A Proactive Approach to Managing Contingencies during Human Robot Collaboration in Manufacturing
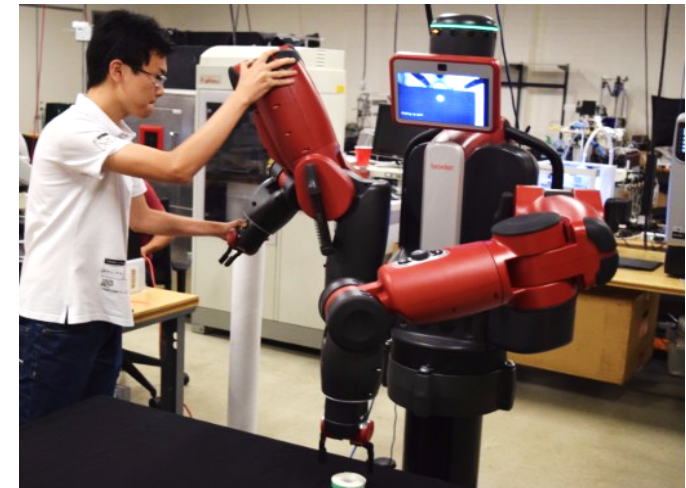
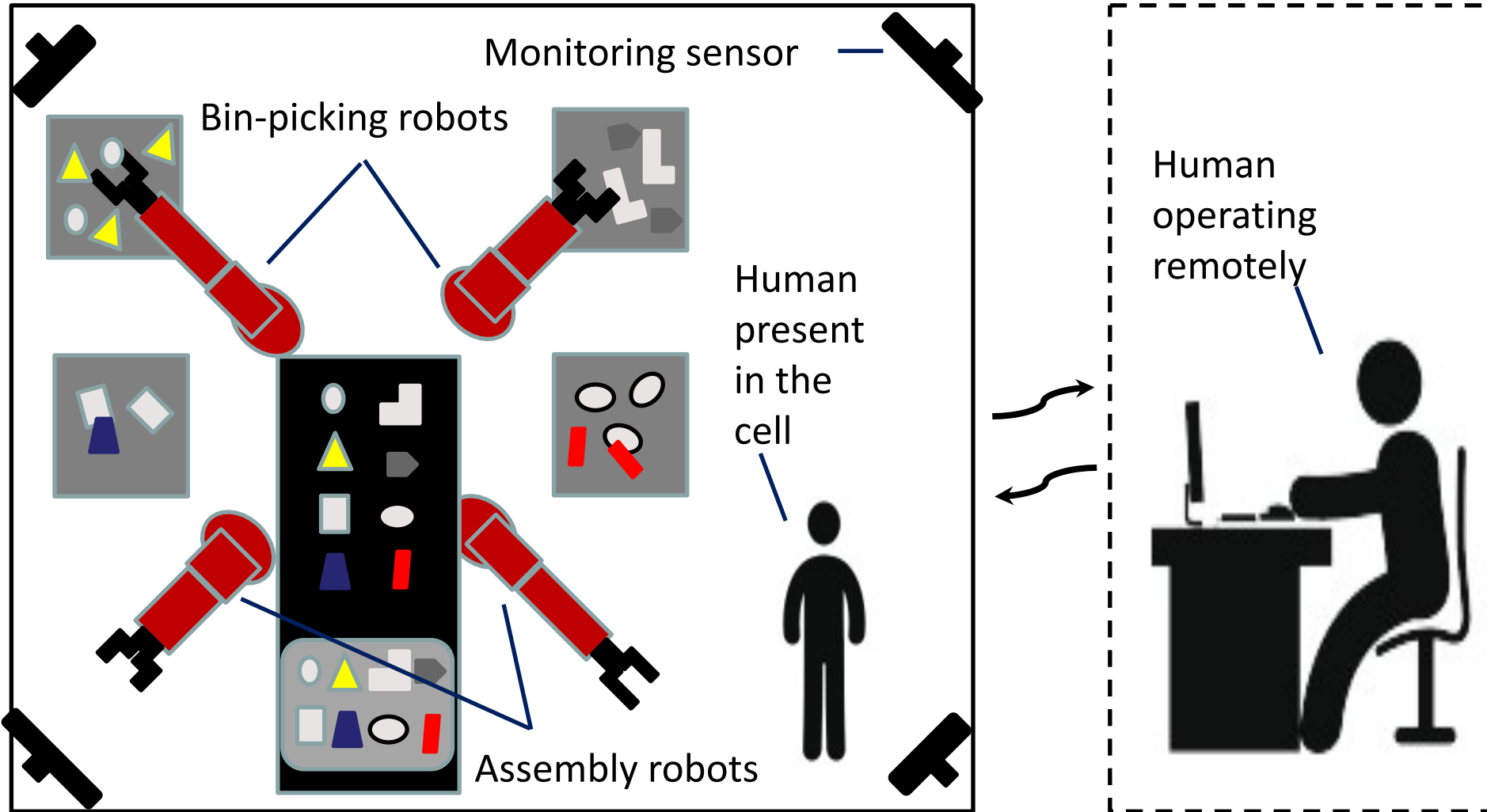## Satyandra K. Gupta, University of Southern California; NSF Award # 1634431

- Robots are currently not used in small volume production runs
- Human-safe industrial robots present an opportunity for creating hybrid work cells
- Deployment of hybrid cells will require proactive management of contingencies

Hybrid Cells

Goals

- Task planning and resource allocation algorithms that explicitly account for managing contingencies

- Computational foundations for real-time monitoring of the task progress during the execution to ensure that tasks are completed in a safe and efficient manner

- Real-time replanning algorithms to handle contingencies and refining plans based on the observed task execution performance

- Methods for information exchange between humans and robots to deal with contingencies

Overview of Approach

Cell Monitoring:
— Tracking human using multi-Kinect tracking system
— Monitoring robot state using joint angles and torque
— Monitoring state of the part using sensors

Automated Planning:
— Geometric reasoning for precedence constraint generation and discrete optimization for task sequencing
— Search-based trajectory planning

Human-robot Interaction:
— Introspection capabilities for getting help from humans
— Augmented reality-based interface for operating with robots

Application: — Finishing — Assembly
— Kitting & Bin Picking

- Monitor system state and re-plan to handle contingencies

- Use contact-based probing to reduce uncertainties in part pose provided by vision-based perception system

- Make adjustments to sequence in real-time

- Reassign tasks

- Issue warning and error messages to human operators

Human robot collaboration during assembly task

Using Introspection to Seek Help from Humans

- Automated perception to estimate part location in the bin and associated uncertainty

- Extraction planning to remove the part from the bin using estimated uncertainty

- If the task completion confidence is low, then the system seeks help from the human operator using Expert-on-Call Concept
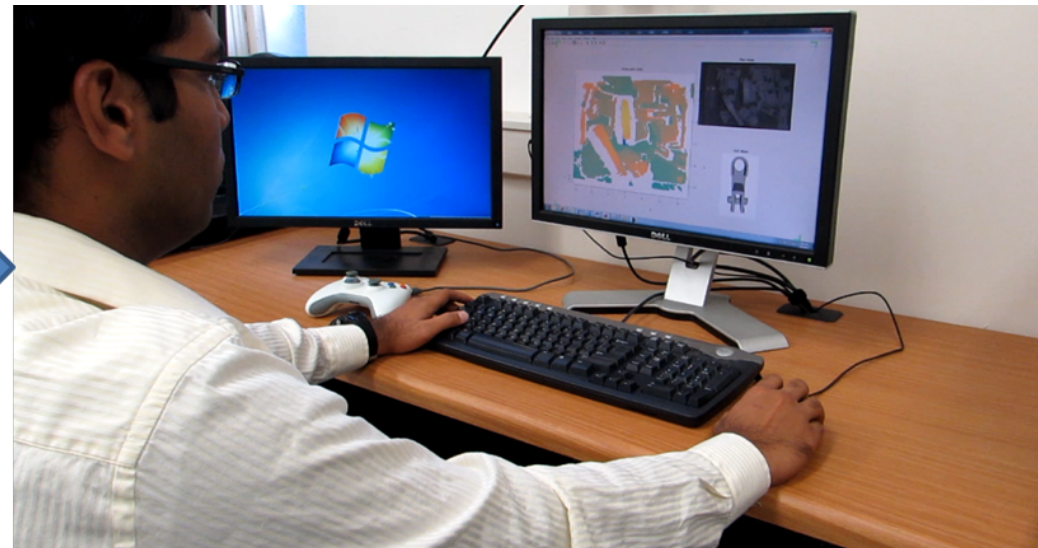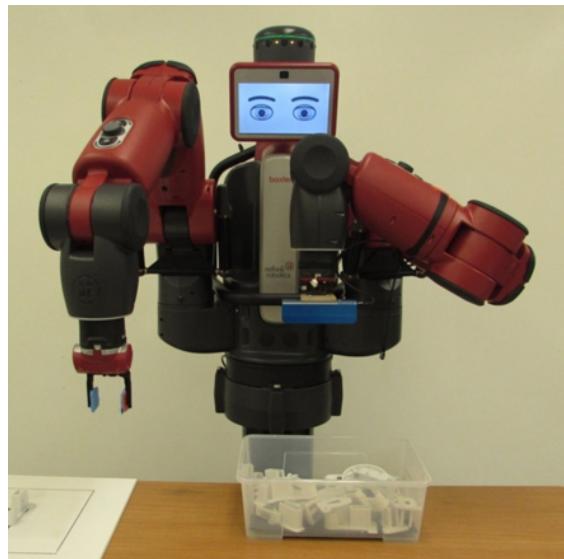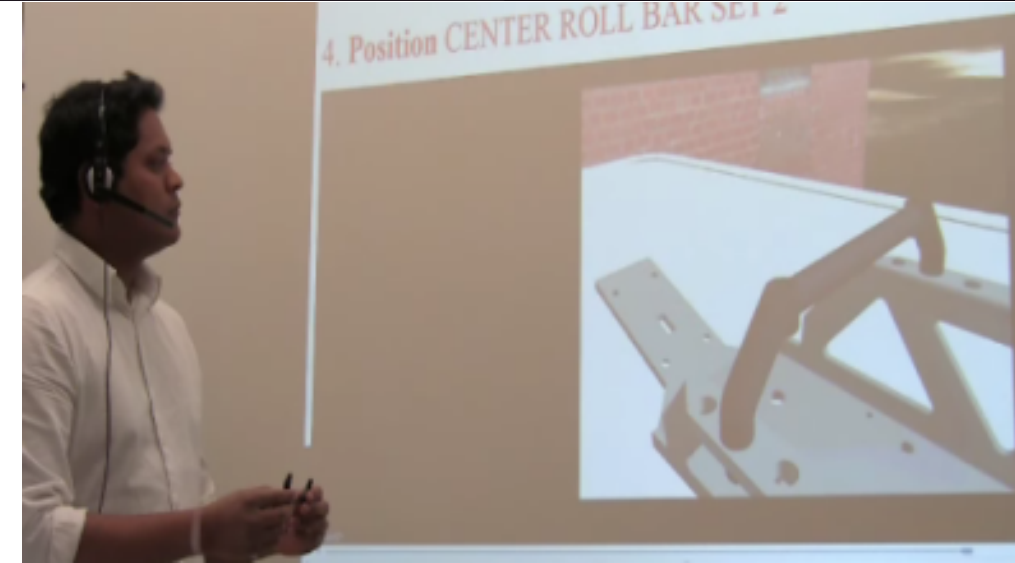
- Augmented reality based interfaces to facilitate information exchange between humans and robots
  - Display safety zones
  - Confirm instructions given by humans
  - Display errors and warnings
  - Display internal system states and enable humans to diagnose problems
- Level of detail control based on the context to prevent cognitive overload for humans
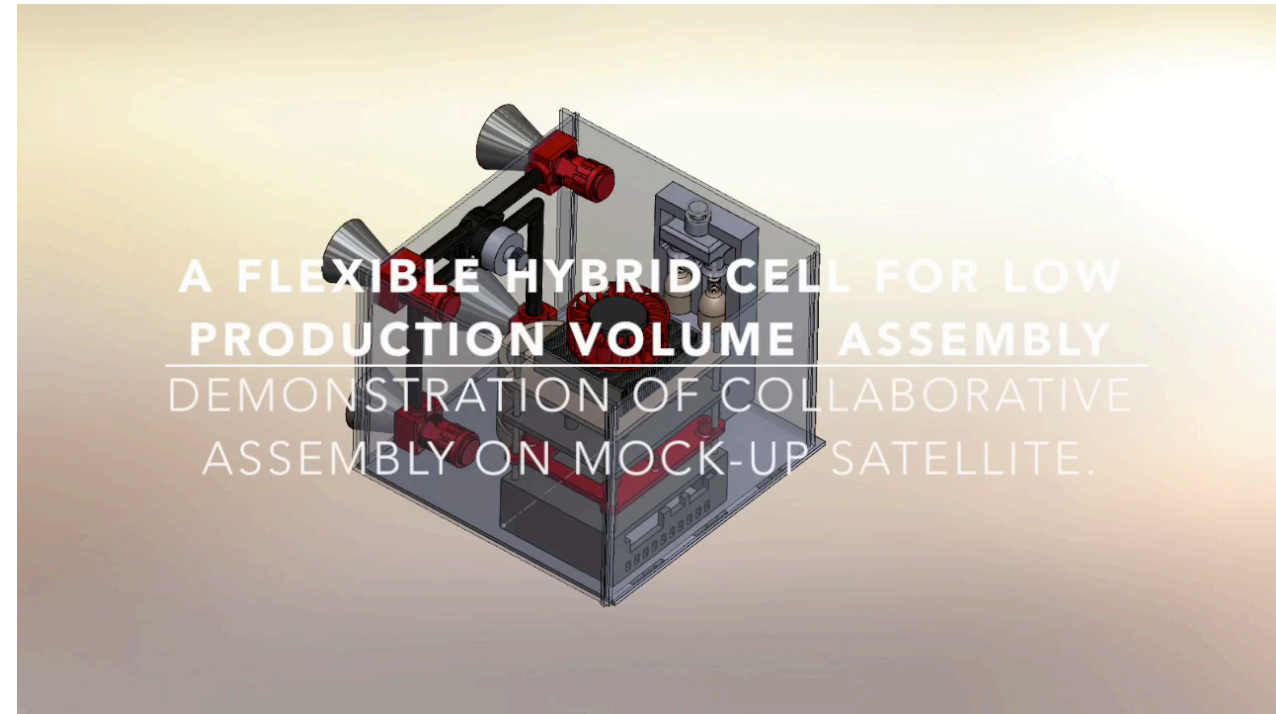
Assembly Application

- Automatically generate robot trajectories for assembly

- Synthesize impedance controllers based on estimated uncertainty to ensure collision free operation

- Seek help from humans when operation is not feasible

A FLEXIBLE HYBRID CELL FOR LOW PRODUCTION VOLUME ASSEMBLY
DEMONSTRATION OF COLLABORATIVE ASSEMBLY ON MOCK-UP SATELLITE.

Broader Impacts

- Introduce robotics in small volume operations and make manufacturing cost competitive in US

- Participated is ARIAC competition organized by NIST

- Enhanced robotics and manufacturing curricula by incorporating research results into graduate course on Manufacturing Automation and undergraduate course on robotics

- Outreach activities for K-12 students to educate and inform them about career opportunities in robotics and manufacturing