An Image Guided Surgical Robot: High Precision Drill/Needle Placement with the UR5 using 3D-2D Image Registration

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Team Members and Mentors

Team Members

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Biomedical Engineering 2017
Computer Science 2017

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Biomedical Engineering 2017
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Mentors

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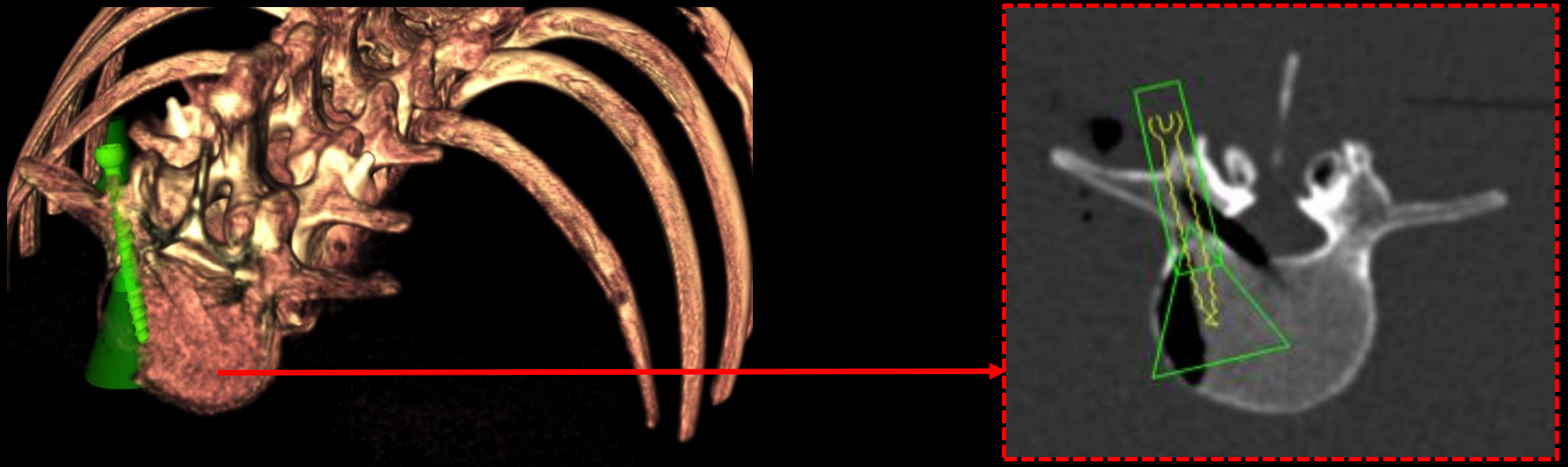
* Presentation photos courtesy of I-STAR Lab

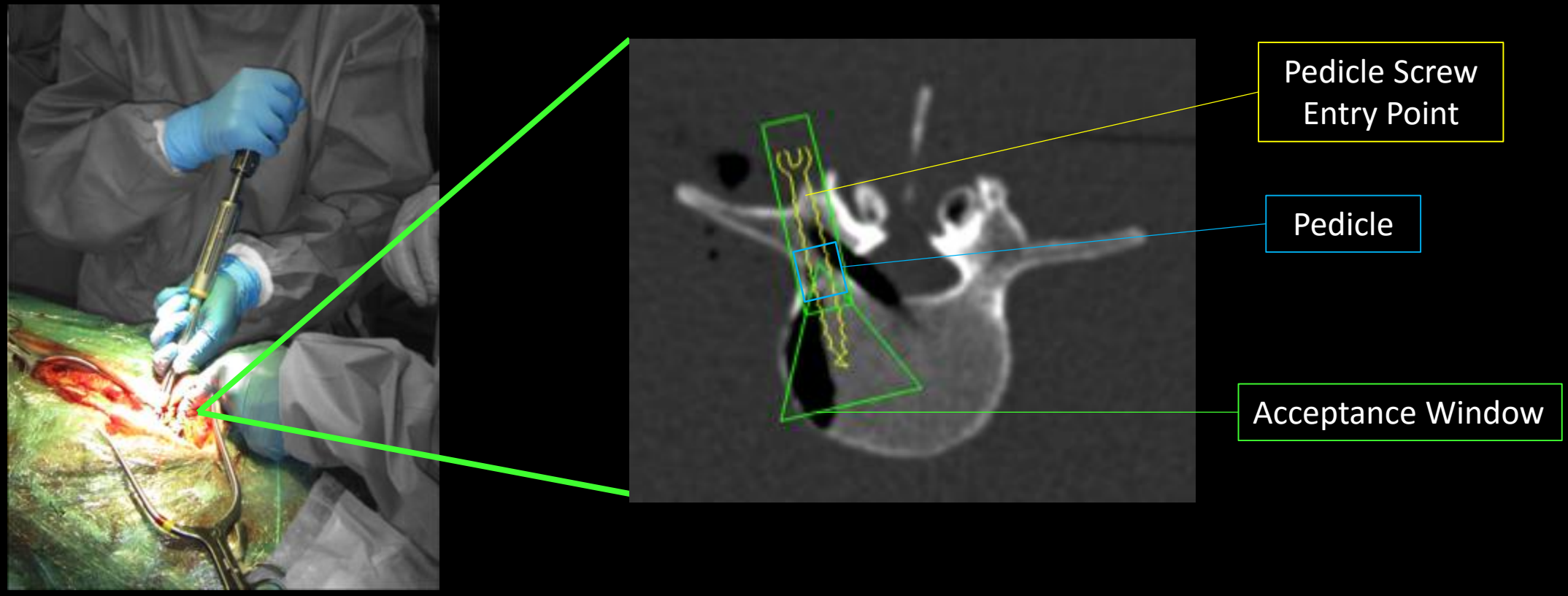
Background and Motivation

- A better future in pedicle screw procedures
- Current complications…
  - Screw dislodgement, accidental breach into spinal cord, etc.



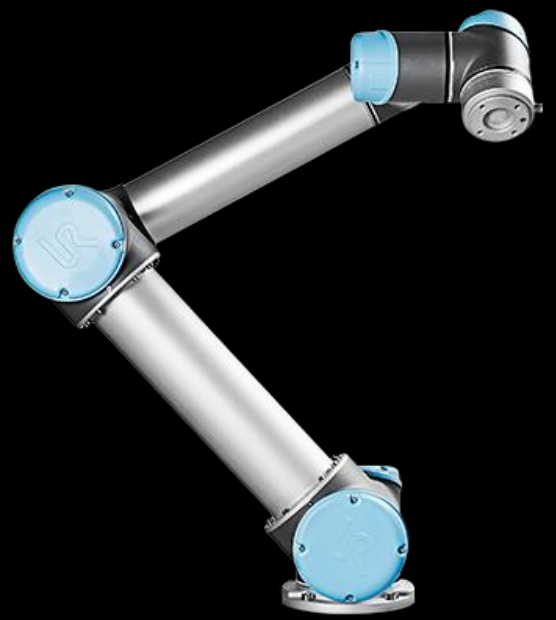
Background and Motivation

- Procedure is generally performed manually
- Precision could be increased with some assistance



Technical Overview

- Noninvasive integration of the UR5 robotic arm into the procedure



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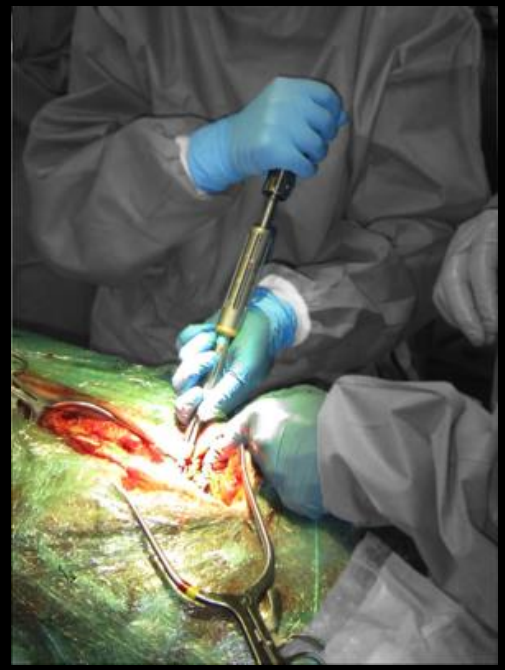


Technical Overview

- Noninvasive integration of the UR5 robotic arm into the procedure

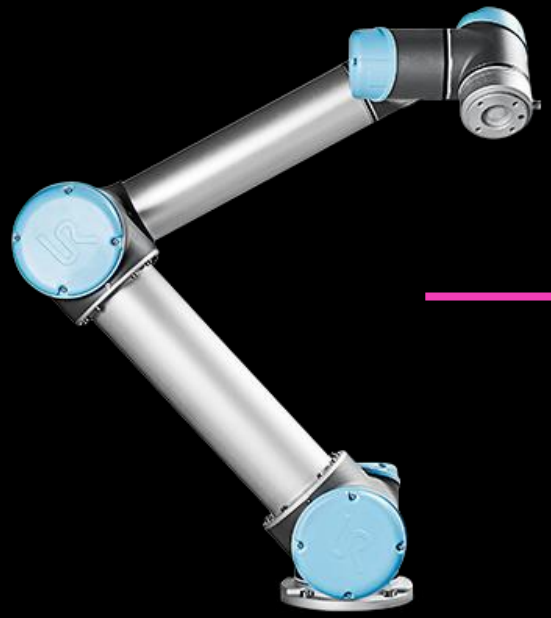
Intraoperative Radiographs

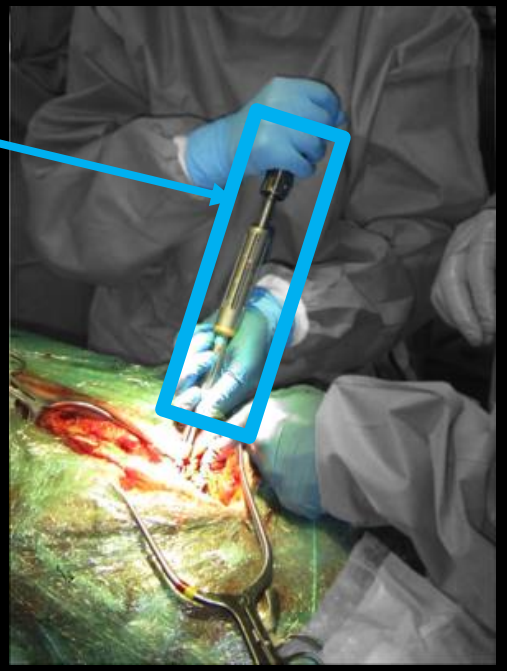
3D-2D Registration

Preoperative CT

Axis Planning

UR5 Robotic Arm





Technical Approach

"Pre-operative" CT

Validate → Refine

Collect time-synchronized measurements from UR5 and optical tracker

Validate → Refine

Perform AX=XB calibration to register UR5 to optical tracker

Validate → Refine

Apply calibration methods to register UR5 to CT data

Apply 3D-2D registration to CT data and radiographs to register volume data to phantom (patient)

"Intraoperative" Radiographs

Validate → Refine

Perform axis planning in CT volume to define UR5 movement/alignment for placing drill guide

Validate → Refine

Define UR5 to drive a drill-guide to a prescribed pose along CT axis and phantom (patient body) surface

Validate → Refine

Workstation

Optical Tracker: NDI Polaris Spectra

UR5 Robot Arm

Pivot calibrated tool tip with OT markers

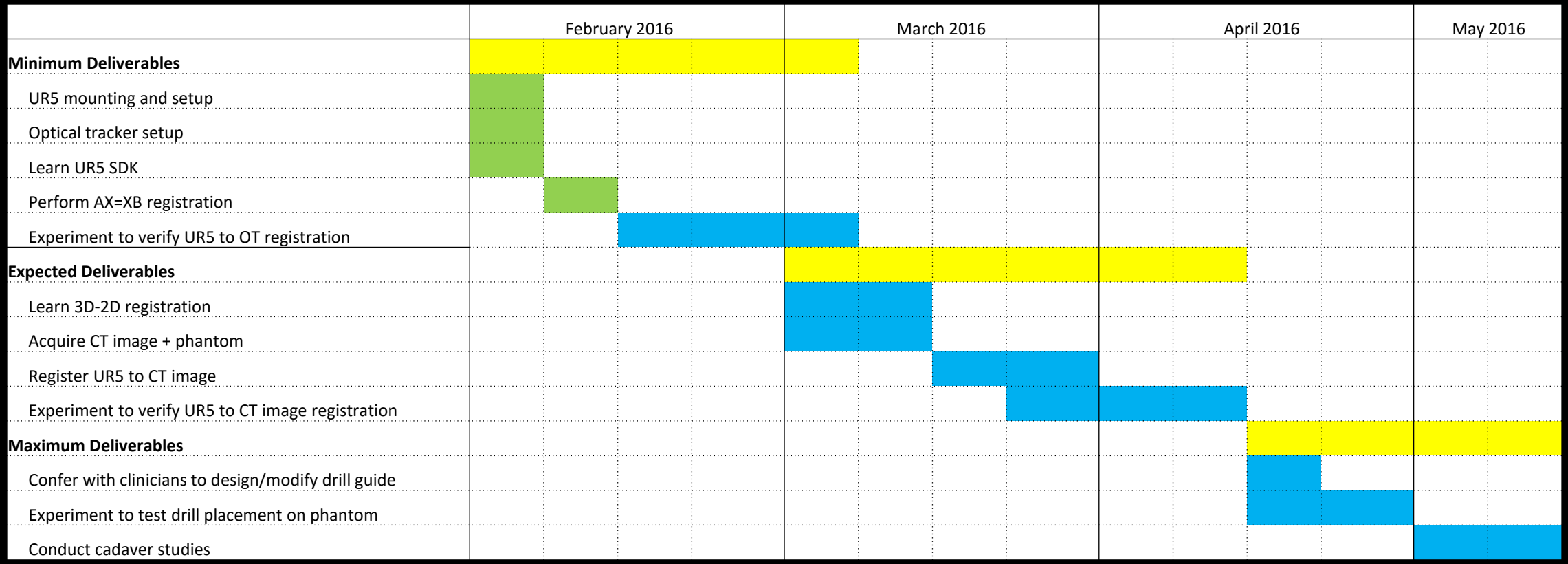
Deliverables

- Minimum Deliverable:
  - Enable tracker based guidance for UR5 robot (i.e. register robot to tracking system)
  - Experimental minimization of calibration error
- Expected Deliverable:
  - Perform 2D-3D registration between radiographs and CT Volume
  - Integrate image based guidance for UR5
  - Experimental optimization of axis planning and error reduction
- Maximum Deliverable:
  - Devise path planning for robot motion in cadaver studies

Dependencies

- ~~JHMI Shuttle~~ ✓
- Fully operational UR5 that can be modified by program ✓
- Fully operational optical tracker along with OT markers ✓
- Optical tracking tools (calibrated) ✓
- Work bench for UR5 mounting ✓
- Computer for UR5 programmatic control and loaded with visualization software for optical tracking ✓
- 3D-2D registration software (in TREK) ✓
- CT data accompanied by corresponding phantom ✓ - to be obtained
- Machine shop access to modify drill guide design ✓
- Mentors ✓

Project Timeline



Management Plan

Vignesh

Lead for mathematical processes

Thomas

Lead for algorithmic implementations

Development of hardware components (needle/drill guide)

Version Control w/ Git

Weekly meetings with mentors (Mondays @ 5:30pm)

At JHMI three days per week (3-4+ hours at a time)

Additional Readings

- Gramkow, Claus. "On Averaging Rotations". International Journal of Computer Vision 42.1/2 (2001): 7-16. Web. 10 Feb. 2016.

- Puvanesarajah, Varun. "Techniques And Accuracy Of Thoracolumbar Pedicle Screw Placement". WJO 5.2 (2014): 112. Web. 10 Feb. 2016.

- Markelj, P. et al. "A Review Of 3D/2D Registration Methods For Image-Guided Interventions". Medical Image Analysis 16.3 (2012): 642-661. Web. 4 Feb. 2016.

- Shah, Mili, Roger D. Eastman, and Tsai Hong. "An Overview Of Robot-Sensor Calibration Methods For Evaluation Of Perception Systems". Proceedings of the Workshop on Performance Metrics for Intelligent Systems - PerMIS '12 (2012): n. pag. Web. 4 Feb. 2016.

- More to follow

REFERENCE SLIDES

Integration of UR5 with Tracking System

$A1*X*B1^{-1} = A2*X*B2^{-1}$ → $A2^{-1}*A1*X = X*B2^{-1}B1$ → $AX = XB$