Changing Perceptions of Robotics in Industry: Recent Accomplishment in Safety and Injury Risk Reduction

Amir Yazdani

Andrew Merryweather

Laboratory of ERGONOMICS AND SAFETY THE UNIVERSITY OF UTAH

LL4MA LAB THE UNIVERSITY OF UTAH

ROBOTICS CENTER THE UNIVERSITY OF UTAH

National Occupational Injury Research Symposium (NOIRS) 2018

Current status

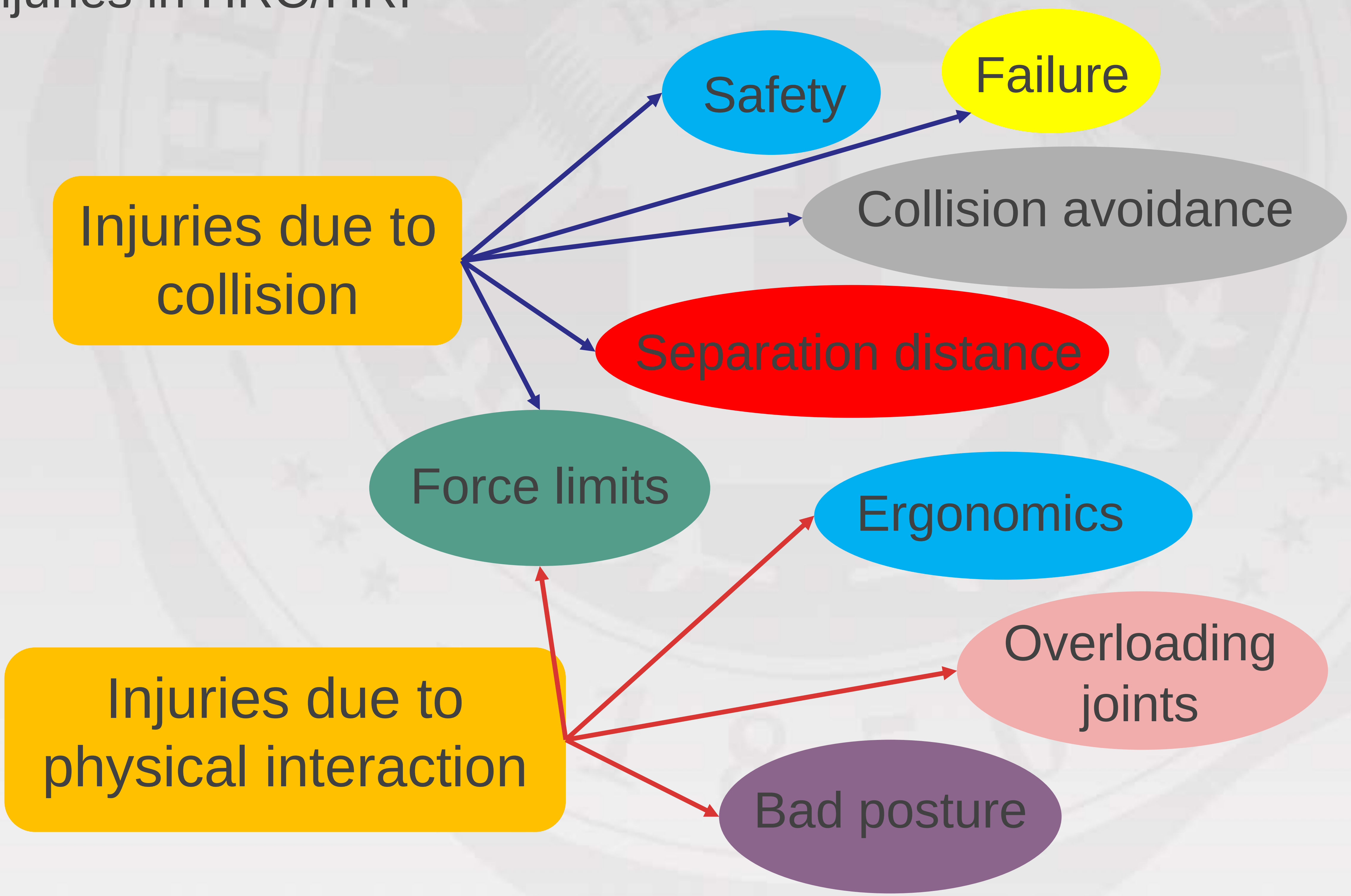
- Robots and cobots in industries

OSHA report:
- Total of 39 incidents in USA from 1984
- 28 of those include fatalities

Image courtesy of Forester

Image courtesy of ASU

Injuries in HRC/HRI



Old/Current Solutions

Limit physical interaction of human worker with robots

- Fences
- Emergency stops
- Limiting force and speed

Image courtesy of Wire Crafters

Collaborative Robots

- Intelligent controllers
- Safety features
- Human awareness and partnership
- Ease of use
- Human demonstration

Image courtesy of Active8 Robots

Near Future Solution

Intelligent Collaborative Robots

- Considering biomechanics and ergonomics
- Artificial intelligence
- Robot learning and perception
- Predicting of human motion and intention
- Re-planning and adapting motion to human motion

Image courtesy of Istituto Italiano di Tecnologia (IIT)

Collaboration in research

Robotics community

- Motion planning
- Obstacle avoidance
- Position/velocity/force control
- Estimation and prediction
- Artificial intelligence
- Haptic feedback
- Decision making

Ergonomics, safety & biomechanics community

- Biomechanics
- Musculoskeletal model
- Posture
- Ergonomics
- Risk
- Safety
- Injury

Image courtesy of NIOSH

Ergonomics in HRC

- Help human to do task in a more comfortable and ergonomic way

Collaborative tasks
- Handover
- Transportation
- Assistance in task

Chen, 2018

Peternel, 2018

Kim, 2018

Ergonomics in HRC

- Sub-problems
  - Dynamic monitoring of human body
    - Motion capture/ markerless tracking
  - Ergonomics evaluation during a HRC task
    - Peripersonal space comfort (Chen, 2018)
    - Overloading torque in human joints (Peternal, 2018)
  - Leads human toward a more ergonomic pose
    - Optimization-based planning (Chen, 2018)

Ergonomics in HRC

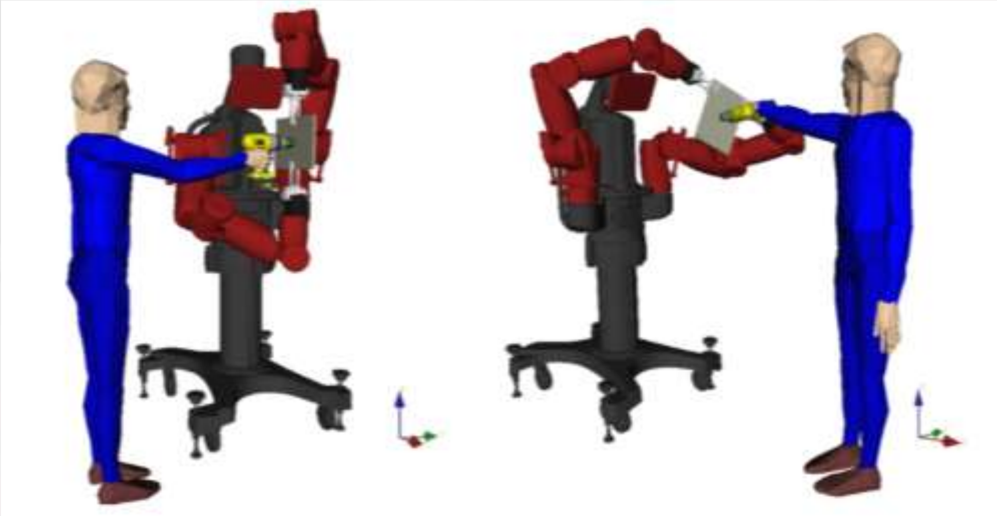
Peripersonal space comfort

Hold the object in a way that maximizes the distance of human to robot

Suggested indices:

- Minimum distance
- Average distance
- Weighted distance

Chen, 2018



(c) Muscular planner (d) Peripersonal planner

Ergonomics in HRC

Overloading torque in human joints

- Quasi-static model of human body (Chen, 2018)

Torque limits are related to { Pose and configuration; Direction of motion }

- Dynamic model of human body

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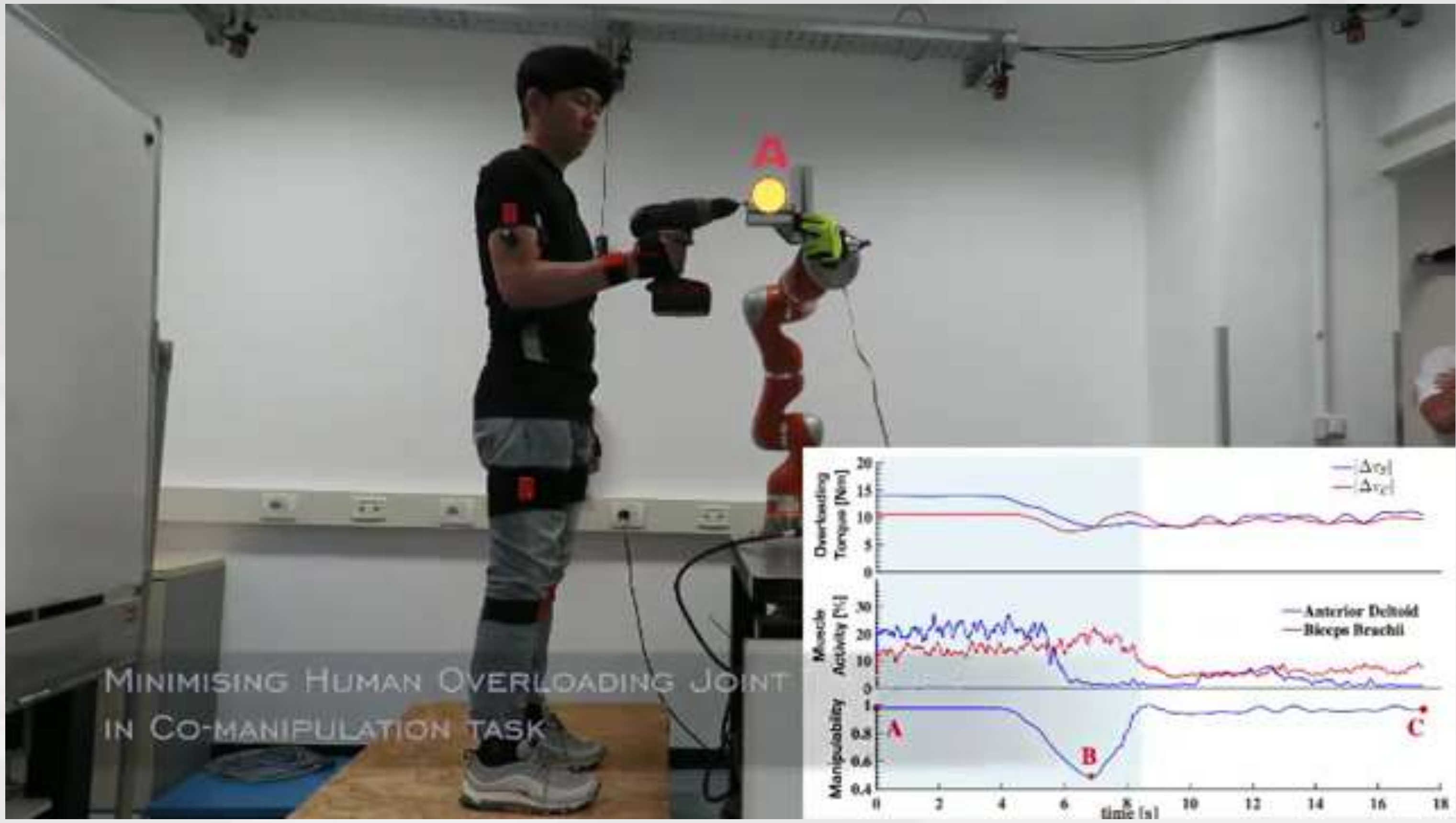
Ergonomics in HRC

Overloading torque in human joints

- Quasi-static model of human body (Chen, 2018)
- Dynamic model of human body

- Derivation of COP
  - Static/dynamic model of human body
  - Measure COP from a force place or insoles (Kim, 2018)
  - Estimate COP from a dynamic model including the effect of external load (Peternel, 2018)



Peternel, 2018

Ergonomics in HRC

Adapting to human fatigue during a task

- Adjust speed of work using model-based muscle fatigue (Sadrfaridpour, 2016)
    - No physical interaction
- An online machine learning algorithm to adapt robot trajectory with a force-impedance controller (Peternal, 2016)
    - Modeled fatigue as a response of a RC circuit

Peternal, 2016

Ergonomics in HRC

Challenges:

- Dynamic model of human motion
- Estimate human posture
- Prediction of human motion and intent
- Metrics for ergonomics and human comfort
- Include human personal factors

Ergonomics in HRC

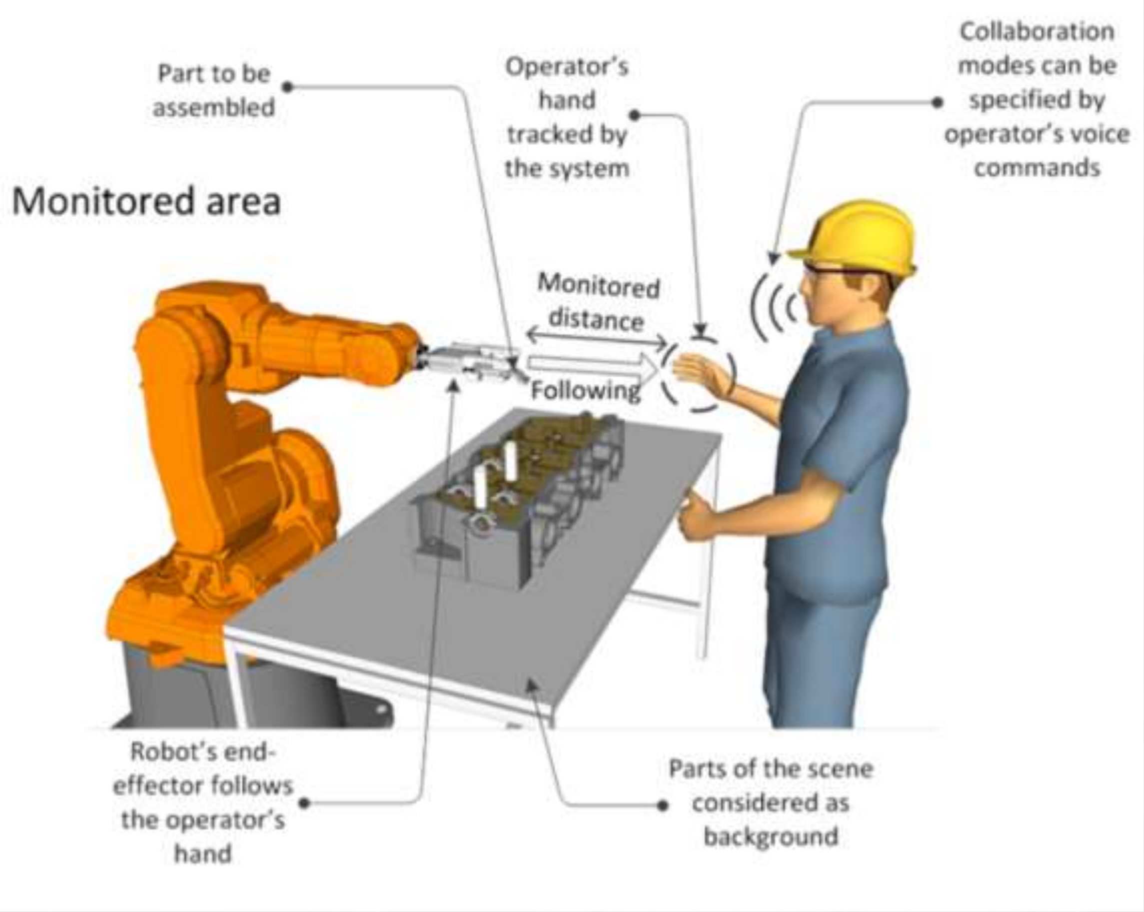
Research ideas and opportunities:

- Dynamic model of human motion
  - Muscles activation
  - Nonlinearity of muscles and their relative relations
  - Interacting behavior
- Estimate human posture
  - Use robot as the sensor
- Prediction of human motion and intent
  - Prediction of fatigue from task and dynamics
- Metrics for ergonomics and human comfort
  - Dynamic metrics including time
- Include human personal factors
  - Weakness and pain in muscles
  - User preferences in doing tasks

Safety in HRC

Safe motion planning

- Monitor human motion
  - Motion capture/markerless tracking
- Predict human motion
  - Learning algorithms
- Avoid collision with human
  - Replanning algorithms such as MPC
- Maintain safety criteria (ISO/TS 15066:2016)
  - Minimum separation distance
  - Relative velocity



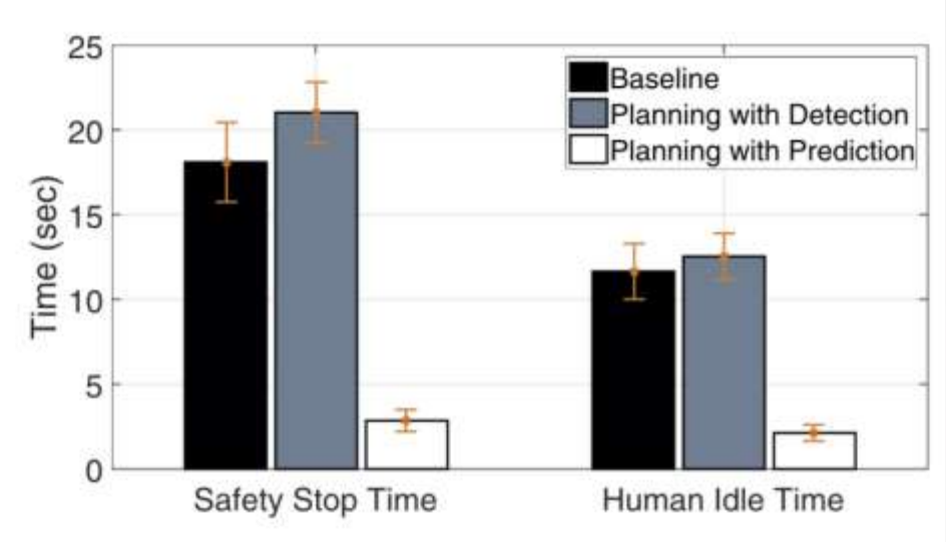
Symbiotic project

Safety in HRC

Human motion prediction

- Supervised learning
  - Inverse optimal control (Mainprice, 2015)
  - Bayesian classification (D'Arpin, 2015) (Fisac 2018)
- Unsupervised learning
  - Gaussian mixture model (GMM) (Luo, 2018)
- Modeling as time series
  - Predicting elbow joint angles in repetitive tasks (Wang, 2018)
- Effect of environmental constraints
  - Object affordance (Koppula, 2013)
  - Intent-aware prediction (Karasev, 2016)

Mainprice, 2015



Unhelkar, 2018

Safety in HRC

Challenges

- Safety metrics
  - Reliable
  - Realistic
  - Human dynamics
  - Robot characteristics
- Human motion prediction
  - More accurate
  - Longer prediction time
- Motion planning algorithms
  - Time complexity
  - Efficiency

Safety in HRC

Research ideas and opportunities:

- Safety metrics
  - Prediction of human motion and intention
  - Uncertainty of human motion
  - Muscle activation during collision
  - Include injury model of collision

- More reliable human motion prediction
  - Reaction of human close to have collision
  - Add personal characteristics into prediction
    - Reaction time
    - Personal preferences in motion

Our researches in The University of Utah

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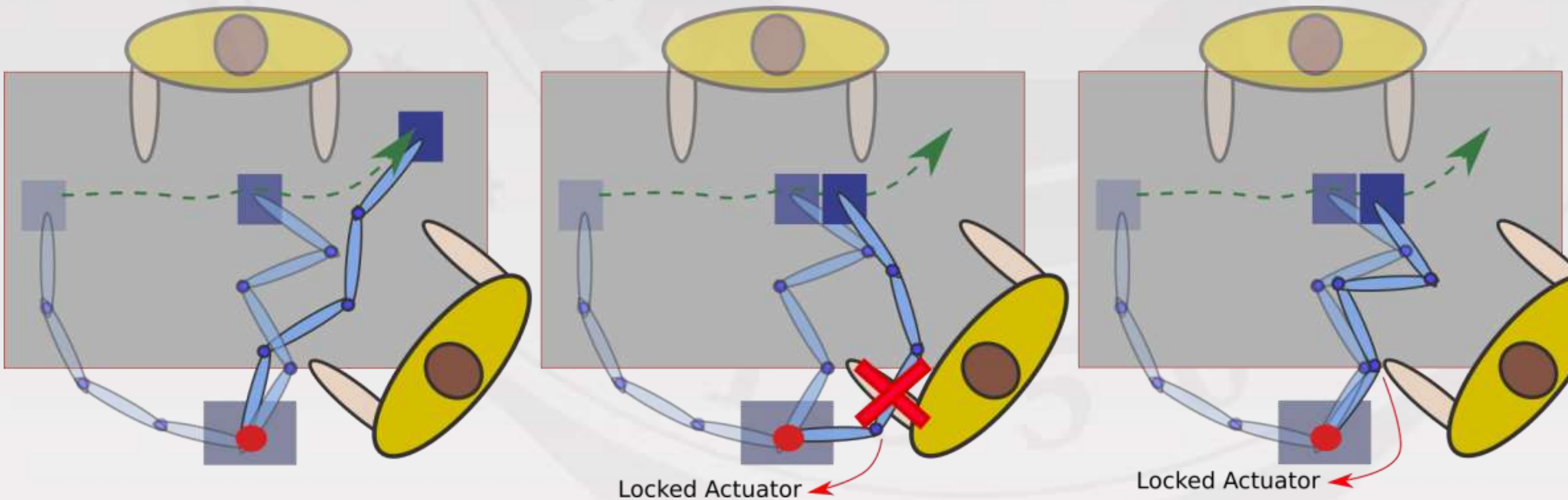
Rocky Mountain Center for
Occupational & Environmental Health

National Institute for Occupational Safety and Health
NIOSH

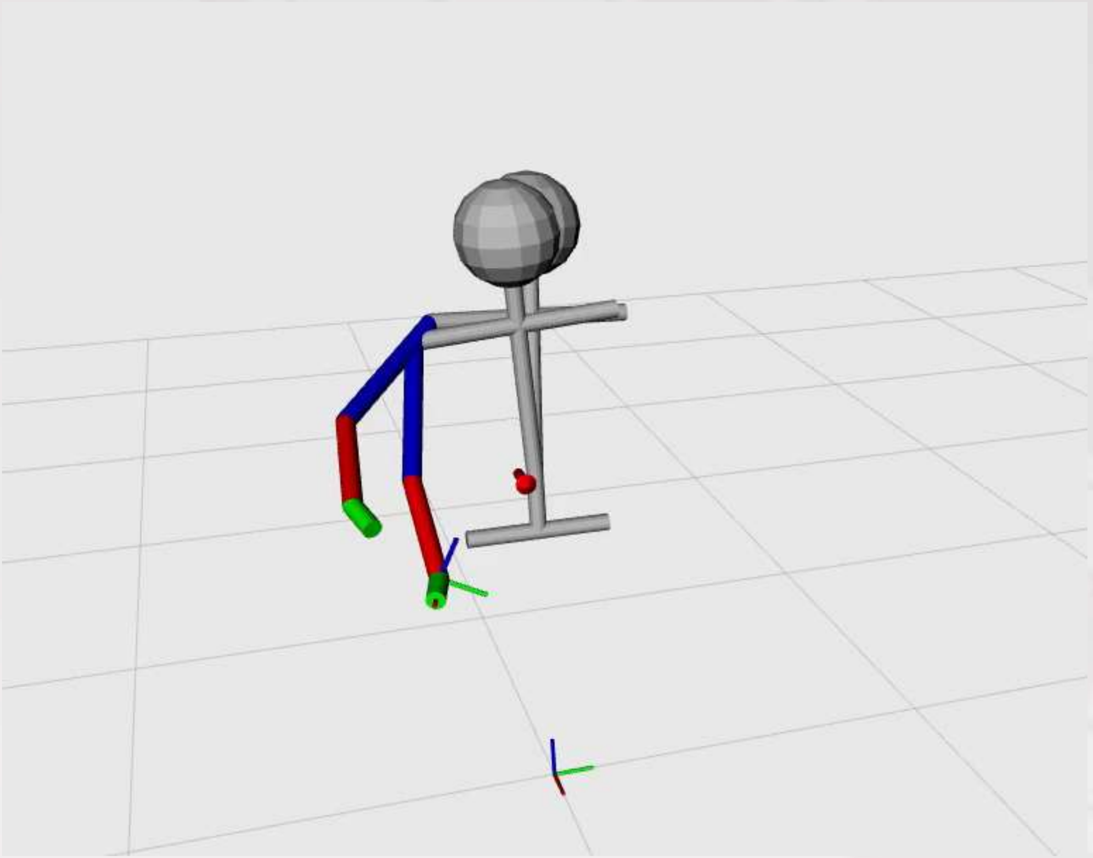
Our researches in The University of Utah

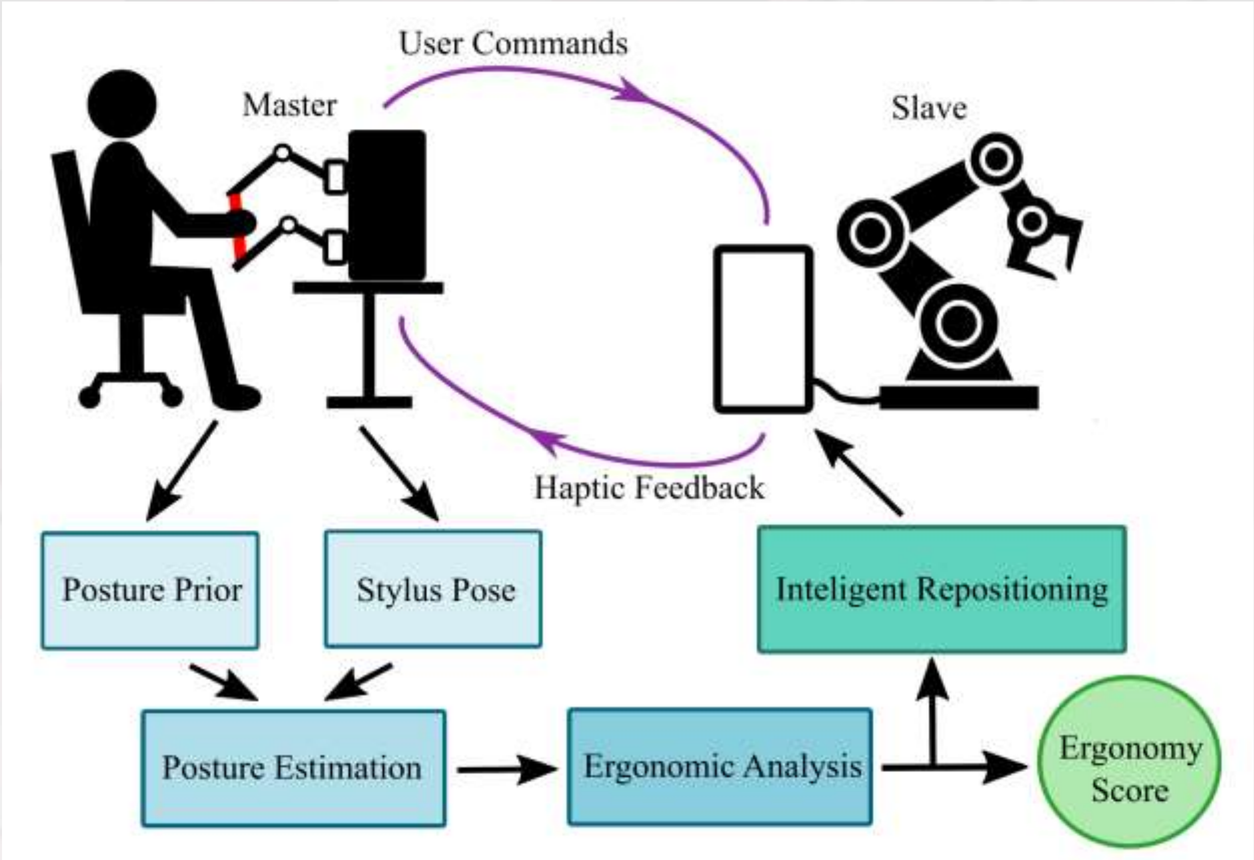
- MPC-based failure tolerant re-planning motion of robots to improve human safety in a shared autonomy



Our researches in The University of Utah

- Posture estimation of human upper body in telemanipulation tasks from a haptic-input device





Our researches in The University of Utah

- Dynamics Model Learning and Manipulation Planning for Objects in Hospitals using a Patient Assistant Mobile (PAM) Robot

Thanks

Questions?