Joint Technology Exchange Group

Underwater Inspection Research

University of Houston

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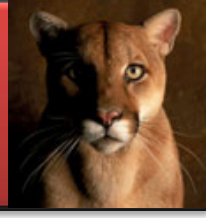
U of Houston Background

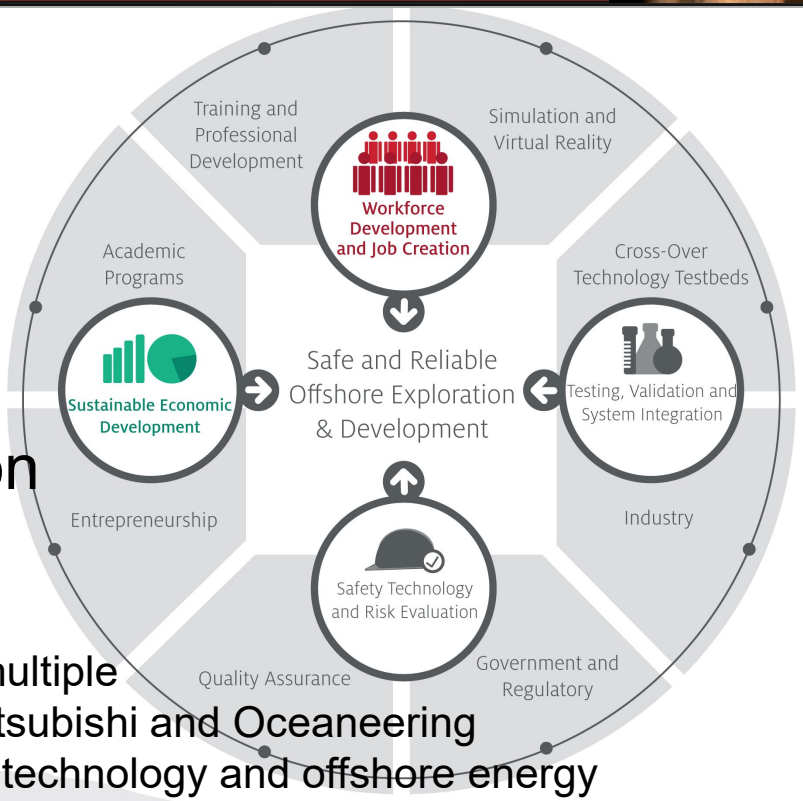
About University of Houston



- Flagship Campus of the University of Houston System
- F2019, ~46,000 students (35,000 ugrad, 11,000 grad) >10,000 degrees awarded
- Hispanic Serving Institution (>30% Hispanic and > 10% African American)
- Tier One Research Institution - >$100M in research expenditures per year.
- Significant Ties to Industry in TX, including Oil & Gas
  - MSc in Subsea Eng (2012) – First in U.S.

U of Houston Collaborations and R&D Strengths

Subsea SYSTEMS INSTITUTE



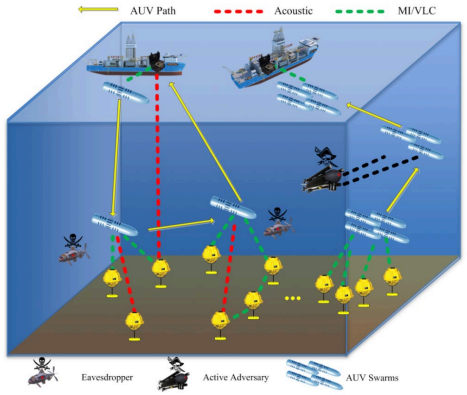
U of Houston, Subsea Systems Institute (SSI), is a federally funded national research center focused on offshore energy exploration and production:

- Established in 2015 under the RESTORE Act
- Works closely with NASA, Rice University and multiple industry partners such as ExxonMobil, Total, Mitsubishi and Oceaneering
- Undisputed leader in transformative deep-water technology and offshore energy operations
- Develops innovative research in underwater areas. Specialties include: robotics and automation, subsea power, human factors, flow assurance, materials and decommissioning
- SSI has extensive experience organizing / managing teams of academia, industry and government

U of Houston Unique R&D Strengths

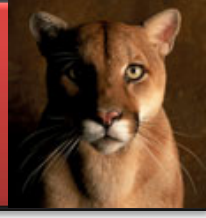
U of Houston has a rich suite of surface and underwater research capabilities:

- Underwater maintenance and sustainment for oil industry
- Subsea systems and communications (signal processing, sonar)
- Robotics
- Drones, Swarms, Autonomous Systems (hull hydrodynamics and bioinspired vehicles)
- Materials and polymers
  - Coatings, heat transfer and 2-phase flow
  - High thermal conducting materials
  - Extreme conditions (high temp, high pressure)
  - Fatigue resistance
  - Anti-corrosion
- Water treatment
- AI/ML
- Waste heat management
- Manufacturing
- Energy Storage / Battery Manufacturing and High Energy Natural Material




Key Research Themes for Underwater Inspection

About University of Houston



- Underwater Inspection Research at UH Driven by Oil & Gas Industry

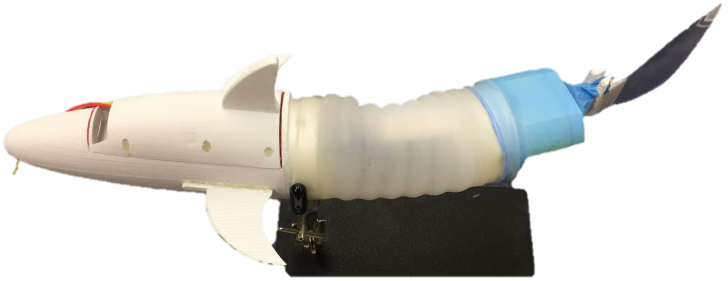
- Today's Focus in Three Primary Areas
  - Sensors and sensing systems
  - Localization in complex and cluttered environments
  - Advanced Data Analysis (AI/ML)


Underwater Robotics and Sensors

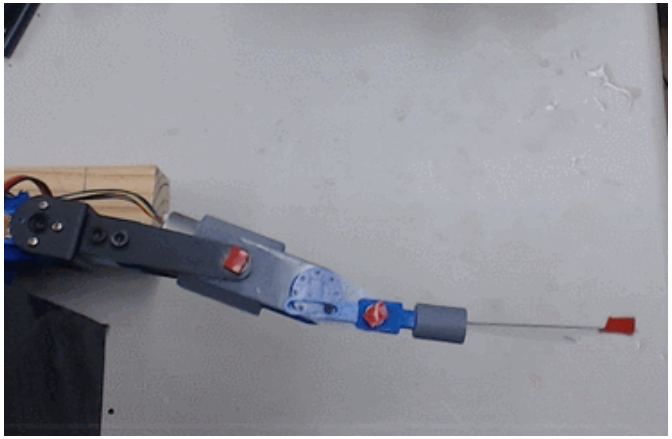
Bio-inspired Robotic Fish - Fabrication and Testing

Zheng Chen
Mechanical Eng.

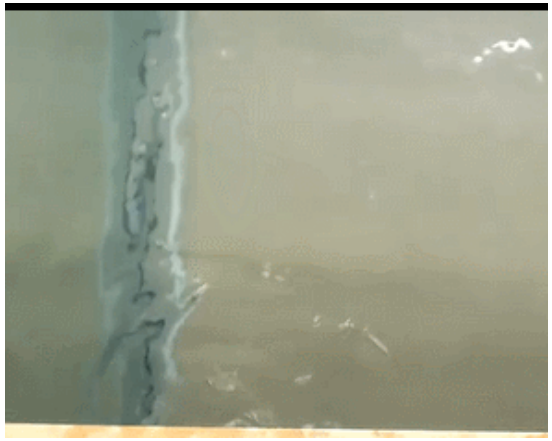
- A three joints robotic fish with one DC motor and one servo motor.
- Wireless control with embedding micro-computer
- Length: 38 cm & Weight: 0.7 kg.
- Swimming up to 0.22 m/s.
- Its novel propulsion mechanism can mimic real fish's swimming pattern.



Prototype of Multi-joint Robotic Fish



Multi-joint Fish Tail



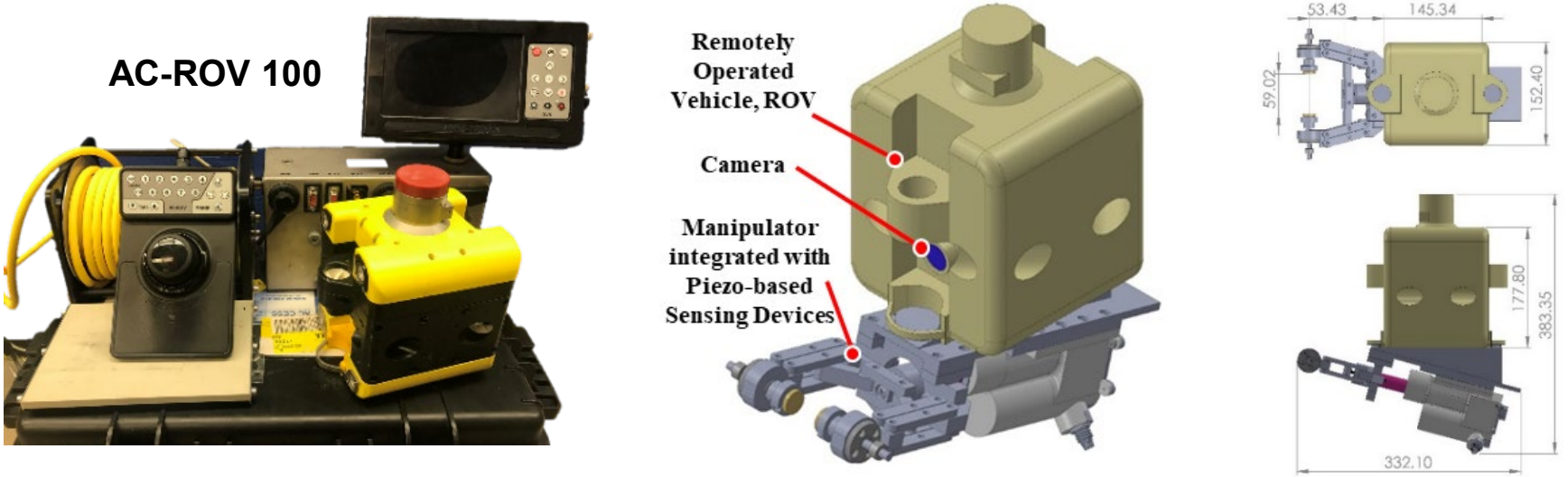
Forward Swimming

Turning Swimming

Underwater Bolted Connection Inspection

Gangbing Song
Mechanical Eng.

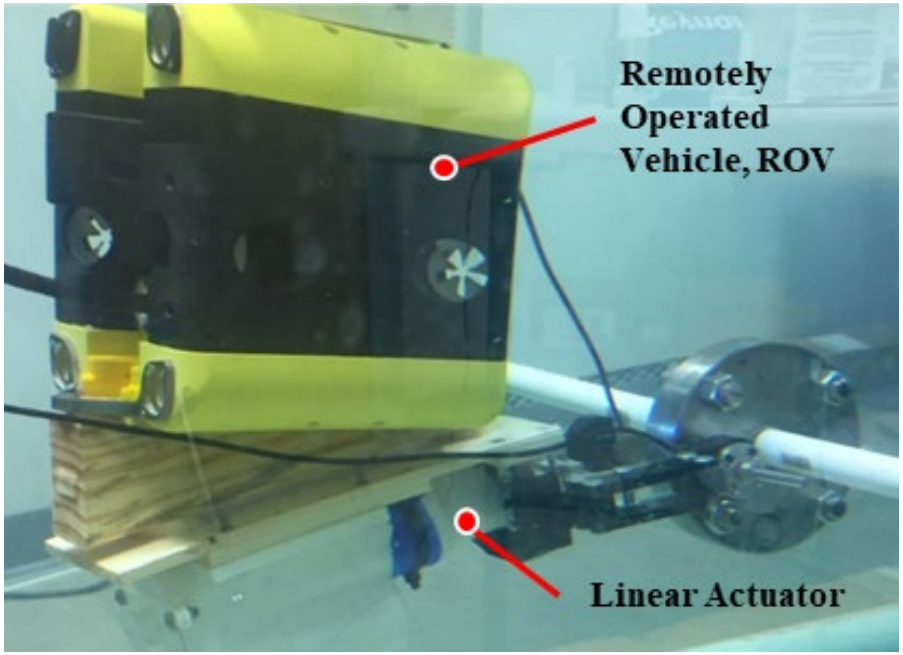
Piezoceramic-enabled and touch-based inspection method for the tightness (looseness) of bolted flange in undersea environment

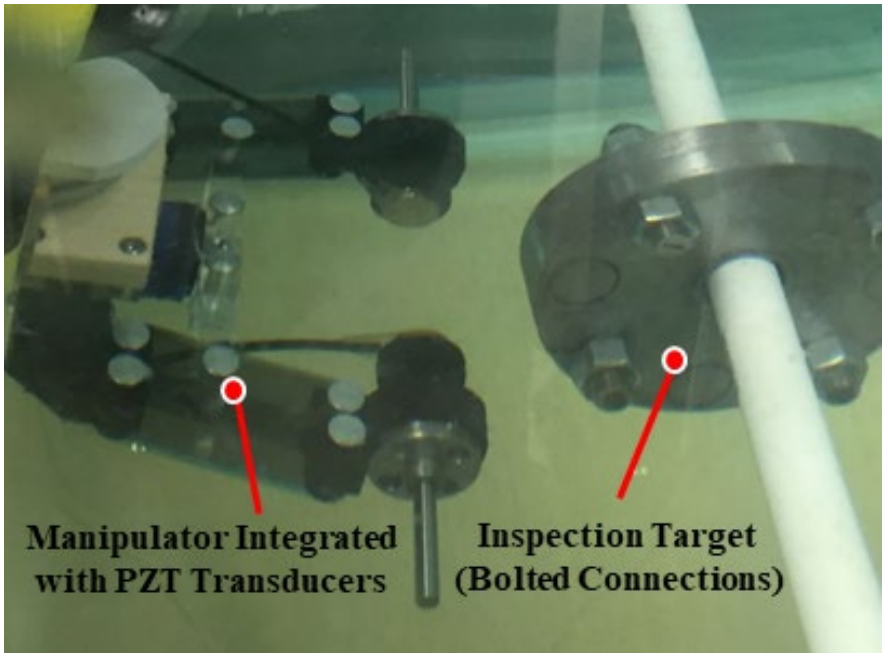


(a) (b) (c)

Illustration of the proposed ROV-enabled robotic inspection system: (a) the ROV assembly; (b) the integration of the ROV with the PZT-based sensing manipulator; (c) the main dimension of the entire ROV enabled robotic inspection system.

Underwater Bolted Connection Inspection



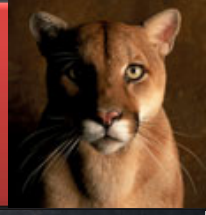



Cooperative Swarms and Localization

Localization between ROVs using triaxial coil antennas

UNIVERSITY of HOUSTON

Localization between ROVs using triaxial coil antennas



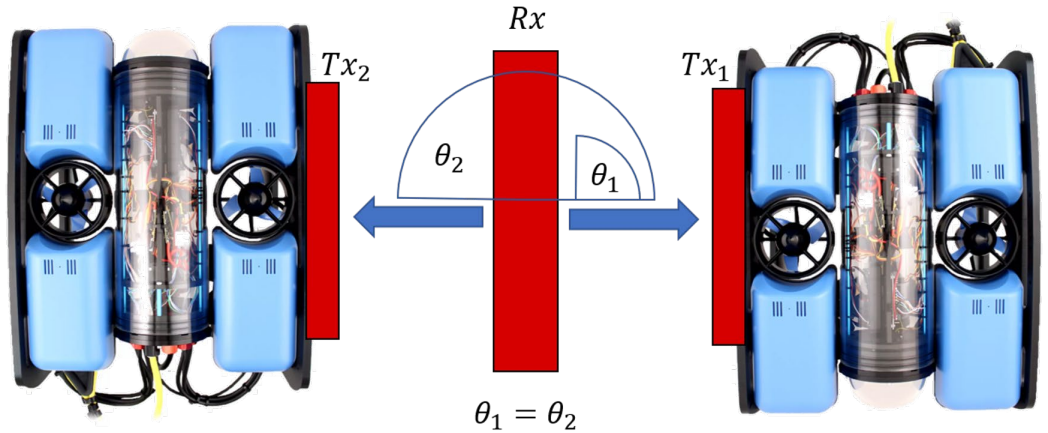
Advantages of coil antennas as a sensor:

- Low Propagation Delay
- Stealth Operation
- Affordable Implementation

Disadvantages of coil antennas as a sensor:

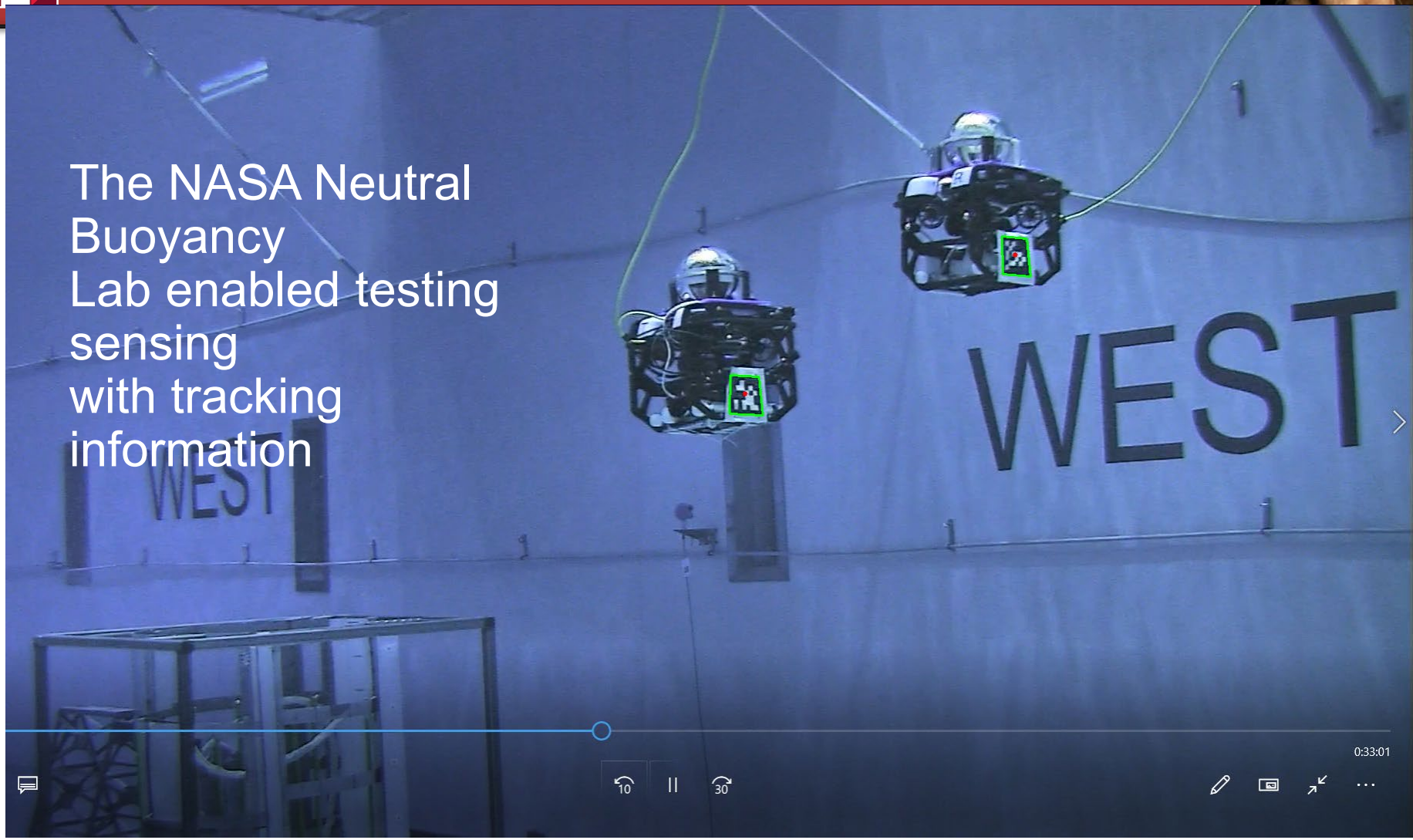
- Short Range
- Location Ambiguity

Aaron Becker
Electrical Eng.



$\theta_1 = \theta_2$
Because the voltage received in both cases is the same

Following of Linear Metal Elements


The NASA Neutral Buoyancy Lab enabled testing sensing with tracking information
WEST
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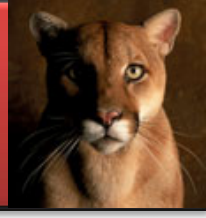
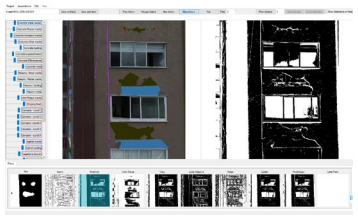
Data Analysis and Machine Learning

Framework for automating inspections Using Machine Learning



Vedhus Hoskere
Civil Eng.

Develop annotated datasets



- Collect images of structure type
- Identify and annotate important features for inspection decision making at a pixel level

Automated data acquisition

- GPS-based automated UAV flights at structures of interest

Data processing for inspection subtasks

Image Material Damage

- Damage identification
- Material identification
- Structural component identification

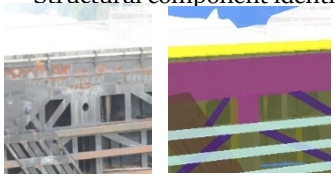
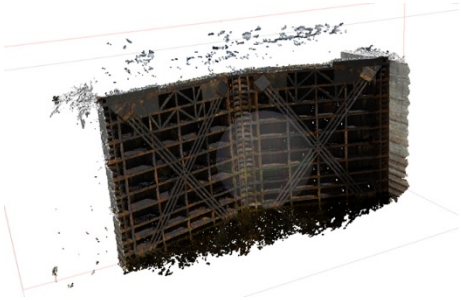


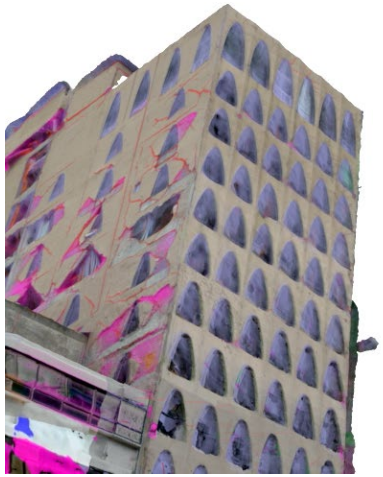
Image Structural components

Visualization of results

- 3D reconstruction
- Project annotations back onto point cloud



Façade inspections



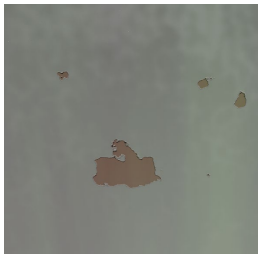
Ongoing USACE Project

Miter Gates of Navigation Locks

$229 billion worth of cargo transported in 2015 by the US inland waterways

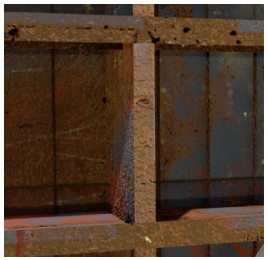
Inspections are vital to mitigate consequences of unscheduled closures

Modeling Other Variables

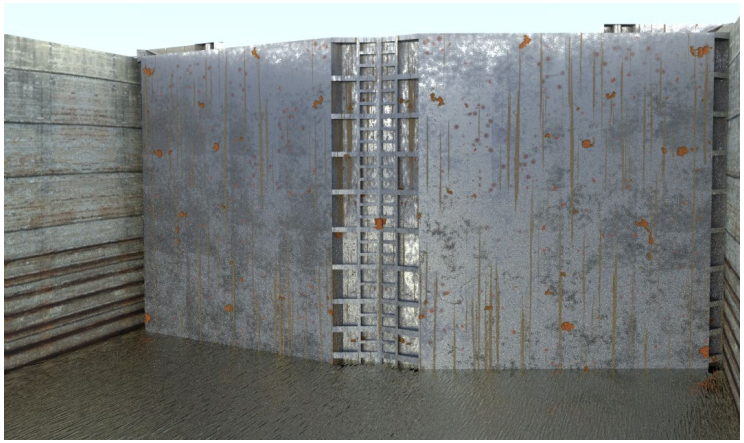


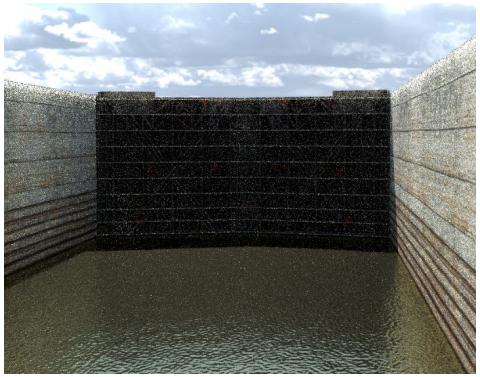
Peeled paint

Dripping rust

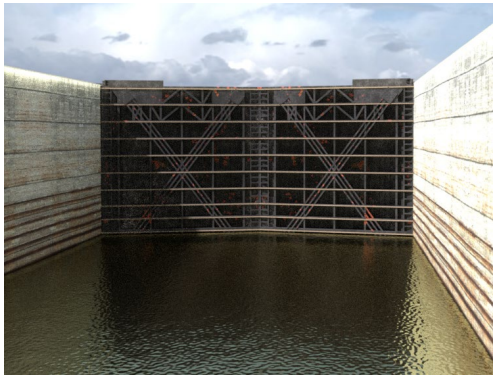


Corrosion



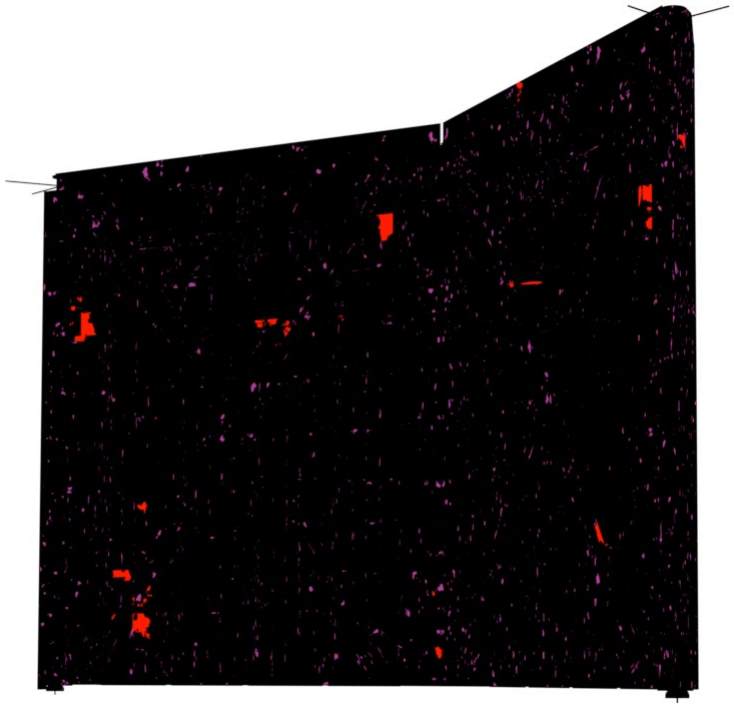


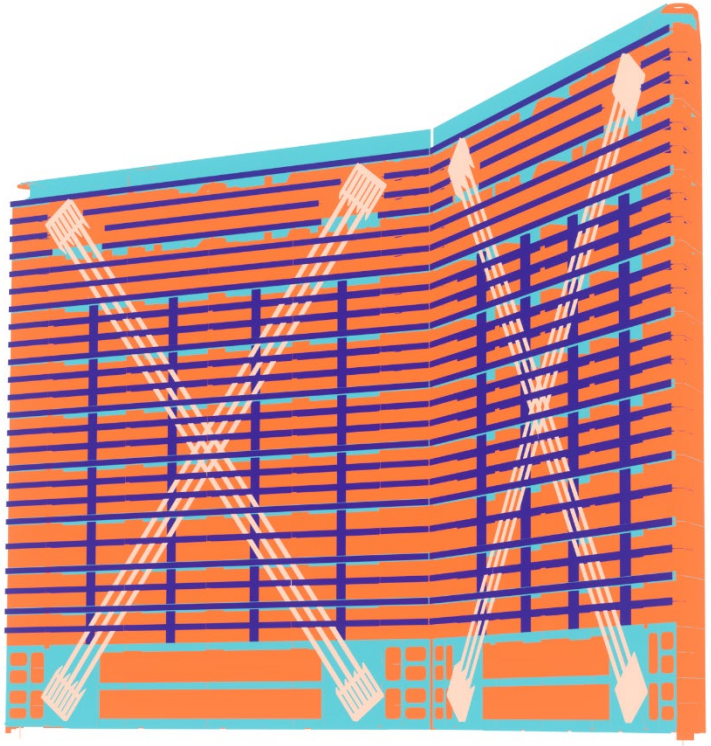
Picture



Synthetic Rendering

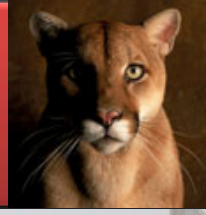
Condition-aware model



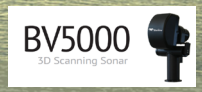


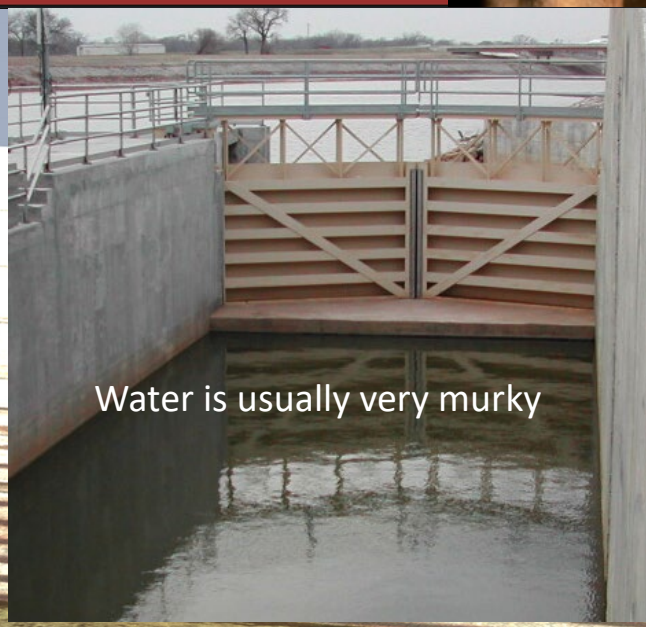
- Miter Gate
- Girders
- Fenders
- Diagonals
- Corrosion 1
- Corrosion 5

Underwater Inspections

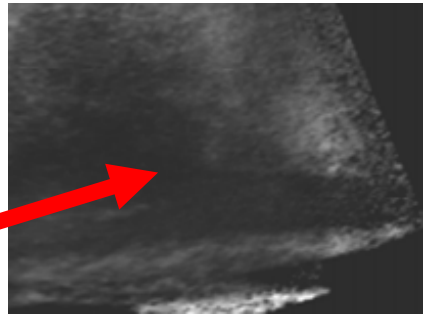


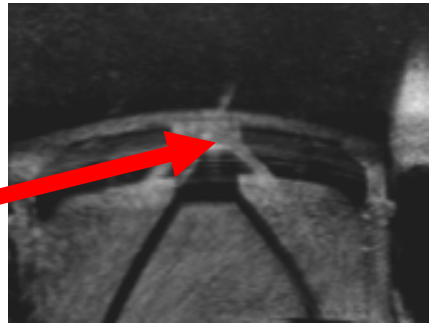
- Inspections are traditionally done by divers using touch + sight
- Army Corps has begun exploring the use of multibeam scanning sonar for data acquisition
- Sensors of interest
  - Teledyne BV5000
  - Tritech Gemini1200ik





Ultrasonic images are useful in murky waters





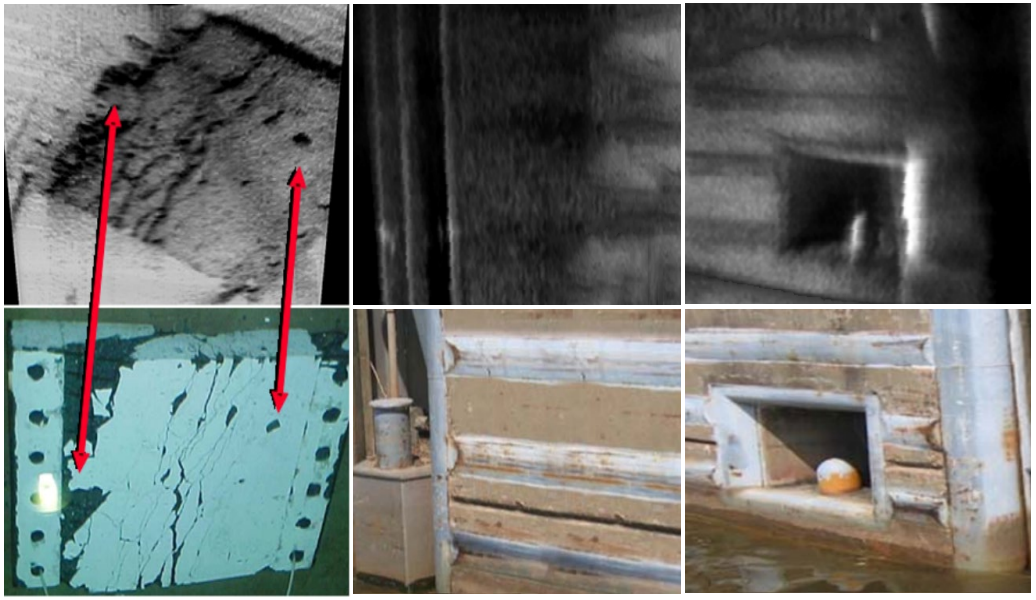
- Ultrasonic sensors can help see things when visible light is unavailable or can't penetrate due to murkiness
- However, the resulting images can be very difficult to interpret

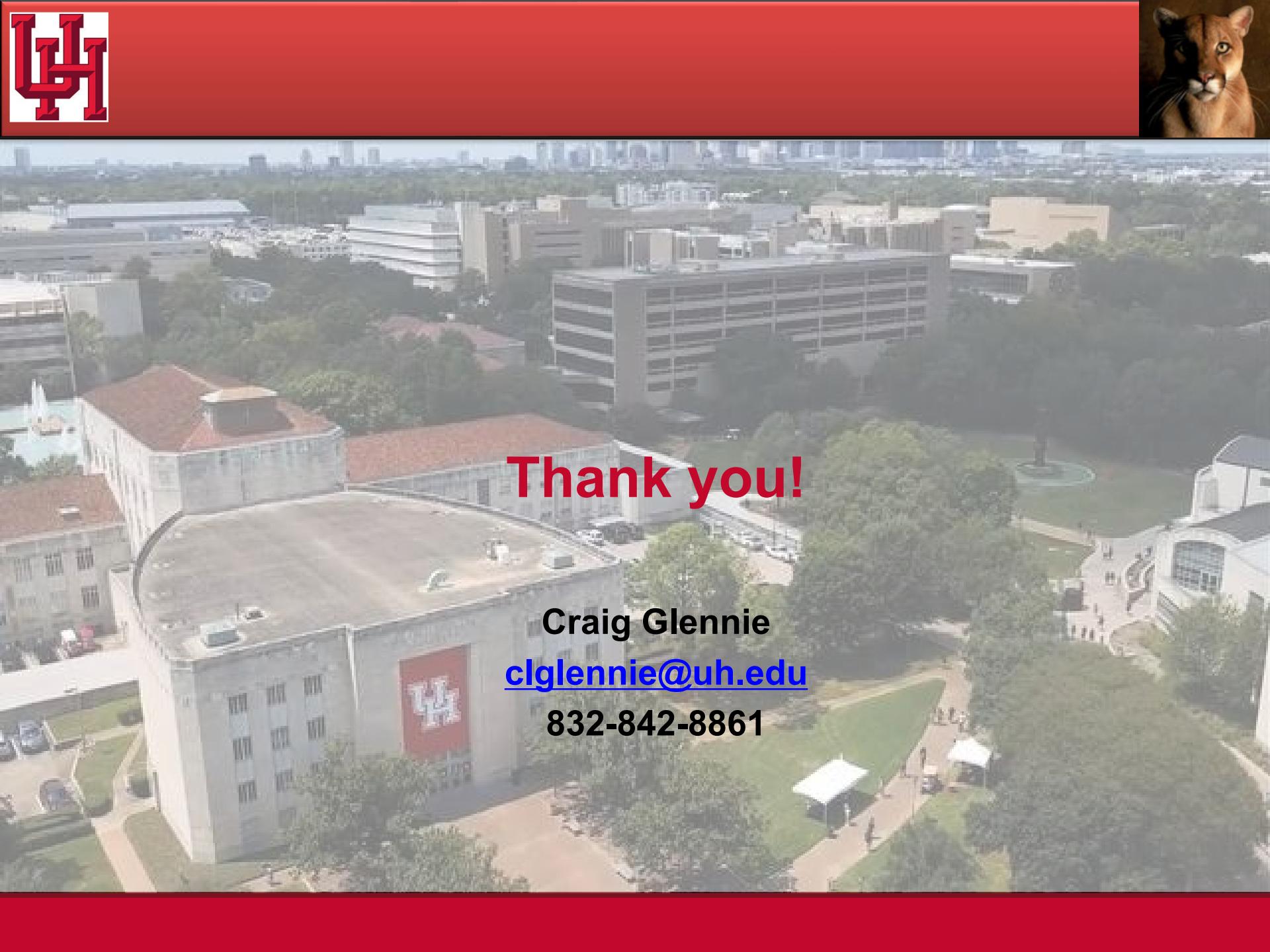
[Underwater Inspection of Navigation Structures with an Acoustic Camera, Evans et al. (USACE)]

Key idea: Deep learning for image interpretation

- Can we train a deep neural network that can make the sonar images more *interpretable*?

- What constitutes *interpretable?*
  - Color corrected
  - Improved resolution (i.e., smart interpolation)
  - Automated defect detection




Thank you!
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