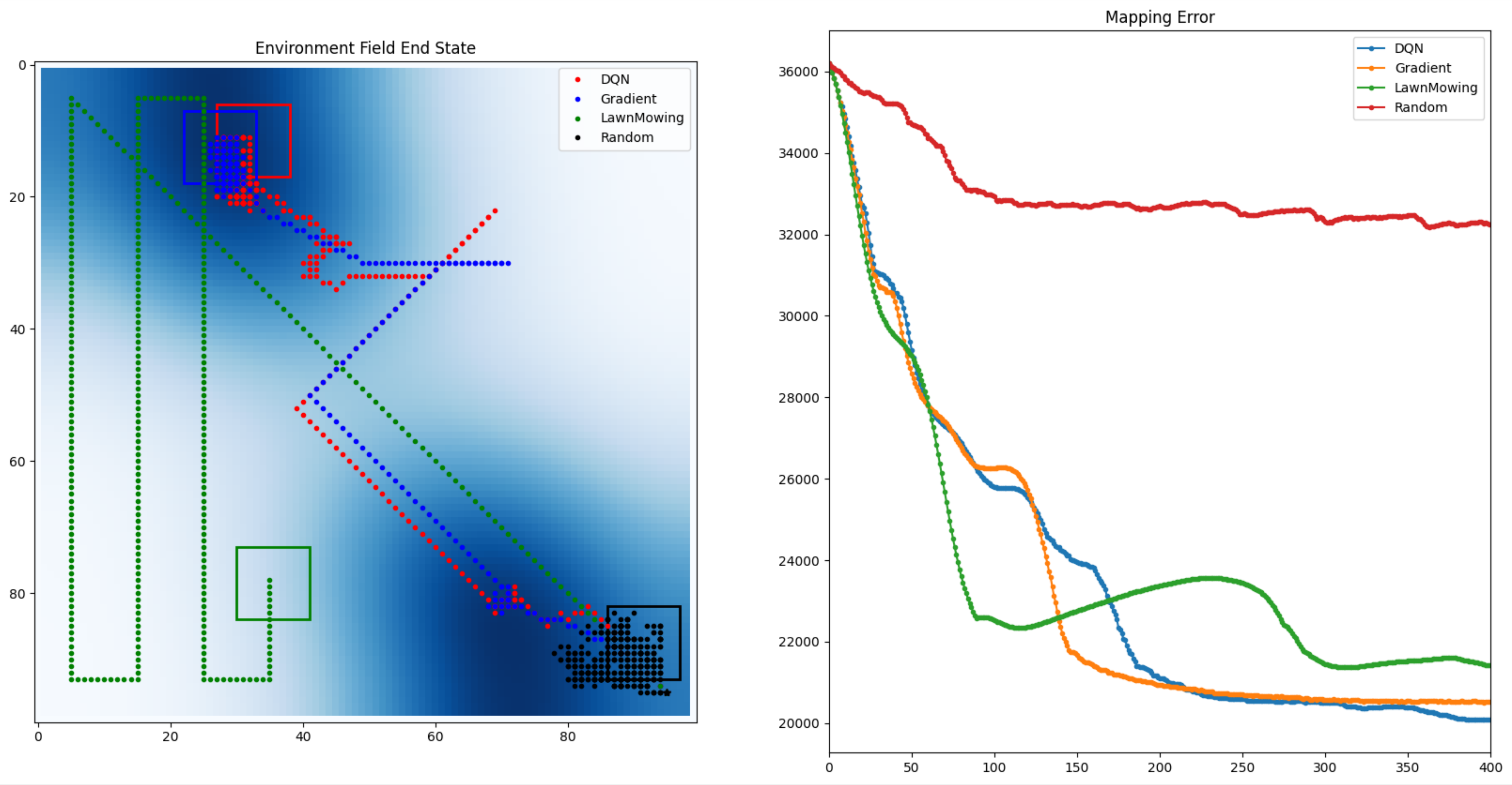
Multi-robot Exploration of Spatial-temporal Varying Fields

Experimental Study – Comparison with Different Trajectories



Questions?

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Experimental Characterization and Computer Vision-Assisted Detection of Pitting Corrosion on Stainless Steel

CALIFORNIA POLYTECHNIC STATE UNIVERSITY, SAN LUIS OBISPO

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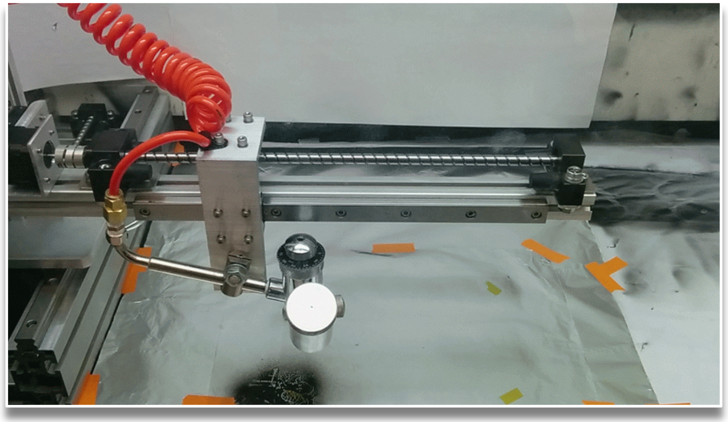
CSU Exemplars in Engineering

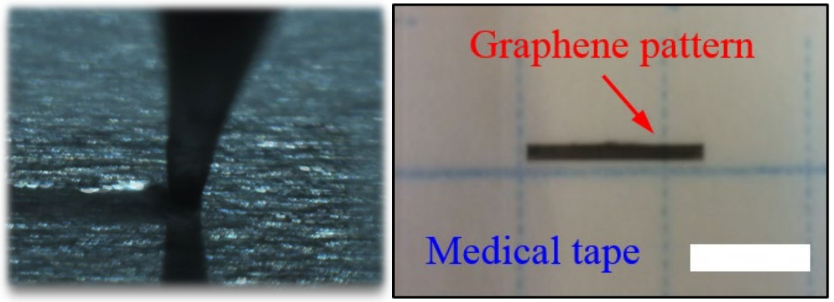
October 4, 2023

Research Overview

Multifunctional Material Design

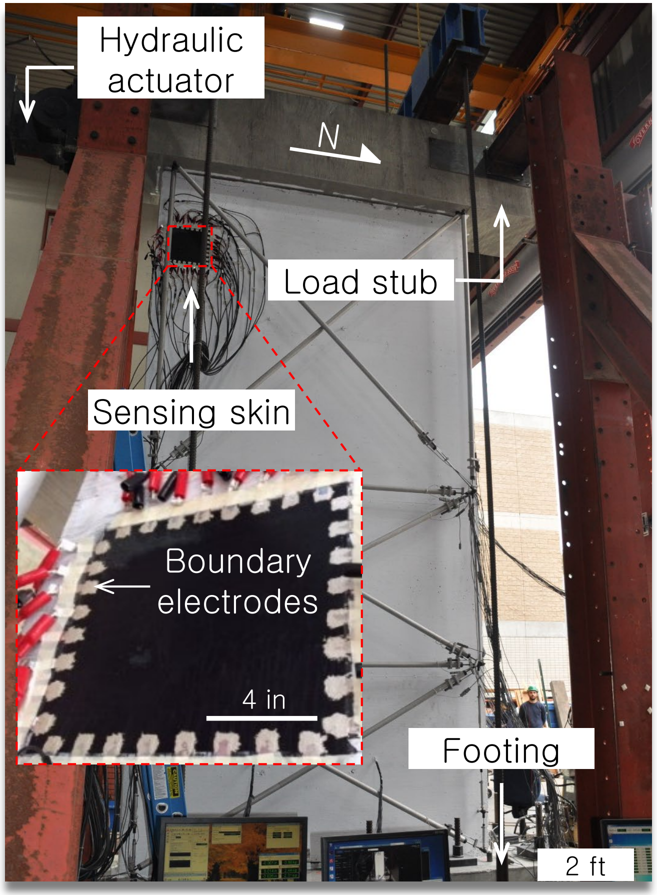


Spray coating of carbon nanotube films

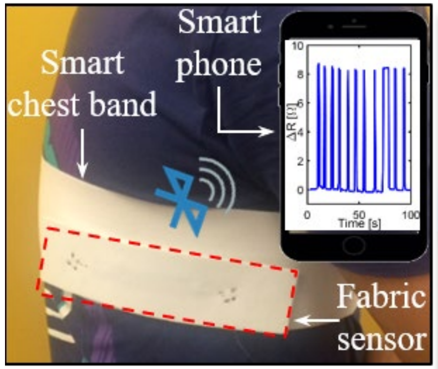


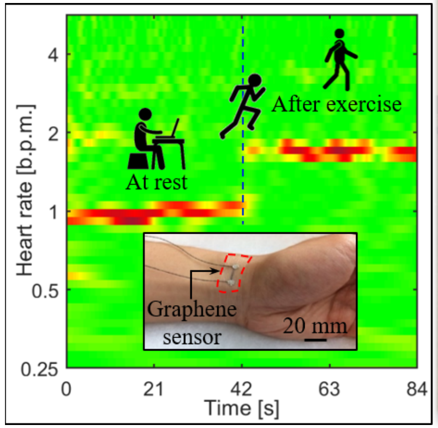
Printing of graphene patterns

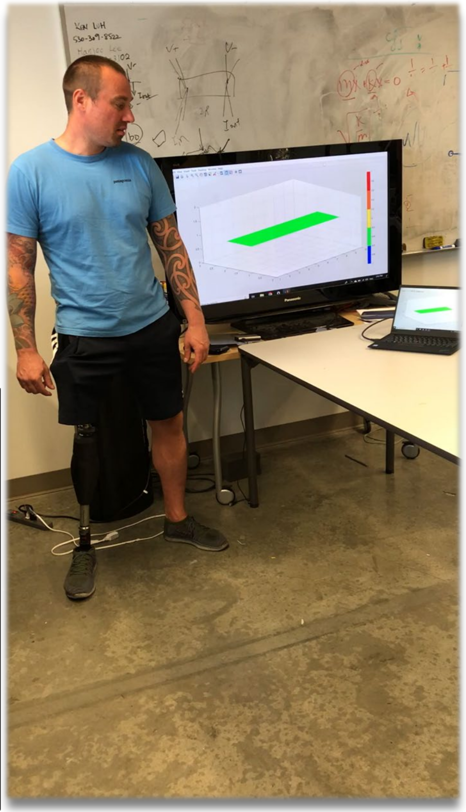
Infrastructure Monitoring



Human Monitoring

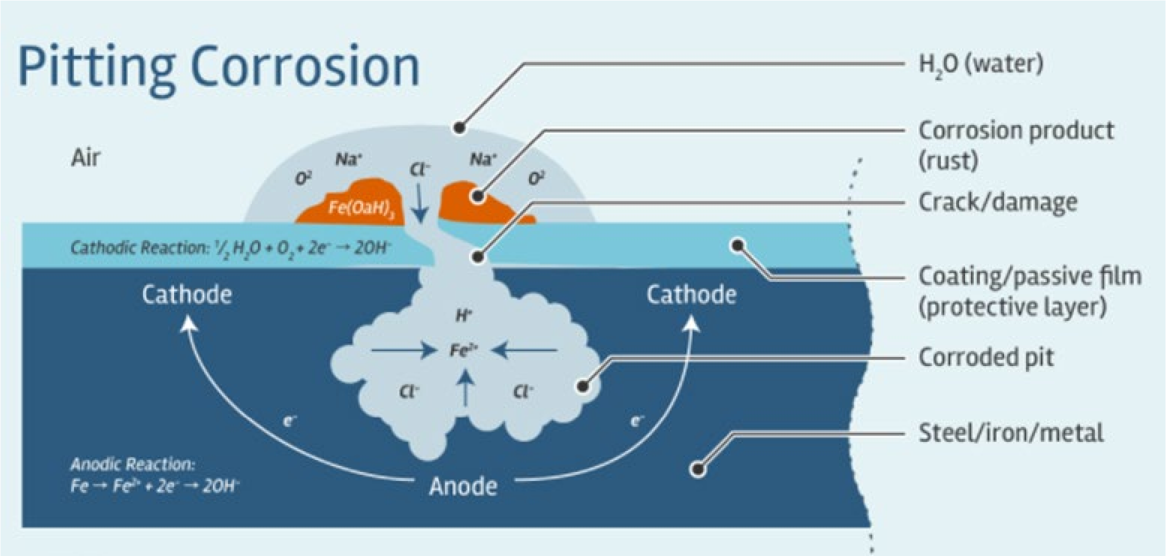




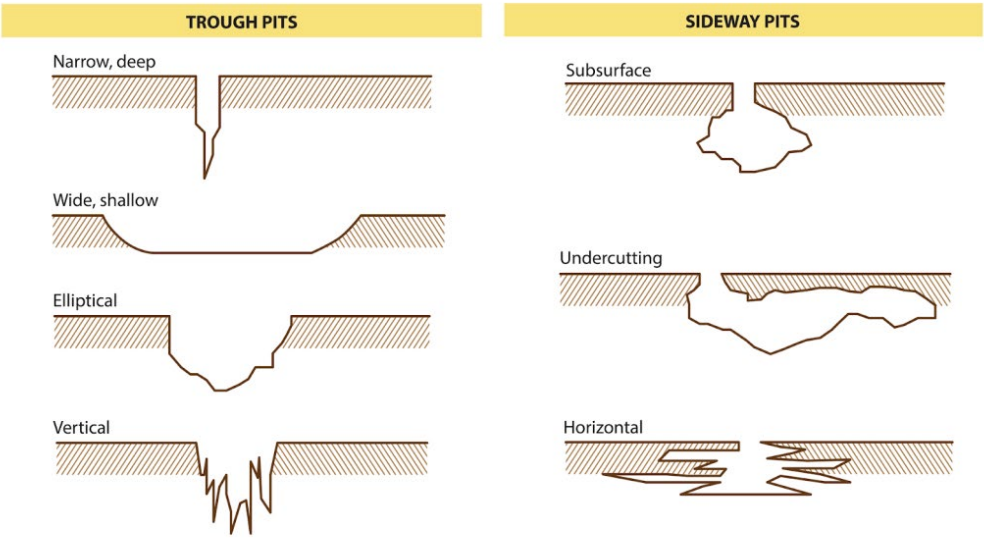


Pitting Corrosion Background

- Pitting corrosion is a type of localized corrosion that is both autocatalytic and irregular, creating cavities within a material.
- Pitting damage can potentially lead to structural failure.
  - Failure occurs at the largest defect on the surface, and cannot be equated wholly to mass loss of external topography
  - Fracture mode can change to stress corrosion cracking, a non-ductile, rupture failure for members under tension stress
- It is challenging to identify, predict, and design against (bypasses corrosion resistance) pitting corrosion.



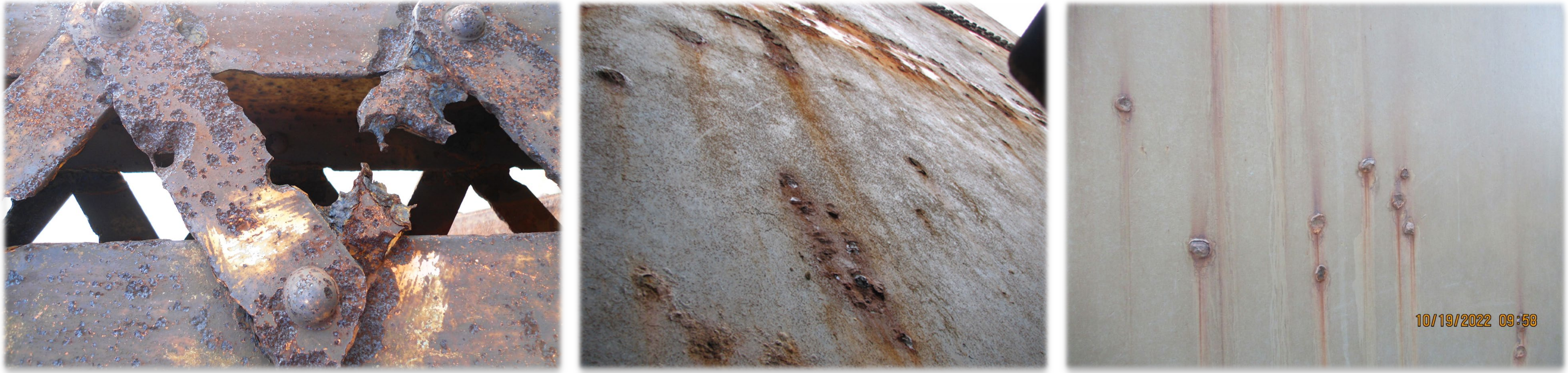
Schematics of pitting corrosion
(Source: D&D Coating Ltd)



Common forms of corrosion pit morphologies
(Source: AMARINE)

Pitting Corrosion Background

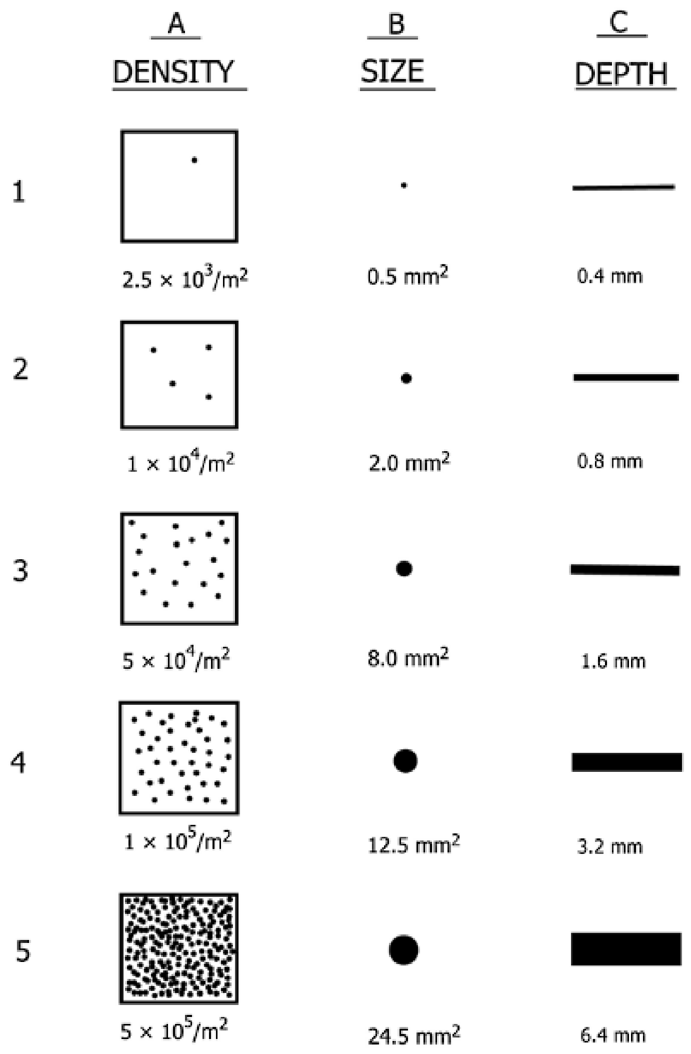
- Various types of structures can be subjected to pitting corrosion.
  - Examples include bridges, metal pipes, aircrafts, and so forth.



Pitting corrosion on Nandu River Iron Bridge truss member (left), St. Lawrence Seaway Navigation Lock vinyl wall system (middle), and skin plate provided by US Army Corps of Engineers (right)

Existing Technologies for Pitting Corrosion Analysis

Existing Technology	Pros	Cons
Visual Examination	• No technology required	• Highly time consuming • Difficult if the area is hard to access (i.e., underwater) • Subject to human error
Metal Penetration	• Cheap technology	• Large error in identifying the deepest pits (i.e., largest pit may not be deepest pit especially for loaded members)
Eddy Current	• Great accuracy using commercial technology	• Expensive • Commercial products designed for specific applications such as pipes
Ultrasound	• Good sensitivity for pitting corrosion	• Expensive • Affected by liquid loading, coatings, and welds • Reference standards and large amount of training and experience is required
Profilometry	• High accuracy • Outputs large amount of useful surface morphology data	• Very expensive • Unable to be taken into the field

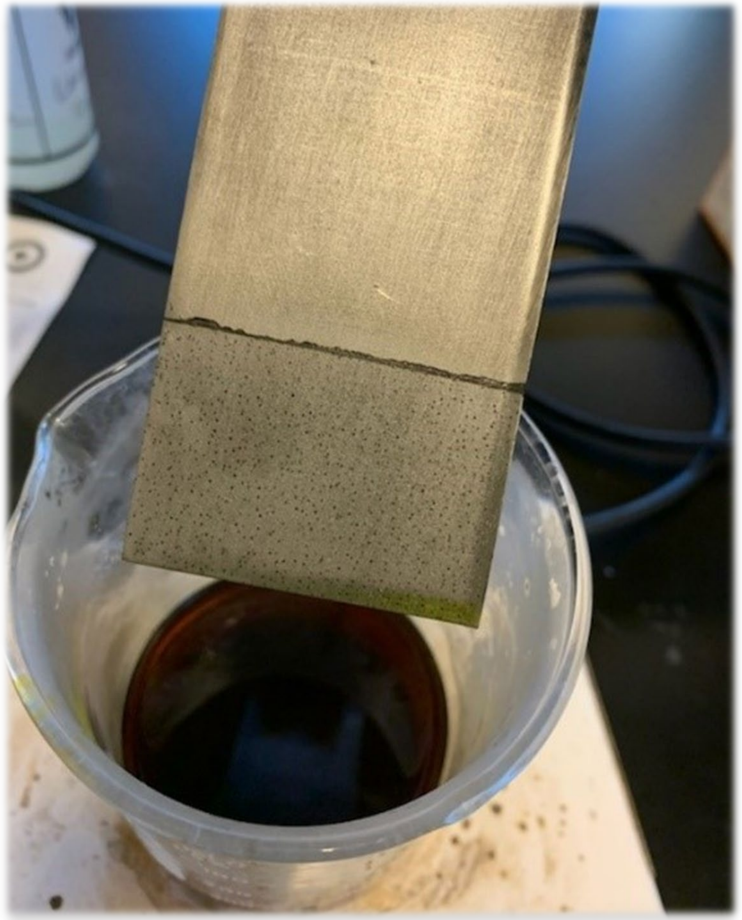


Standard rating chart for pitting corrosion *(Source: ASTM G46-21)*

Accelerated Pitting Corrosion Experiment

- Materials
  - AISI 304 Stainless Steel (50.8 × 63.5 × 4.7625 mm^3)
  - Iron (III) Chloride
  - Deionized (DI) Water
  - Hot Plate / Stir Plate
  - 500 mL Beaker
  - Sandpaper
  - Sodium Bicarbonate
  - Glass Thermometer
  - pH Test Strips

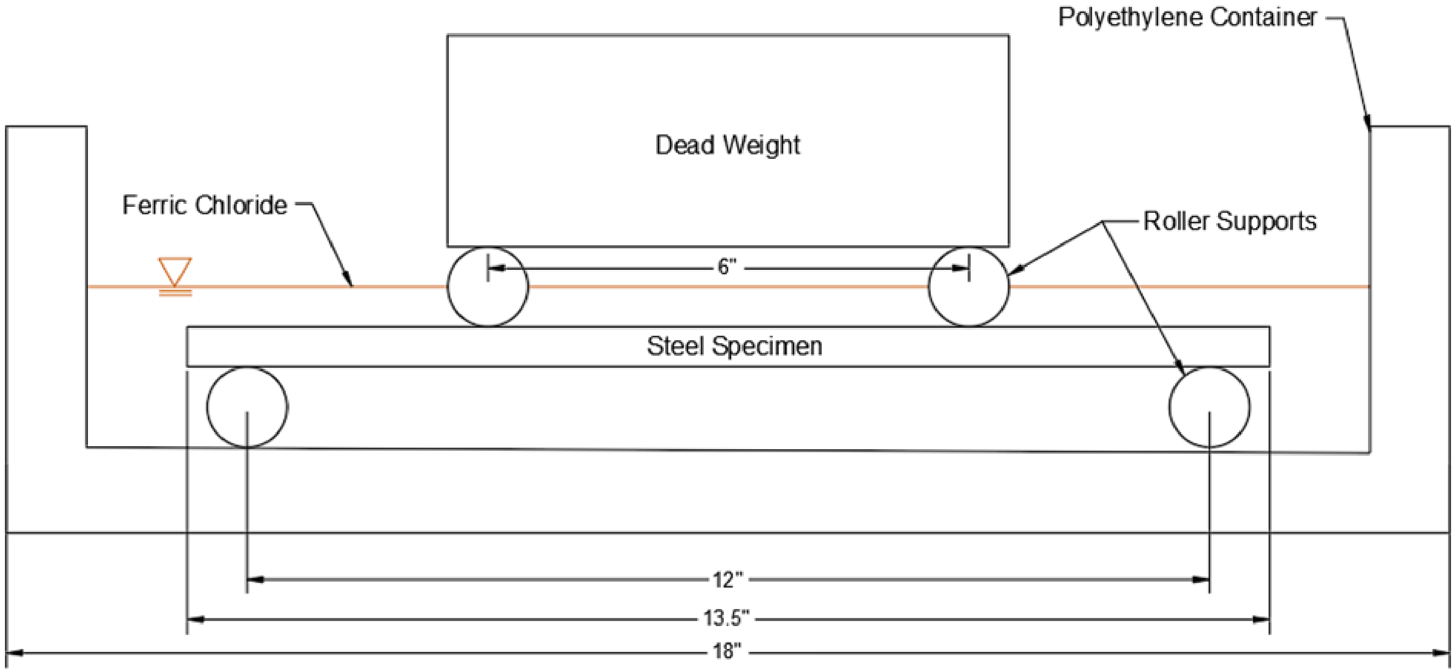
- Procedures
  1. $FeCl_3$ solution was prepared by dissolving 16.22 g of $FeCl_3$ powders in 200 mL of deionized (DI) water through stirring and was heated to 50°C.
  2. Steel specimens were sanded to remove the surficial protective oxide layers and wash with DI water.
  3. The specimens were then submerged in the solution for a desired timeframe (i.e., 1, 2, 3 hr).
  4. Once the desired timeframe was reached, the specimens were thoroughly washed with DI water and air dried for at least a day.



Beaker containing heated ferric chloride and a pitted steel specimen

Load-Coupled Corrosion Experiment

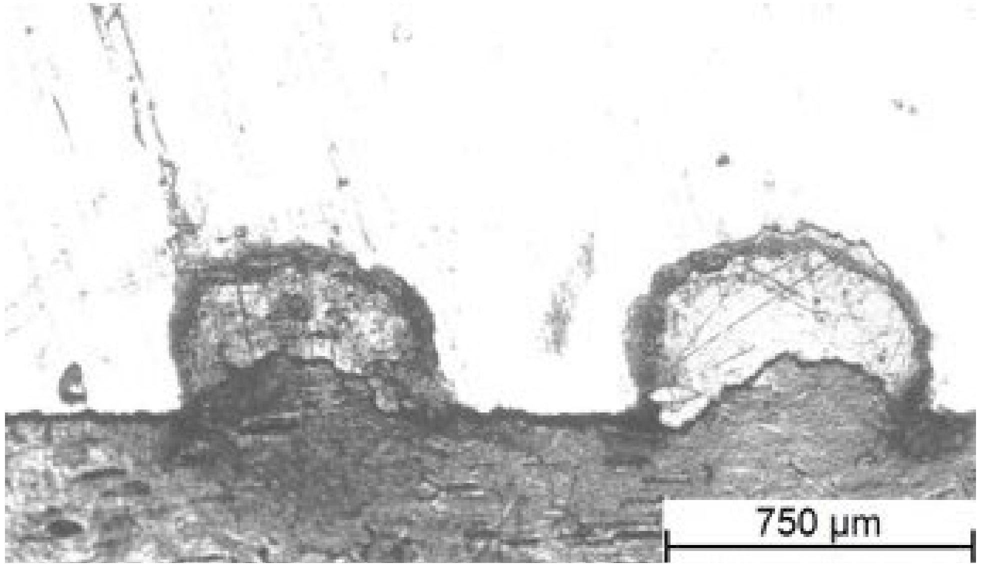
- Procedures
  1. The 0.5M $FeCl_3$ corrosive solution and steel specimens ($50.8 \times 342.9 \times 4.7625\ mm^3$) were prepared following the same procedures as the corrosion experiment.
  2. Each steel specimen was submerged in the corrosive solution and subjected to a four-point bending load simultaneously, generating 28 MPa max stress.
  3. Once the desired timeframe was reached (i.e., 1, 2, 3 hr), specimens were washed thoroughly with DI water and air dried for at least a day.



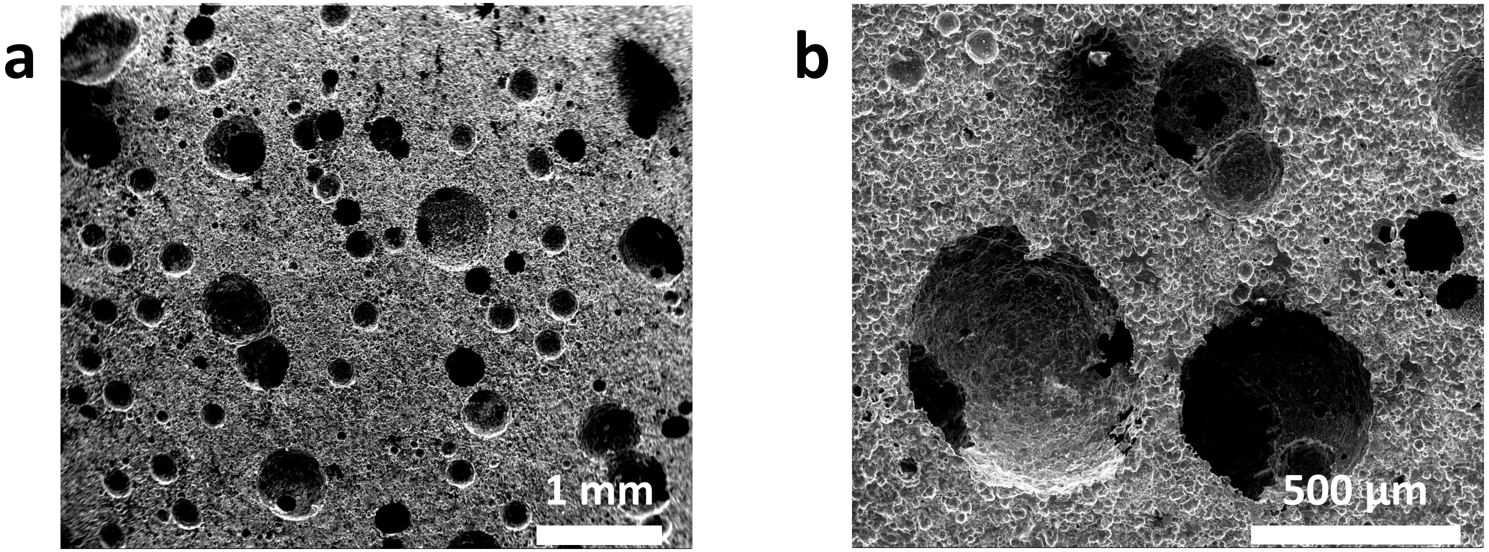
Schematics (left) and an optical image of the experimental setup for the load-coupled corrosion test

Microscopic Imaging of Pits

- Both optical microscopy and scanning electron microscopy (SEM) have been used to characterize micro-scale pit morphology
  - While microscopic imaging enabled detailed observation of the pits developed at different stages, it was challenging to perform scalable characterization.



Optical image of the cross-sectional view at 50x magnification



SEM images of pits after a three-hour accelerated corrosion experiment

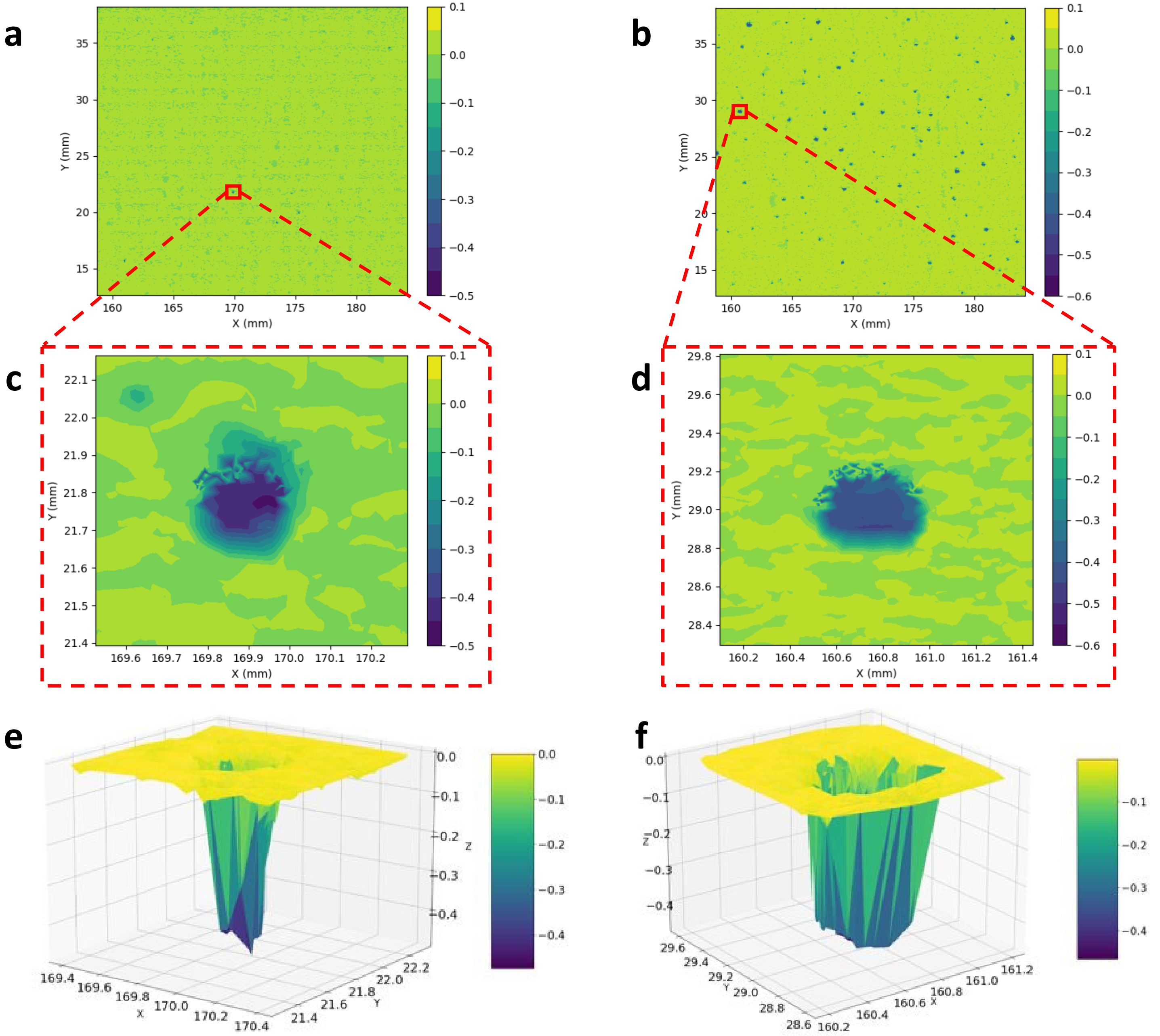
Pit Morphology Characterization

- All specimens were inspected using a Micro Vu Vertex system equipped with an LSM4-2 laser distance scanner.
  - The resolutions were 4 microns and 0.03 microns along x and y directions, respectively.

- Python codes were developed for processing and visualizing the data (3D coordinates for about 2 million data points per scan).
  - The code locally adjusts the surface plane by calculating local neutral axis and shifting nearby points to zero height.
  - A pit is classified as having eight points in proximity that all fall below the surface threshold.

Micro Vu Vertex system with a laser distance scanner during scan of load-coupled specimen

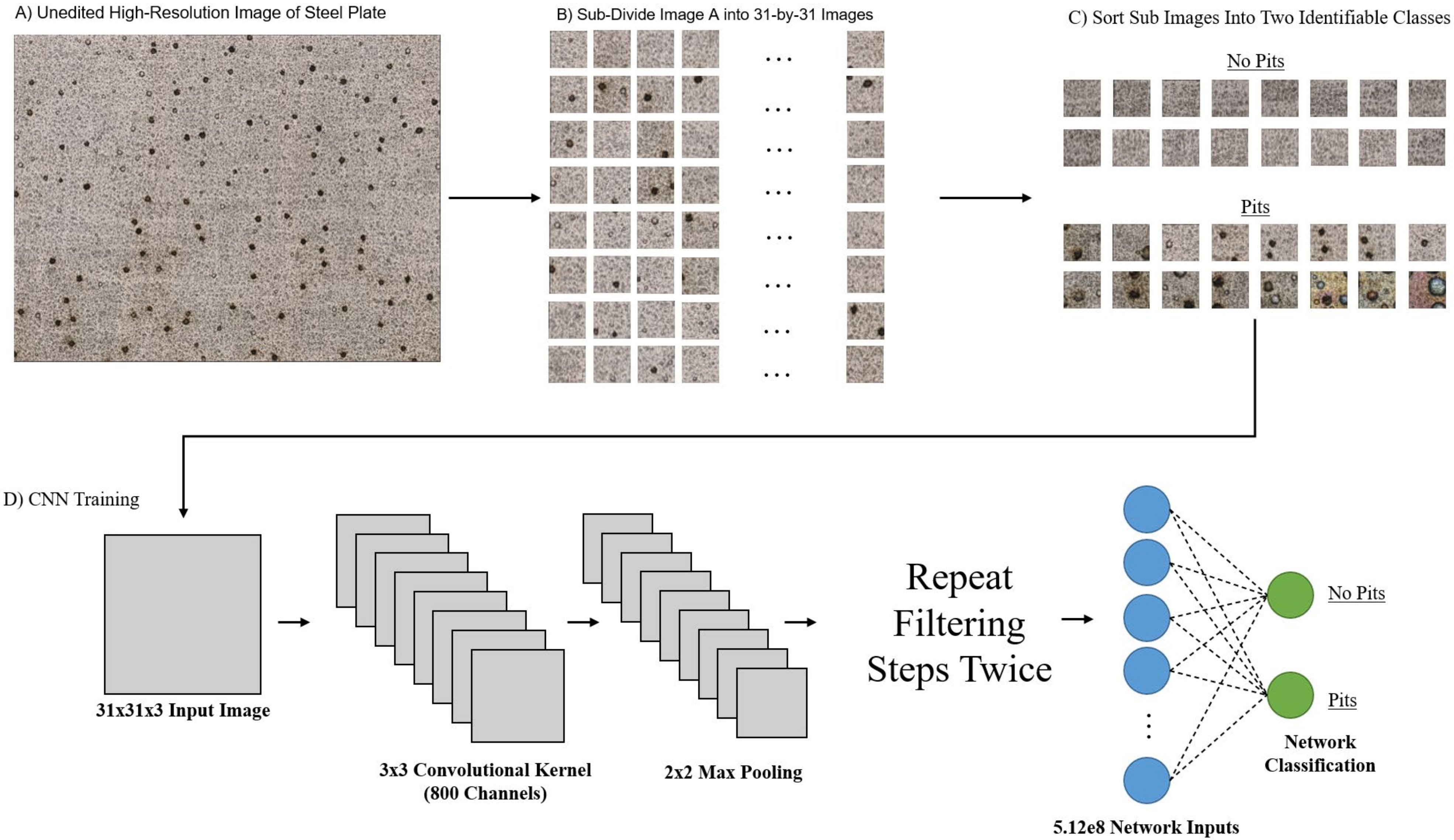
Pit Morphology – 2D and 3D Contours



Color contour plots of 25.4 × 25.4 mm^2 central regions on the a) tension and b) compression sides of a steel specimen subjected to 3-hr of load-coupled corrosion experiment. c) and d) Zoomed-in views of individual pits highlighted in a) and b), respectively. e) and f) Visualization of 3D morphologies of pits shown in c) and d), respectively.

Computer Vision Technique

- To detect pit damage in a more efficient and scalable manner, a convolutional neural network (CNN)-based computer vision technique was implemented to inspect optical images of steel specimens.

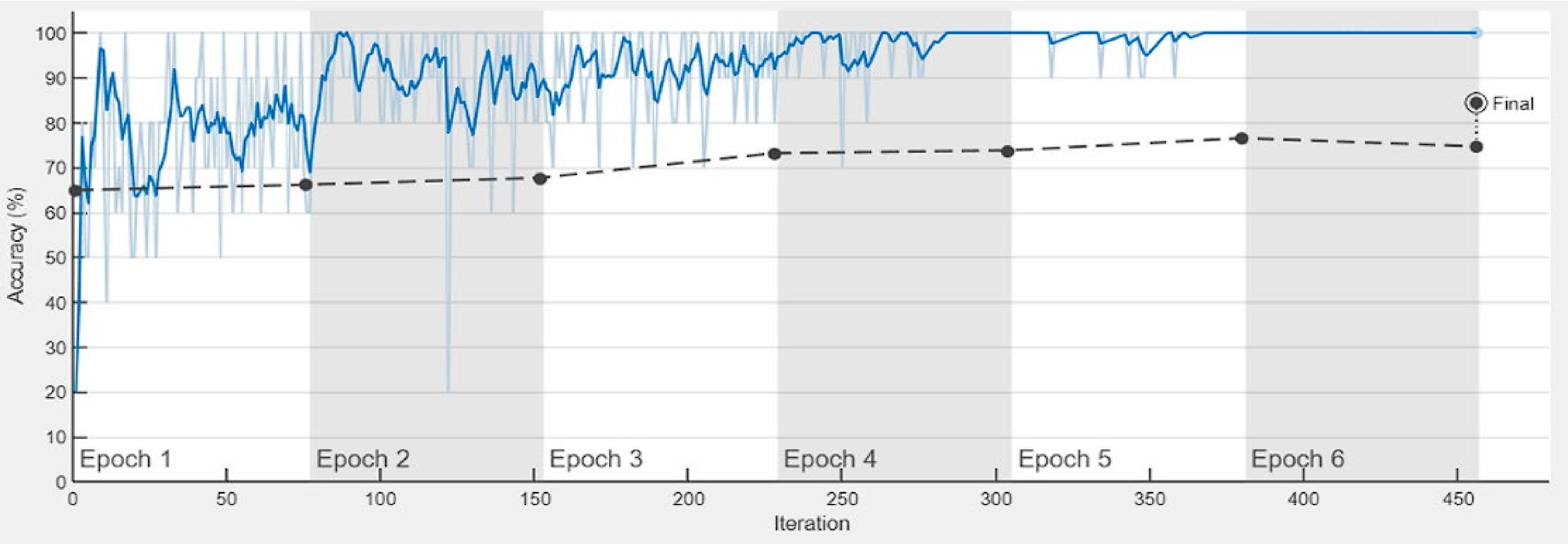


Training CNN

- An image library was established by partitioning 443×340−pixel images into smaller 31×31-pixel sub-images for training and testing the CNN. The training library included two classes:
  - "Pit" – consists of 740 images
  - "No Pit" – consists of 353 images
- 70% of the images in each class were used for training and 30% are used for validation.
- Training augmentations that limit the CNN from memorizing the training data include:
  - Randomly reflecting the images horizontally and vertically
  - Randomly translating the image up to 30 pixels horizontally and vertically
- The CNN was trained with a learning rate of 0.0003 over six epochs.
  - To prevent overfitting that would occur at large epochs due to the limited library size

CNN Performance – Accuracy

- The final classification accuracy was 84.45%.
  - Further training (i.e., more epochs) would lead to overfitting.



Classification: Pit

Classification: No Pit

Accuracy plot during training with blue line showing the smoothed training accuracy and black line showing validation accuracy at the end of each iteration for MATLAB-based CNN (left) and examples of validation outputs of the trained MATLAB-based CNN algorithm (right)

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Acknowledgements/Questions

CALIFORNIA POLYTECHNIC STATE UNIVERSITY, SAN LUIS OBISPO

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Next Steps/Closing Remarks

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https://www2.calstate.edu/impact-of-the-csu/research/stem-net

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STEM-NET Virtual Research Café 10.0

Date: Wednesday, October 18, 2023
Time: 11am-12pm

Register Here →

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Topic: NSF CAREER Awardees
Date: Wednesday, November 1, 2023
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