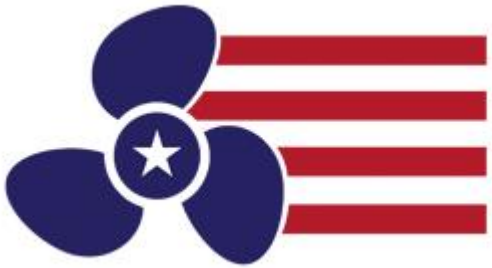


NATIONAL INSTITUTE FOR
UNDERSEA VEHICLE TECHNOLOGY

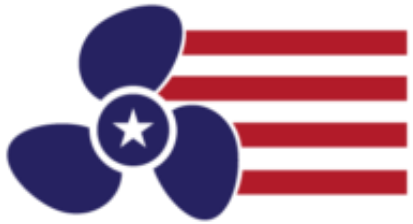
Advancing Manufacturing Processes

Manbir Sodhi

Professor

Mechanical, Industrial & Systems Engineering

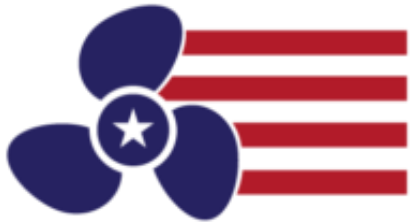
University of Rhode Island



Advancing Manufacturing Processes

Overview

- Discussion of research projects related to:
  - Process Monitoring and Optimization
  - Highly Automated Manufacturing
  - Manufacturing Systems and Operations Design
  - Operational Efficiency
  - Use of Robotics for Manufacturing Tasks
  - Design for Manufacturing and Assembly
  - Metrology



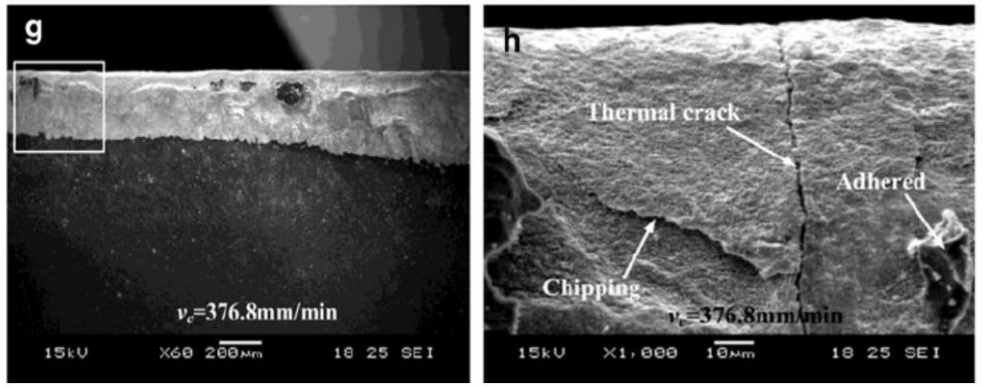
Advancing Manufacturing Processes

Research Expertise

- Work presented here will include projects led by:
  - Prof. Ashwin Dani, Assistant Professor, ELE, U.Conn
  - Chengzhi Yuan, Assistant Professor, MCISE, URI
  - Paolo Stegano, Assistant Professor, ELE, URI
  - Kunal Mankodia, Assistant Professor, ELE, URI
  - Manbir Sodhi, Professor, MCISE, URI
  - Bin Li, Assistant Professor, Computer Engineering, URI
  - Dr. Thomas Wettergren, NUWC
  - Dr. Gregory Jones, URI/NUWC
- Also working in related areas are:
  - Dr. Jay Wang, Professor, MCISE, URI
  - Dr. Valerie Maier-Speredelozzi, Associate Prof, MCISE, URI
  - Dr. Gretchen Macht, Assistant Prof., MCISE, URI

Process monitoring and optimization

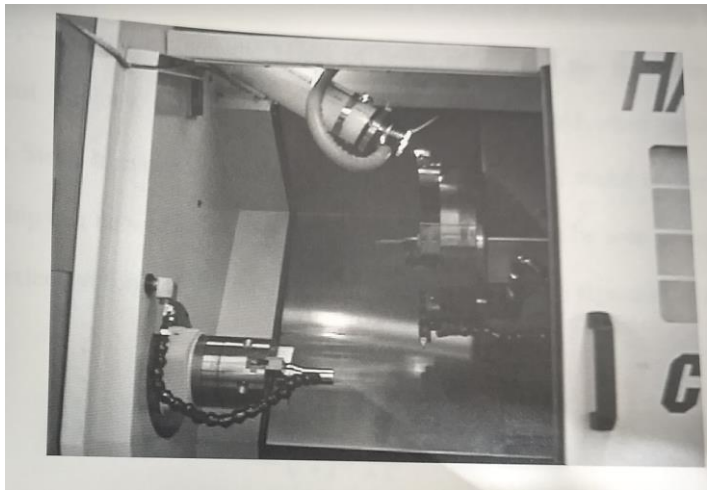
- Real time monitoring and control of manufacturing processes.
- Machining example:
  - High strength materials: Stainless steel, Ti, Nickel Alloys.
  - TiCN, AlCrN and Multi-layered coatings on tools:
    - URI – **Thin Films Lab** for developing novel coatings for machining aerospace materials.
    - Scanning Electron Microscopy (several at URI) for analyzing tool failures.
    - Elemental Mapping and Line Scan software for analysis of the distribution of elements in chips and the tools – diffusion and adhesive wear of cutting tools.
    - High resolution surface topology (Atomic Force Microscope) for characterizing tool life and wear.
  - Real time data collection:
    - URI have developed high sampling rate data collection systems:
      - Force, current, vibration and other sensors.
      - Network of sensors for distributed data collection, machine condition monitoring and reporting.
    - DOE Expertise for characterizing processing conditions.

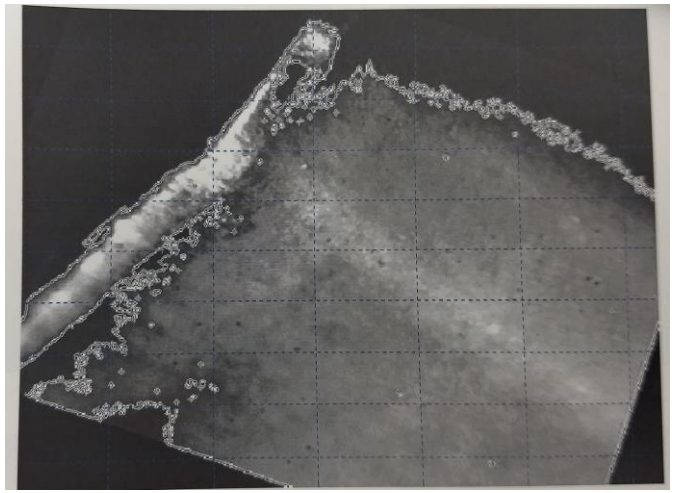


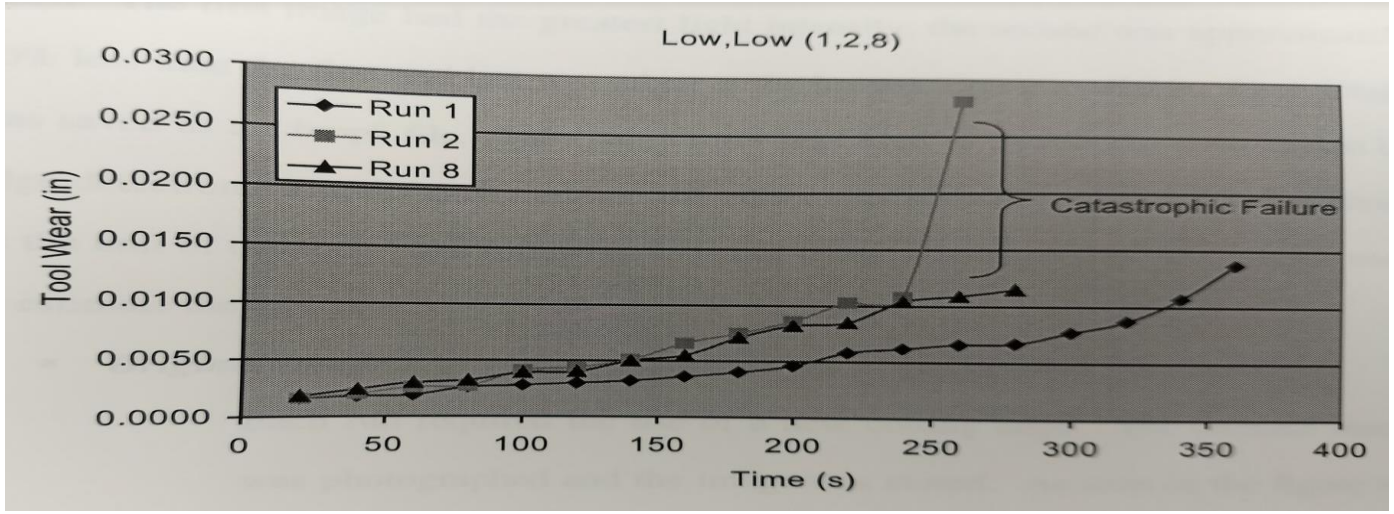
Junzhan Hou, Wei Zhou, Hongjian Duan, Guang Yang, Hongwei Xu, Ning Zhao, The International Journal of Advanced Manufacturing Technology, February 2014, Volume 70, Issue 9–12, pp 1835–1845

Process monitoring and optimization

- Tool-condition and wear monitoring.
  - Use of acoustic emission for tool condition monitoring – successfully detected wear after calibration tests.
  - Tool-wear monitoring on a CNC lathe using Computer vision.
  - Use of multiple cameras and image processing algorithms for measuring wear.
  - Improved methods for wear detection – flank and crater wear.

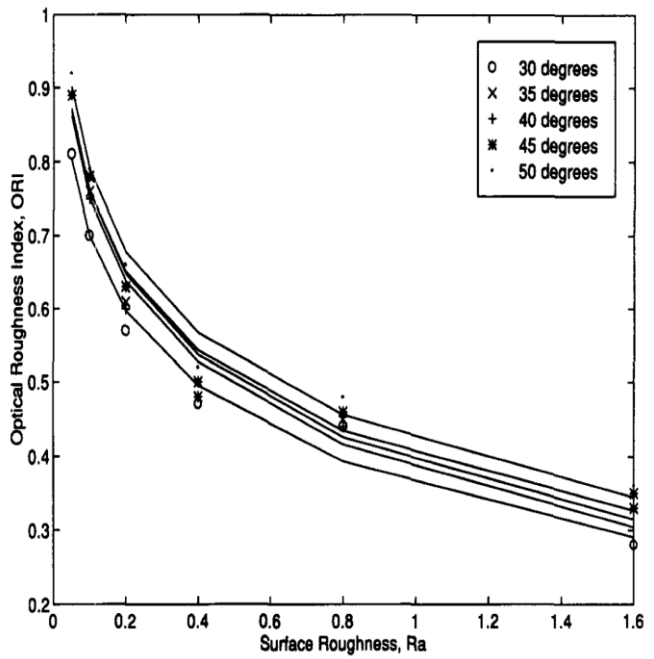


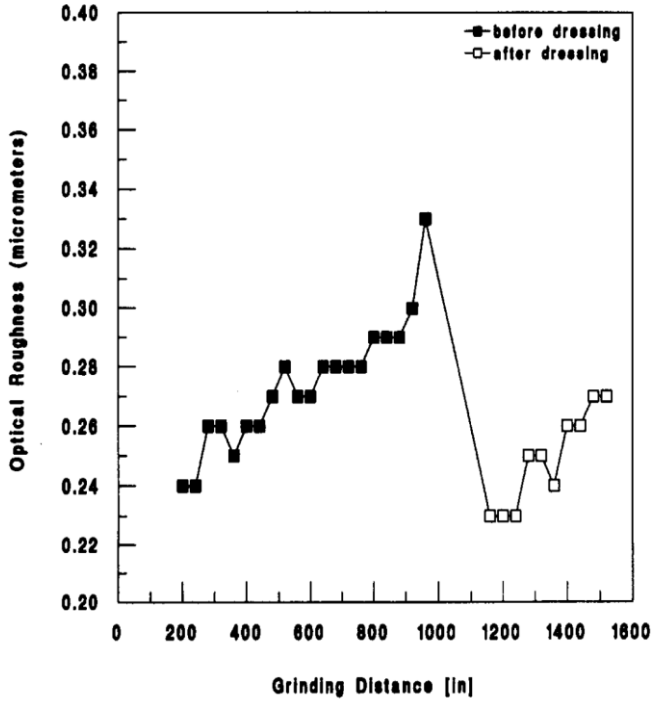




Process monitoring and optimization

- Grinding and surface roughness monitoring:
  - Wear monitoring of grinding and other finishing methods.
- Funding sources:
  - National Science Foundation.
  - Society of Manufacturing Engineers.
  - Industry



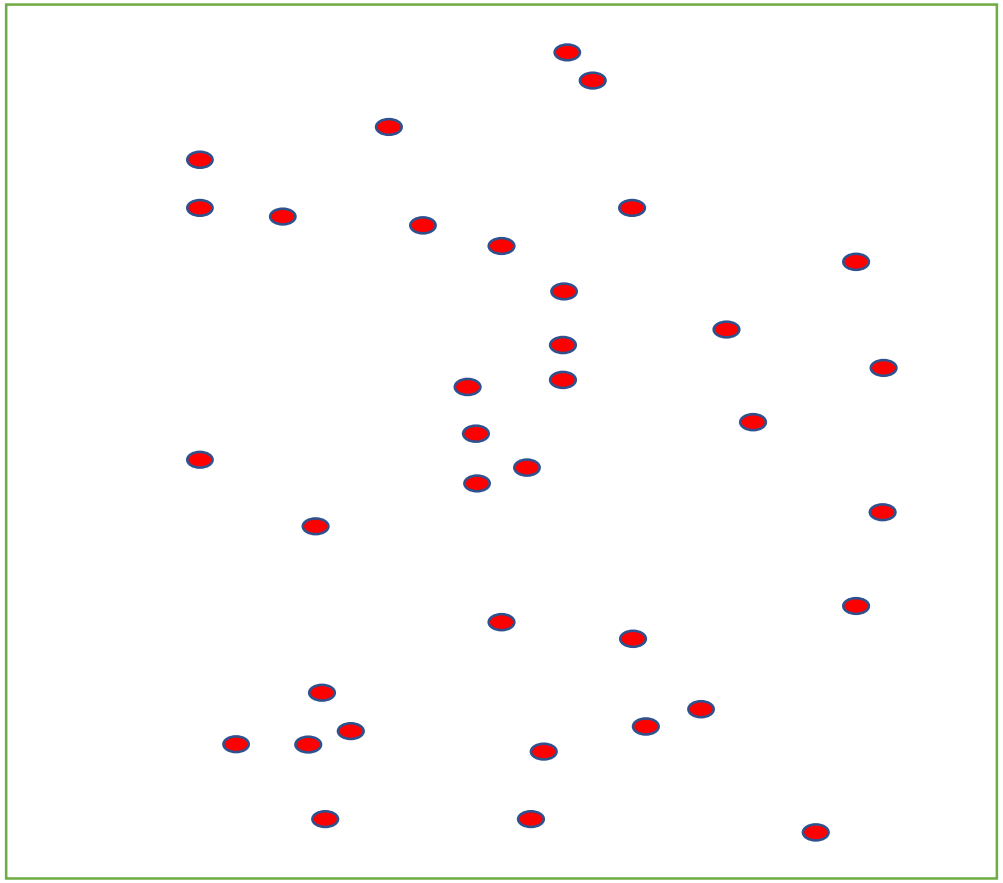


Manufacturing Systems and Operations Design

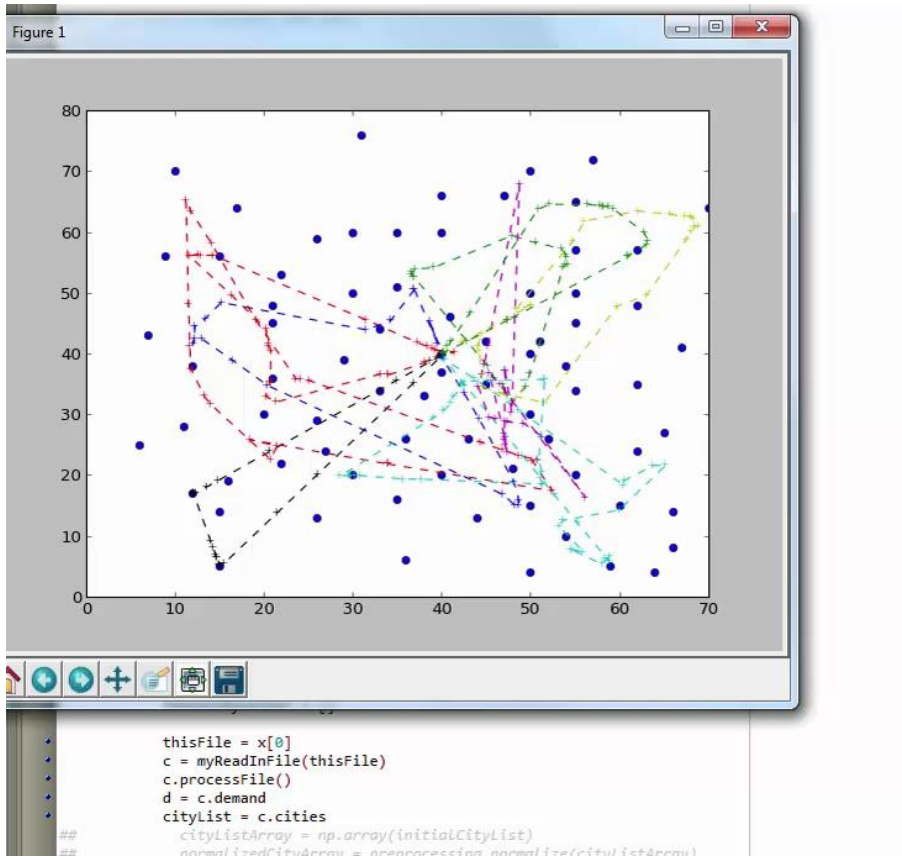
- Layout design: Fixed product considerations. Modeling workflow as traffic platoons (based on Varada K, Yuan C, Sodhi M. Multi-Vehicle Platoon Control With Time-Varying Input Delays. ASME. Dynamic Systems and Control Conference, doi:10.1115/DSCC2017-5123.)

Vehicle Routing Problems

- Critical for Manufacturing Logistics
- Occur in UV and UUV routing.
- Difficult to solve – NP Hard.
- Variety of solution approaches using:
  - Genetic Algorithms.
  - Particle Swarm based solutions.
  - Neural Networks.
  - Large scale combinatorial optimization.
  - Learning algorithms.



Advancing Manufacturing Processes

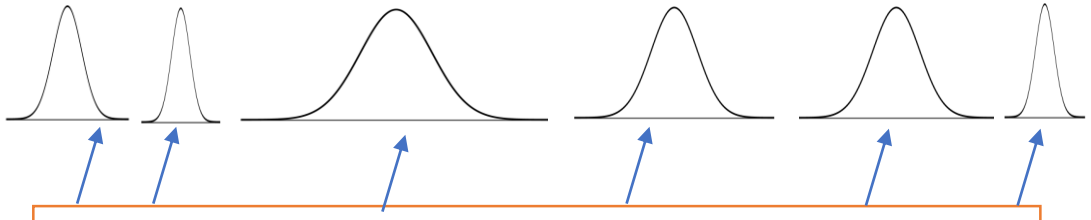


Advancing Manufacturing Processes

Highly Automated Manufacturing Systems Design

- Design of automated manufacturing lines for small/medium scale production.
- Automation for manufacturing:
  - Equipment is half the story.
  - How it is used is the other half.
    - Computer = hardware + software
  - Example from Machining:
    - Setting up a CNC for extended, unmanned operations.
      - Operations can be unreliable!
      - Tools can fail.
      - Tools wear with usage.

Highly Automated Manufacturing Systems Design



N tasks with variable times (normally distributed)

Single Machine

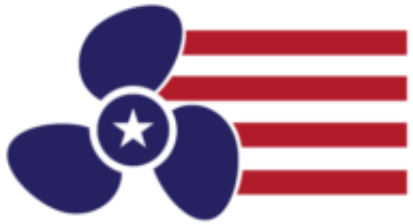
Sequence is not important.

If each job can fail – machine is blocked: Sequence is important

If each job can be processed at different rates – sequence and job processing rates are important.

If each job can be processed at different rates and machine or job can fail – sequence and job processing rates are important.

For automated operation of machines or systems, the level of analysis increases significantly - And gains from optimized operations are significant.



Advancing Manufacturing Processes

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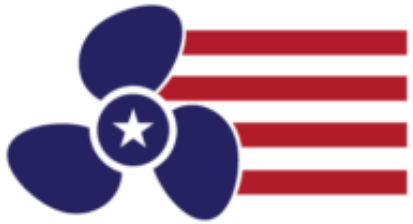
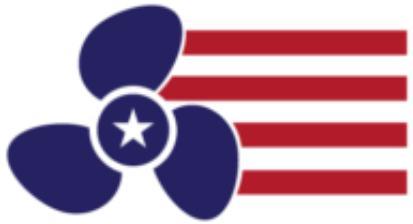


Manufacturing Systems and Operations Design

- Large scale manufacturing systems:
  - Workforce scheduling models.
  - Project planning and control (Schedule Maintenance and RePlanning Tool (SMART)) :
    - Variable & uncertain task durations.
      - Project completion estimation.
    - Limited resources.
      - Manpower capacity limits.
      - Equipment limits.
      - Budgetary limits.
  - Operations scheduling:
    - Job scheduling and sequencing.

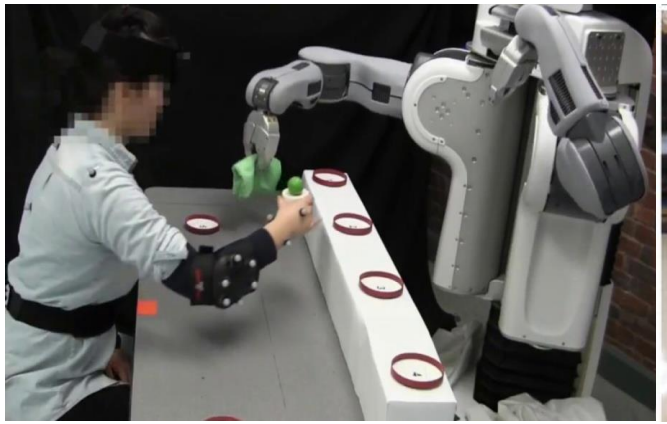


Operational Efficiency

- Location of property and people:
  - Machine utilization tracking
    - Machine state detection:
      - Sensors for : up, down, setup, idle state detection.
      - Distributed sensor based data collection.
      - Low energy sensors for sustained data collection from machines.
  - Personnel and materials location:
    - Non-GPS location.
- RFID and Computer Vision based sensing:
  - Work in progress location.
  - Personnel detection.

Using Robots for Assembly Tasks: Technologies

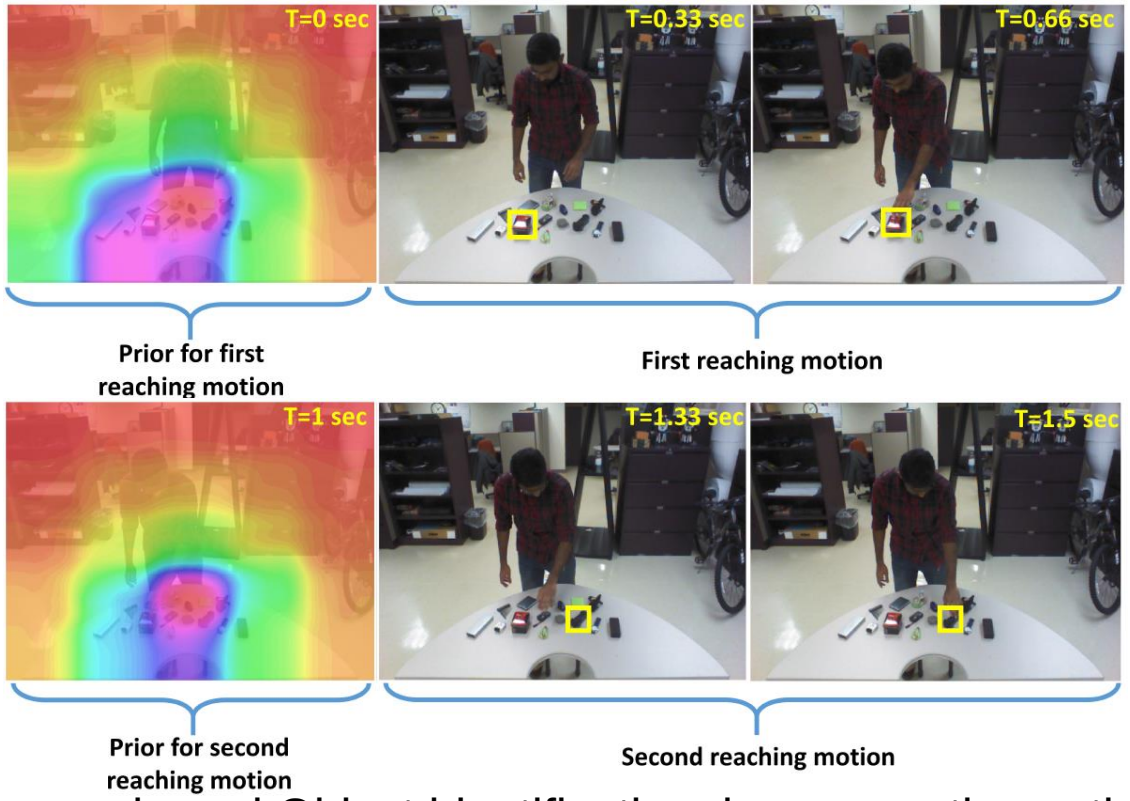
- Perception - Object Classification, type estimation and localization Human goal intention inference for collaborative assembly tasks in Manufacturing
- Easy collision free, optimal robot motion plan generation and adaptation to various tasks on different robot platforms
- Motion Planning Modules – Assembly task modeling and task allocation, path planning to execute required tasks

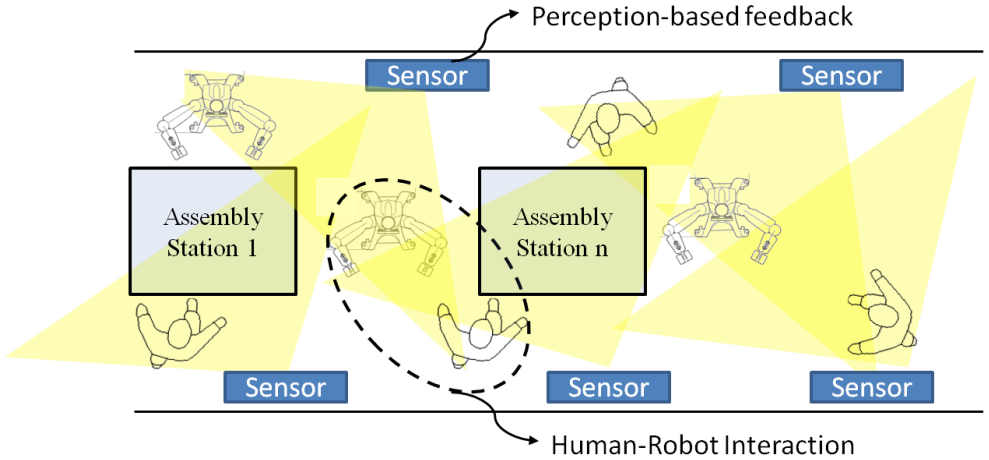




Safety, Efficiency Improvement in Collaborative Tasks are important aspects

Using Robots for Assembly Tasks: Perception Results

Perception Results



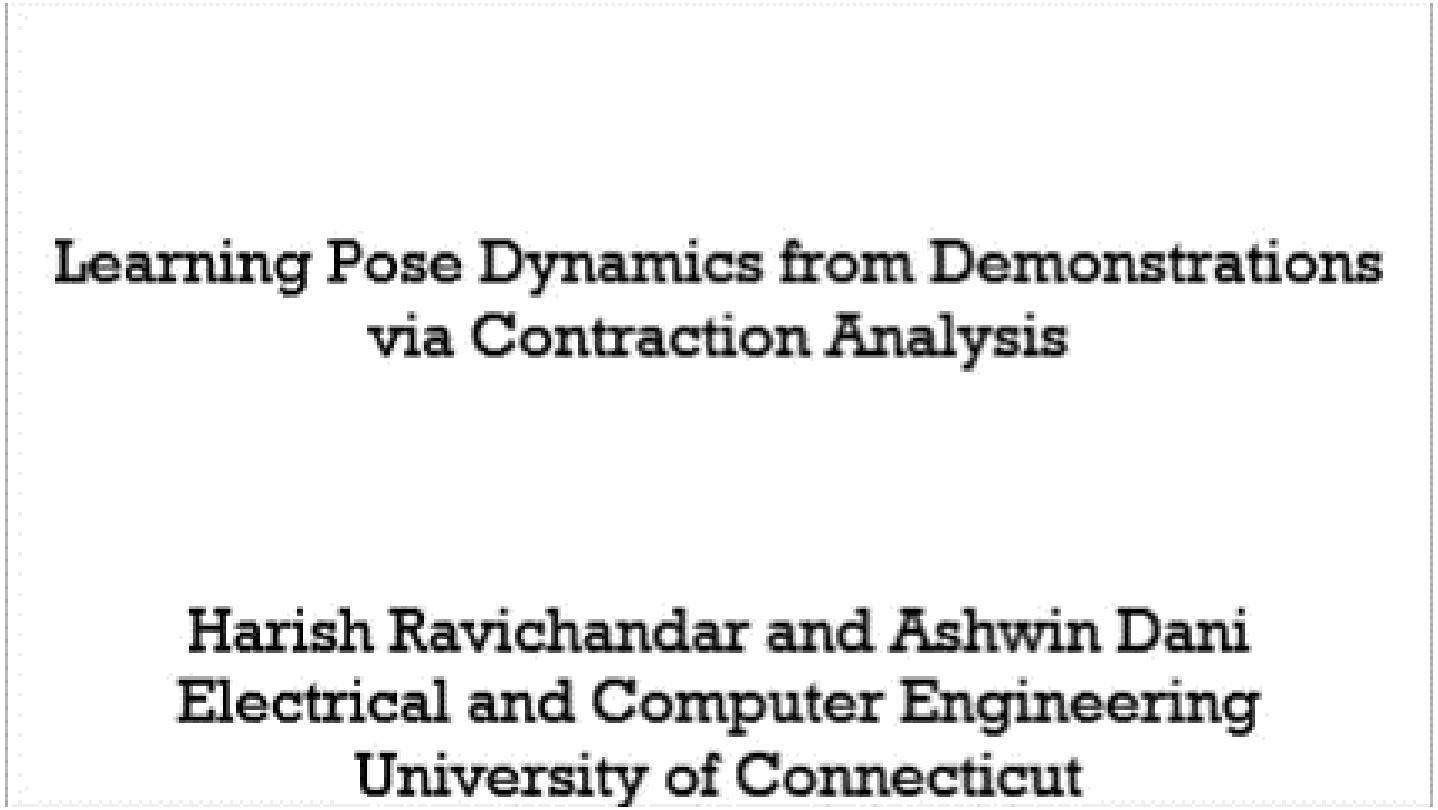


Human-Robot Teams in Manufacturing

Image-based Object identification, human motion estimation and task inference

Using Robots for Assembly Tasks

- Easy Programming of Robots and Adaptation to Various Tasks (**Dr. Ashwin Dani, UCONN**).

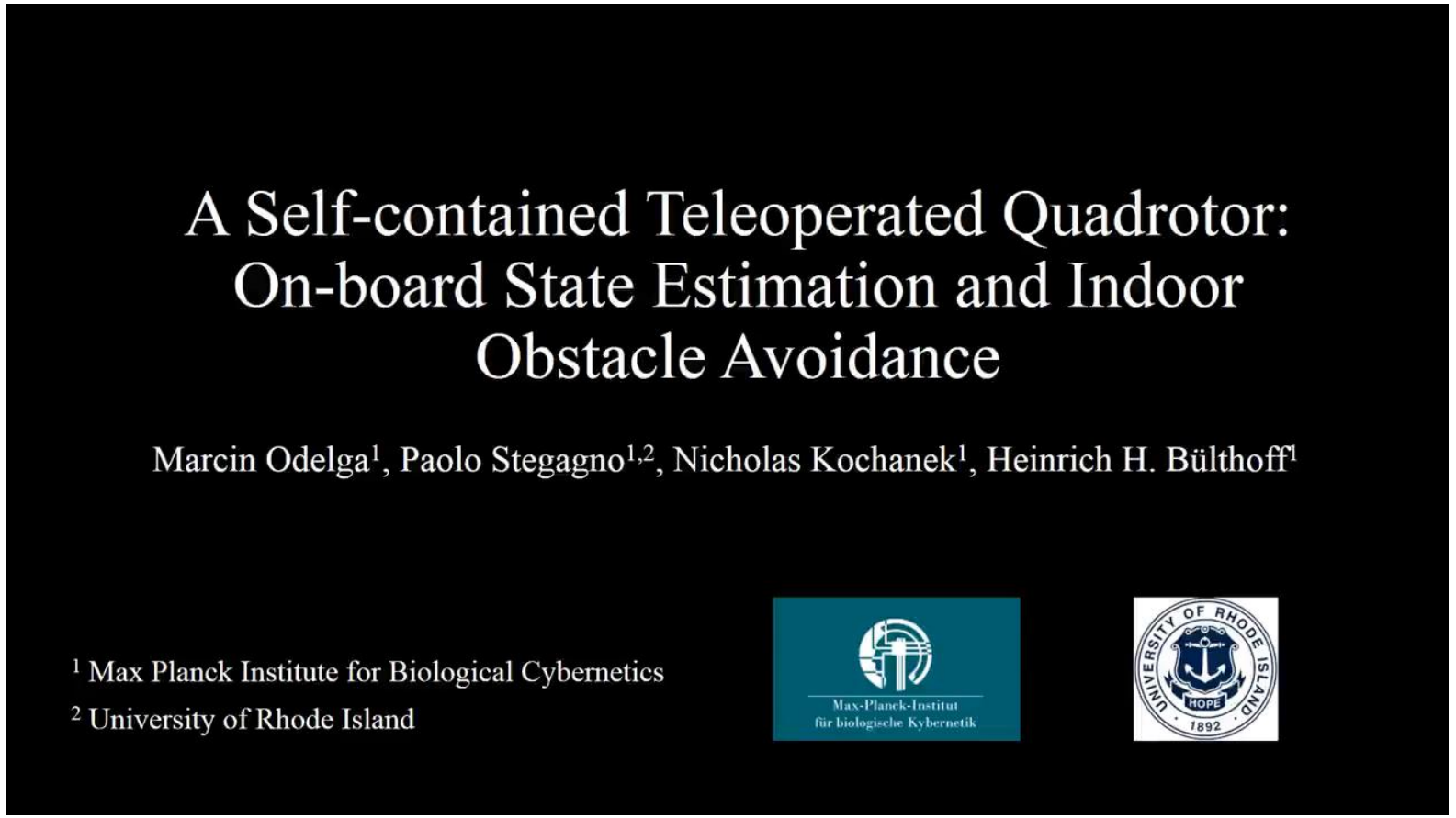


Learning Pose Dynamics from Demonstrations
via Contraction Analysis

Harish Ravichandar and Ashwin Dani
Electrical and Computer Engineering
University of Connecticut

Robotics for Manufacturing: Navigation

- Obstacle Detection and avoidance in manufacturing environments (**Dr. Paolo Stegano, URI**)

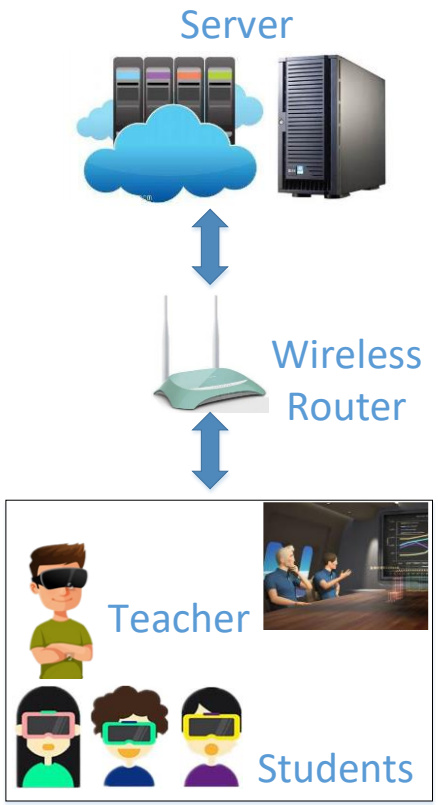


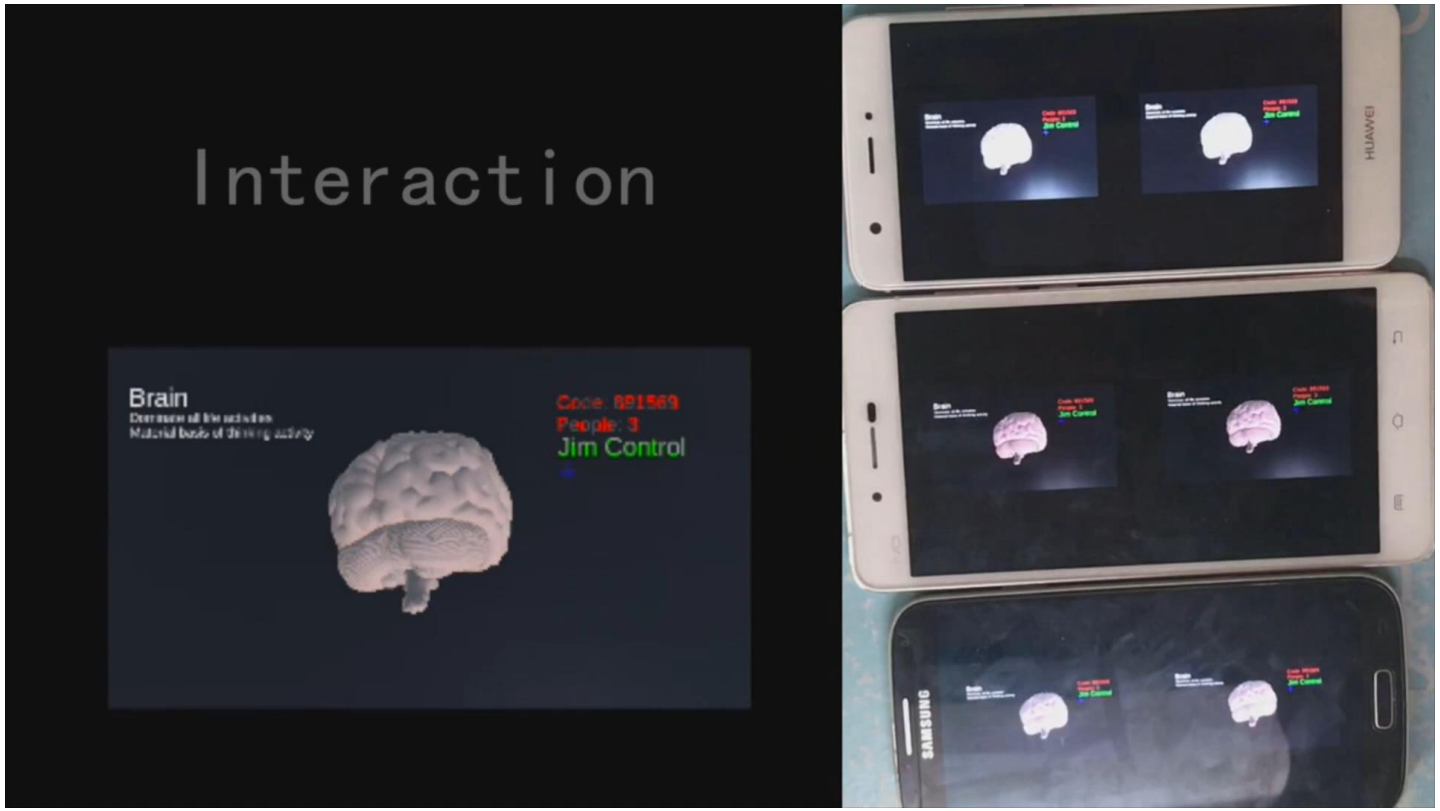
Design for Manufacturing and Assembly

- The goal of DFM/DFA is to reduce manufacturing and assembly costs by anticipating geometry related complexities.
- URI has extensive experience in DFM/DFA.
- Extensions of DFM/DFA for NIUVT
  - Design for service
  - Design for low volume production

PROCESSES	METHODS
Machining	Cost models
Joining Operations	Emergy/Energy based
Sheet Metal Operations	Overhead allocation

Augmented and Virtual Reality applications





Metrology: Measurements

- “How round is your circle ?”
- Use of high speed cameras for metrology:
  - 1000 fps cameras – data storage and processing capabilities.
  - Real time information processing – embedded systems, fog computing

    (Dr. Kunal Mankodia, Director, Wearable Systems Laboratory)
  - Multi-camera metrology – Geometry measurement, data clouds with uncertainty.

    (collaboration with Dr. Rainer Tutsch, TU-Braunschweig).