ACTIVE SENSING STRATEGIES FOR CONTACT WITH COMPLIANT WHOLE-BODY CONTROL FRAMEWORK

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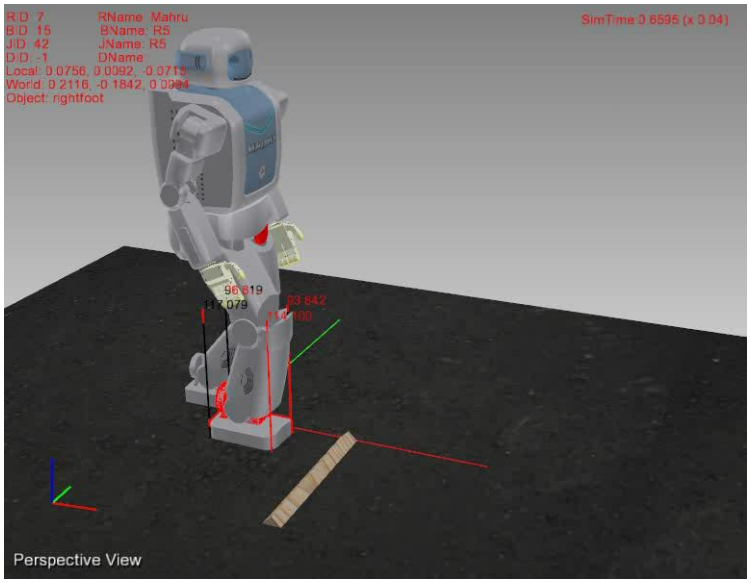
ROBOT IN MULTI-CONTACT

- *Whole-body Control Framework*
- *Contact Information*
- *Reference Motion/Contact Force*



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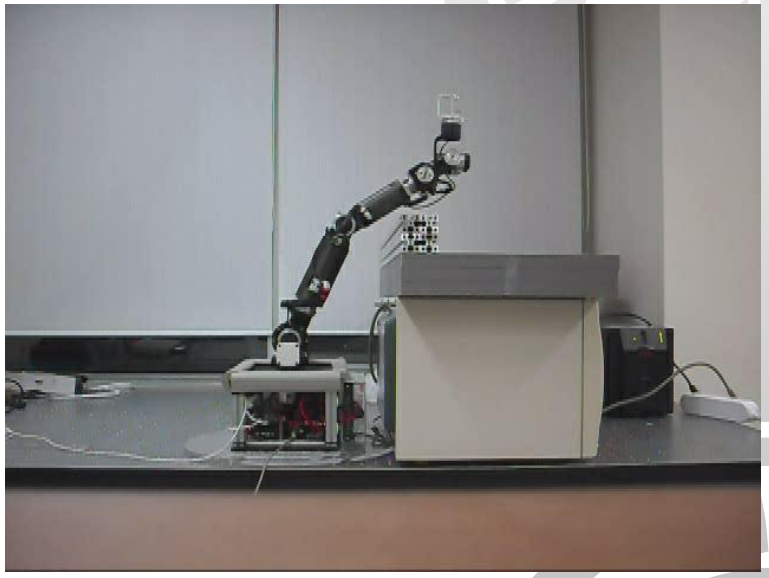
ACTIVE SENSING FOR CONTACT

- *Active sensing using compliant motion* can help identify or estimate the contact situation
  - Especially when other sensors are limited
  - Vision or laser may not be available or precluded
  - Force/torque sensor is biased during dynamic motion



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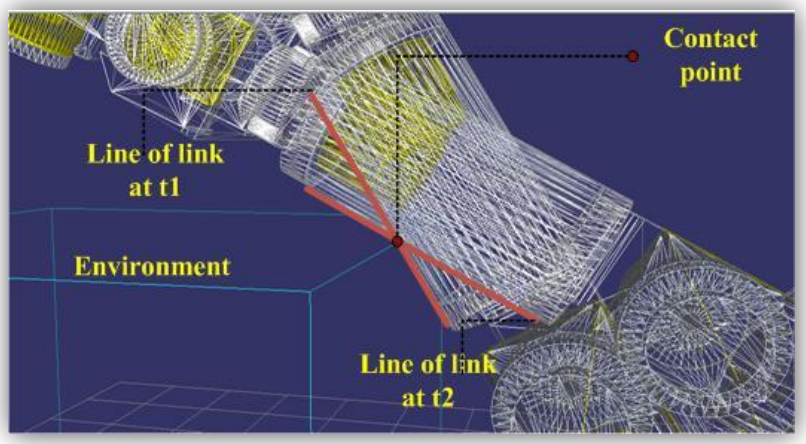
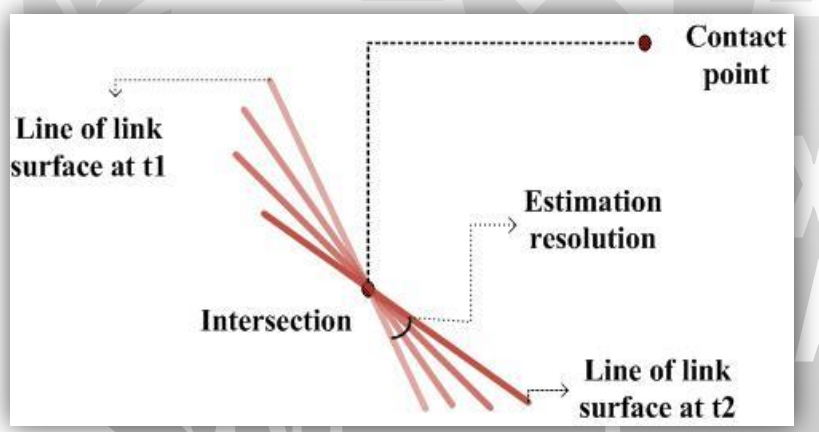
ACTIVE SENSING FOR CONTACT

- Active sensing using compliant motion requires
  - Compliant motion control due to uncertainties
  - Algorithms or strategies to estimate contact situation

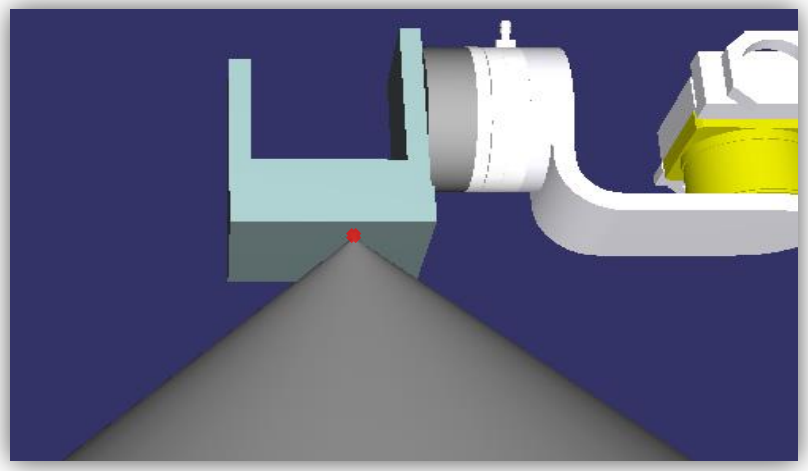


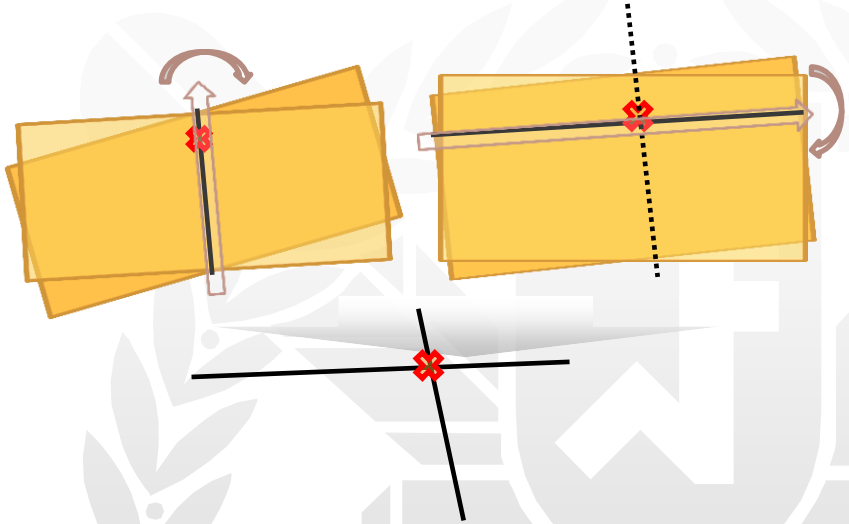
- Compliant Motion/Force Control



- Robot Geometry

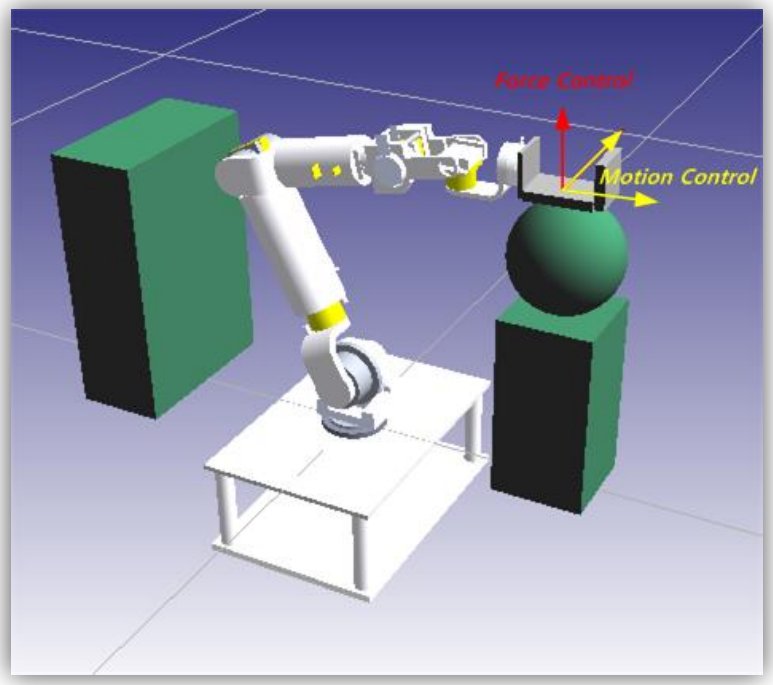
ACTIVE SENSING: CONTACT ESTIMATION





- Robot Geometry
  - Kinematics & Geometry
- Compliant Motion/Force Control
  - Force control in the contact normal direction
  - Motion control in the null-space

ACTIVE SENSING: CONTACT ESTIMATION



Control framework of the robot in contact

$$A(q)\ddot{q} + b(q,\dot{q}) + g(q) + J_c^T(q)f_c = \Gamma$$

$$\Gamma = J_c^T(q)F_c + N_c^T\Gamma_0$$

Motion control in Null-space

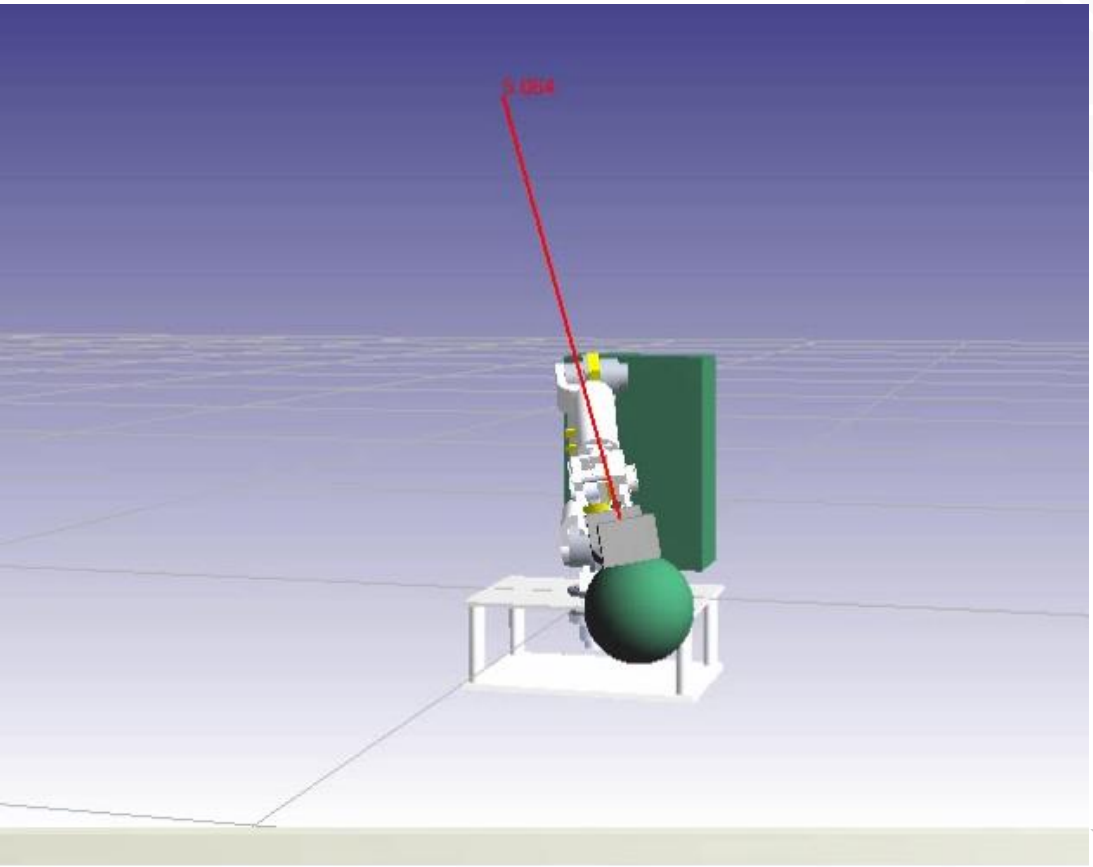
$$\Gamma_0 = J_m^T(q)F_m$$

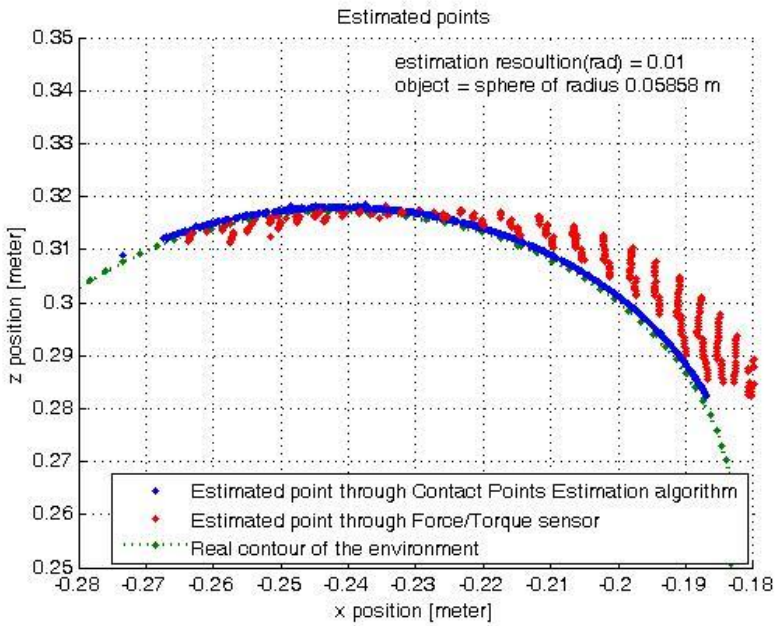
Contact Jacobian

$$J_c^l = (n_c^l)^T J^l \qquad J_c^l : \textit{Local Jacobain of } l_{th} \textit{ link which contact occurs.}$$

$$n_c^l = \begin{pmatrix} \hat{n}_1 \\ \hat{n}_1 \times p_1 \end{pmatrix} \qquad n_c^l = \textit{contact normal space matrix}$$

ACTIVE SENSING: CONTACT ESTIMATION





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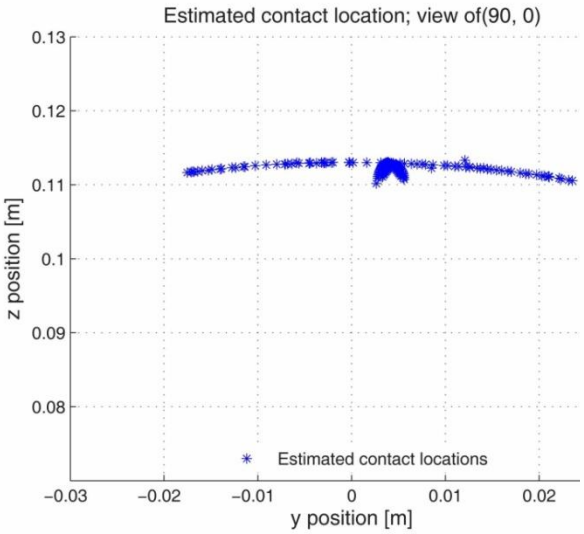
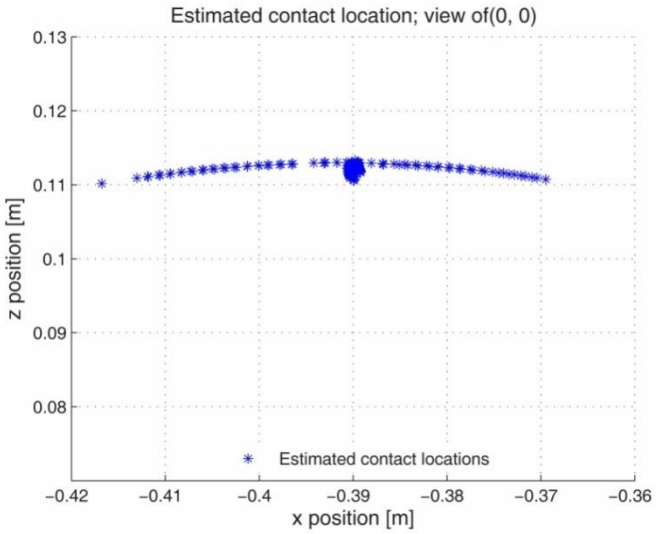
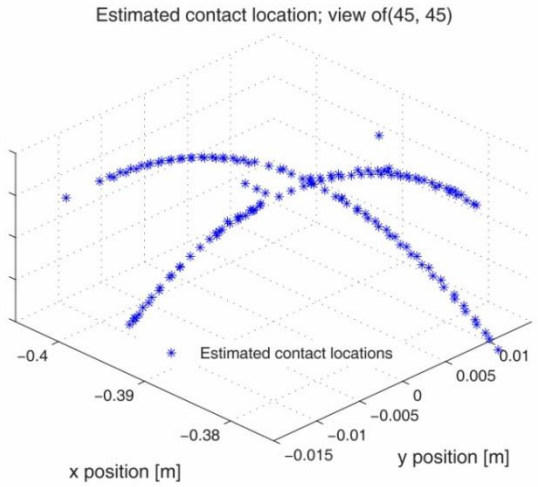
ACTIVE SENSING: CONTACT ESTIMATION







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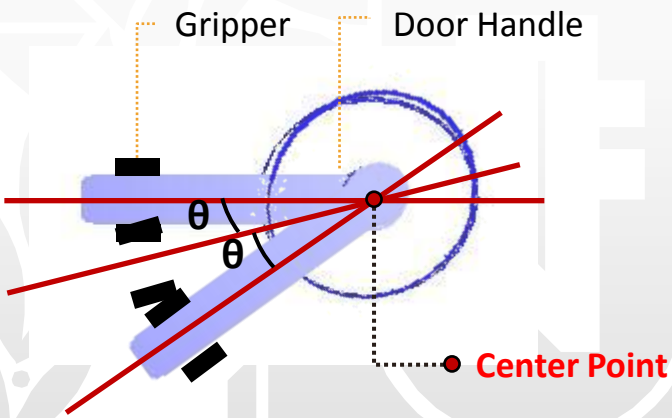
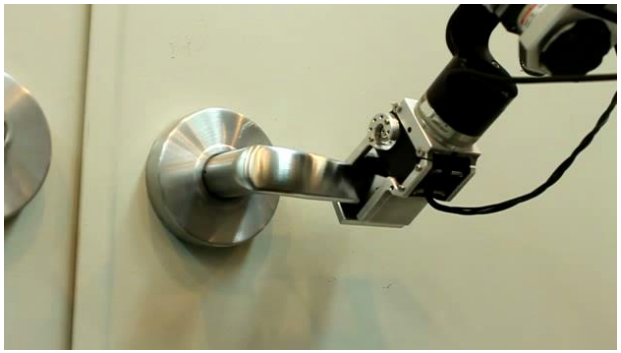
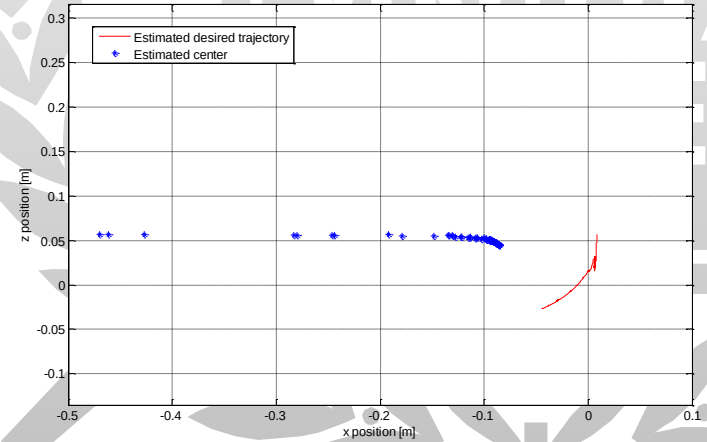
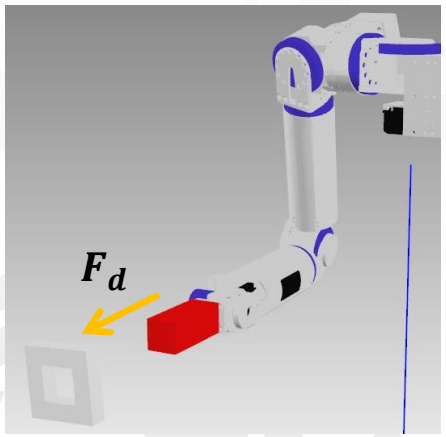
ACTIVE SENSING: CONTACT ESTIMATION

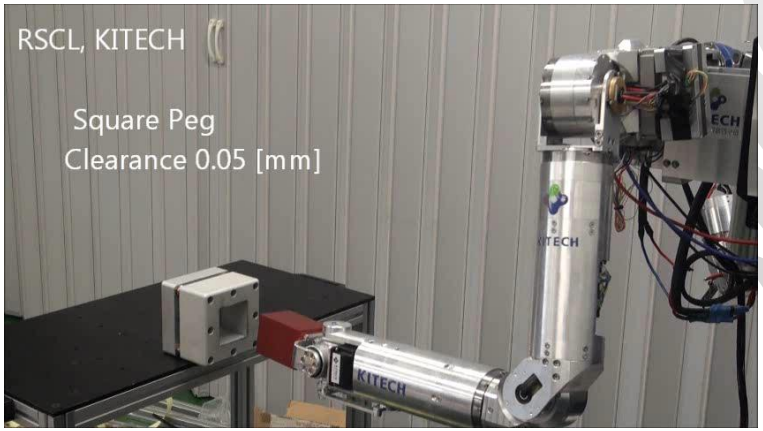


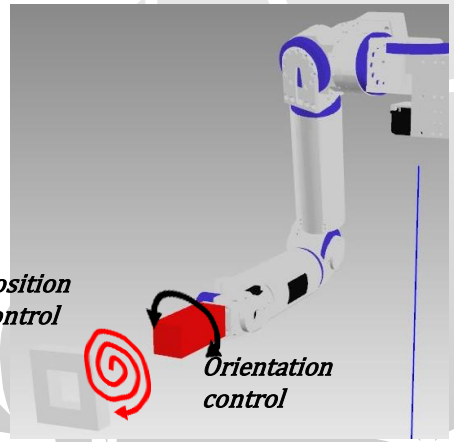




ACTIVE SENSING: PEG-IN-HOLE







- **Developed by Dr. Ji-Hun Bae at KITECH (Korea Institute of Industrial Technology)**

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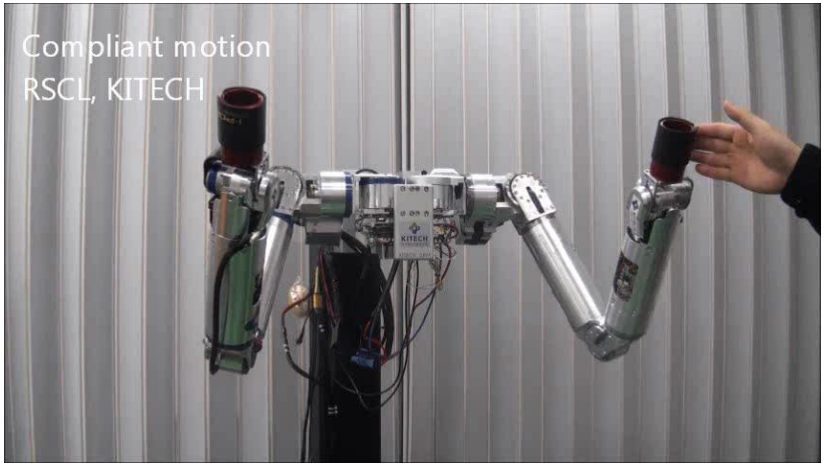
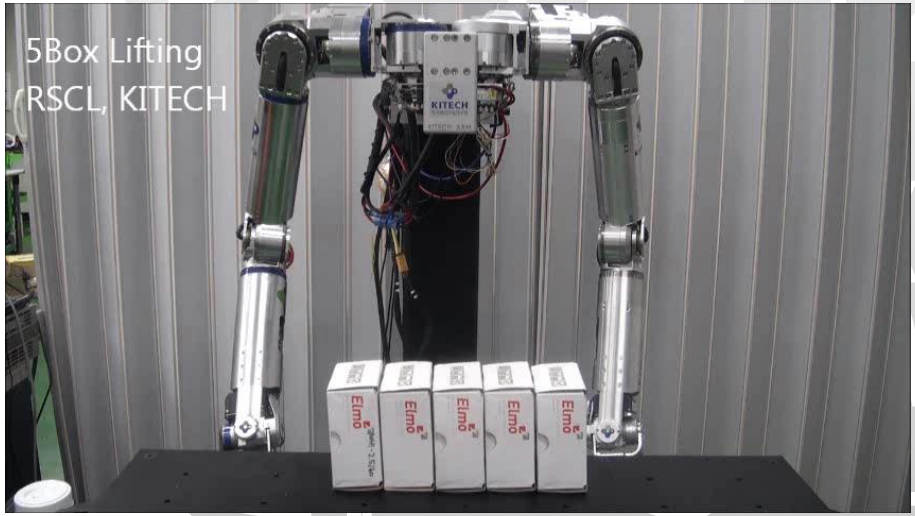
ACTIVE SENSING: PEG-IN-HOLE



Compliant motion

5Box lifting



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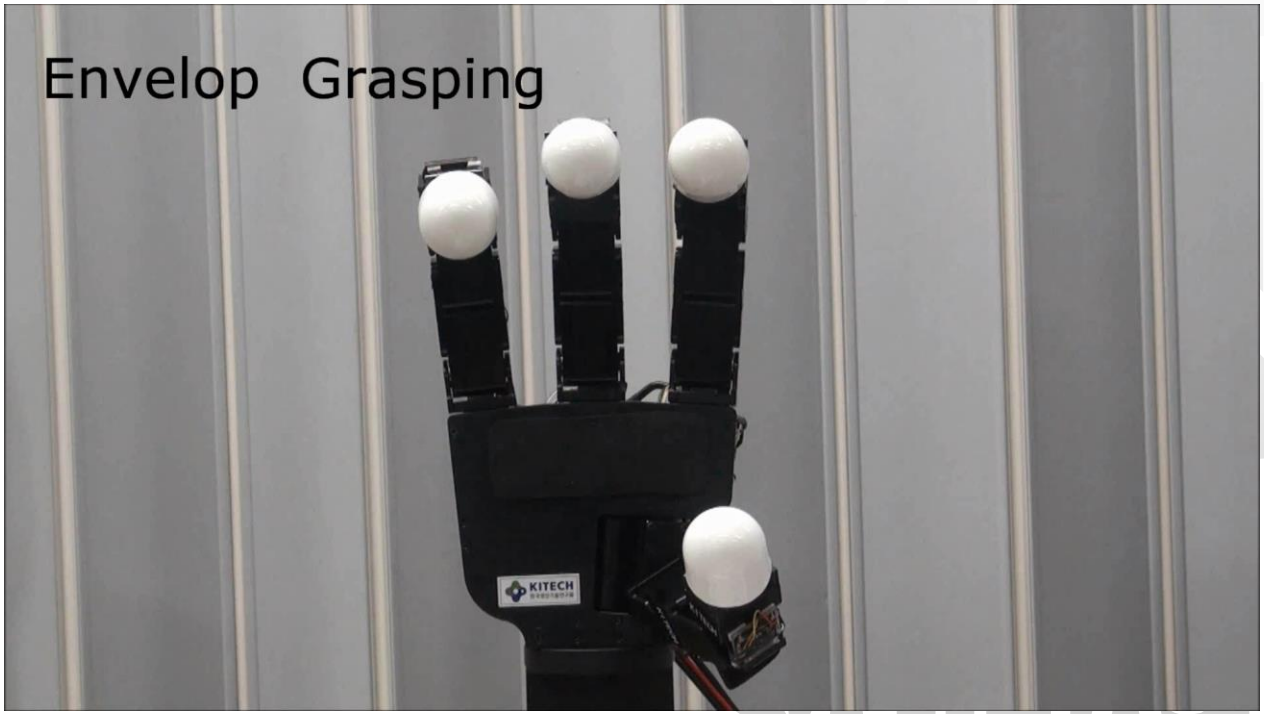
GRASPING



- Developed by Dr. Ji-Hun Bae at KITECH (Korea Institute of Industrial Technology)

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TELEOPERATED ULTRASOUND SYSTEM

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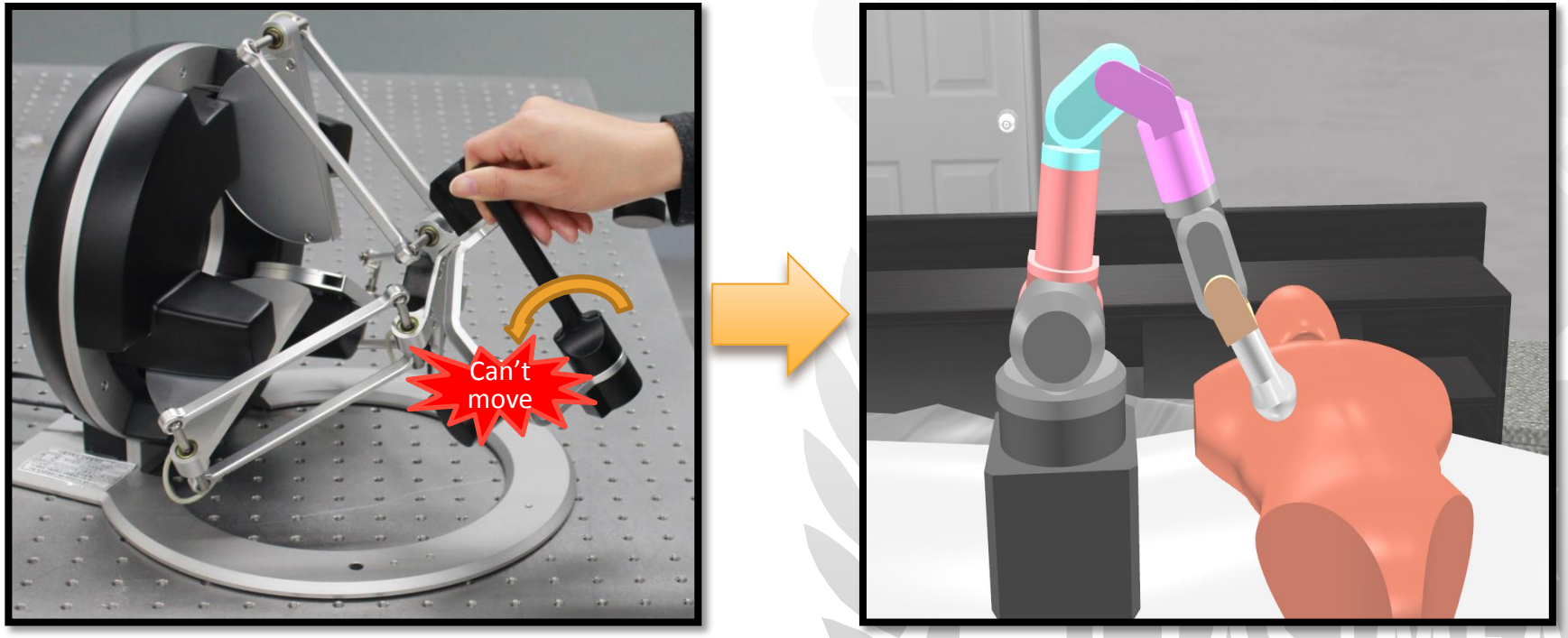
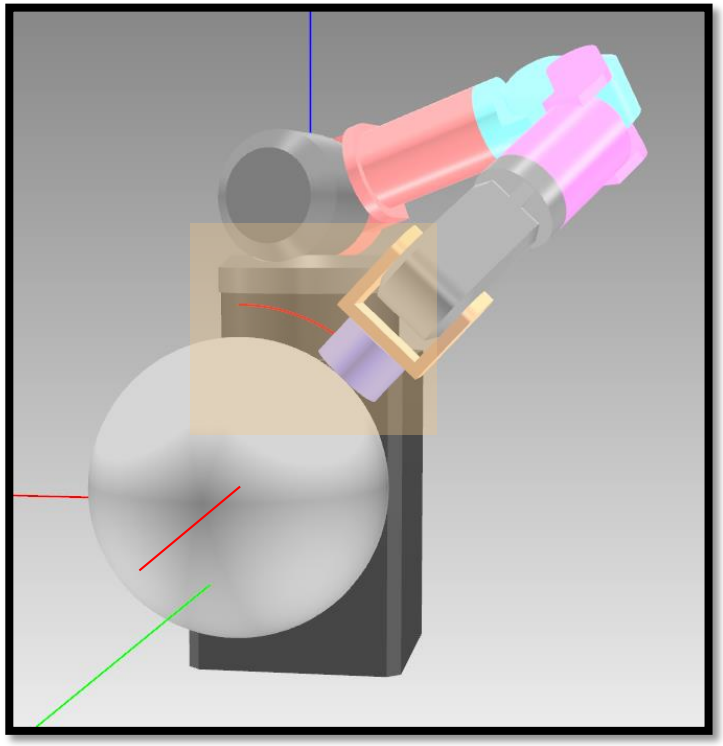
ACTIVE SENSING FOR CONTACT NORMAL



- The orientation workspace of haptic device is different from that of robot.
- The difficulty of orientation manipulation only from video feed.

ACTIVE SENSING: ORIENTATION COMPENSATION

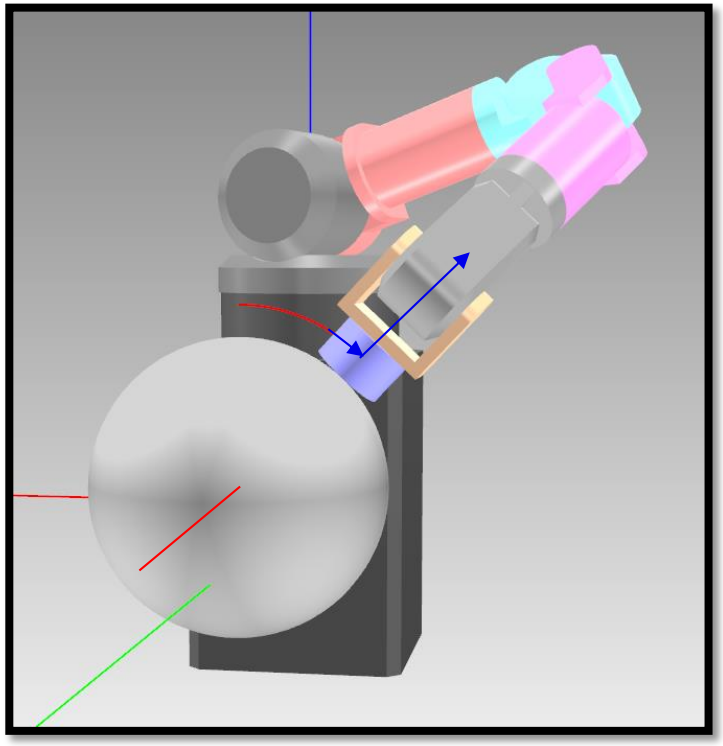


- The normal axis is computed from the eigenvalue decomposition of covariance matrix.

$$C = [r_1 \quad r_2 \quad r_3] \begin{bmatrix} \lambda_1 & 0 & 0 \\ 0 & \lambda_2 & 0 \\ 0 & 0 & \lambda_3 \end{bmatrix} [r_1 \quad r_2 \quad r_3]^T$$

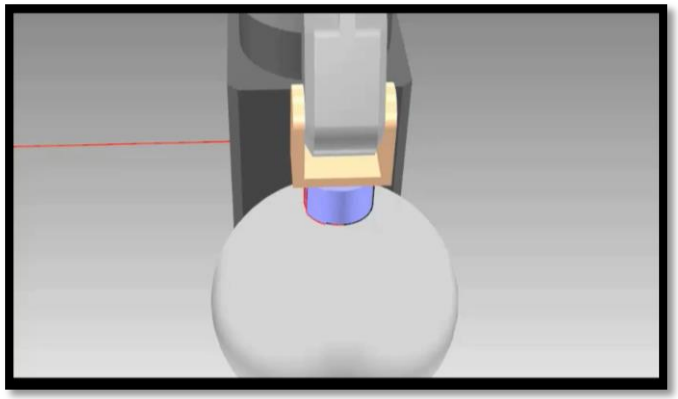
- In curvilinear motion, r_3 becomes the orthogonal direction of the plane.

ACTIVE SENSING: ORIENTATION COMPENSATION

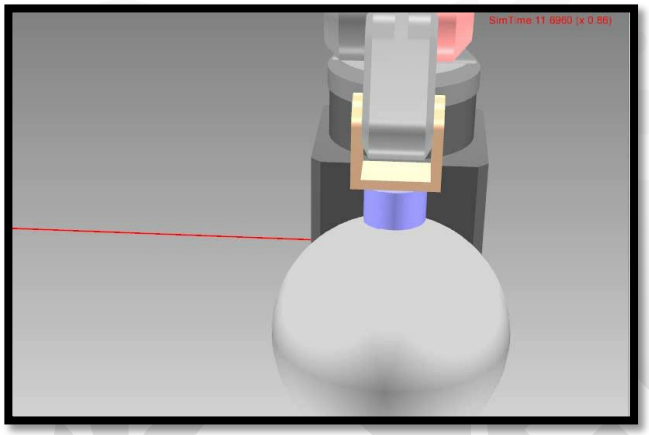


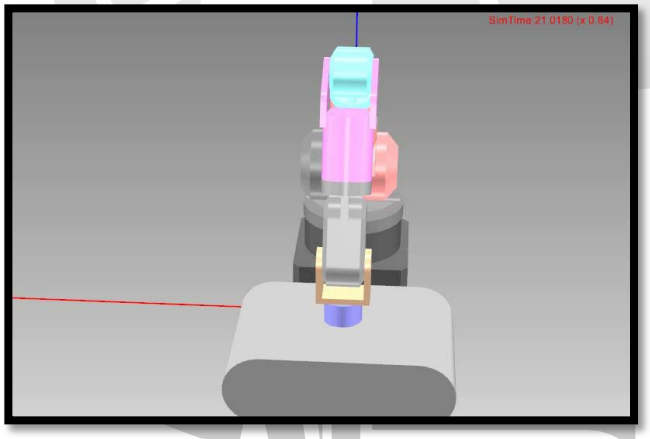
- Tangential vector is computed using the trajectory
- Contact normal vector is obtained by rotating the tangential vector

ACTIVE SENSING: ORIENTATION COMPENSATION



Without the algorithm





With the algorithm

ACTIVE SENSING: CONTACT ESTIMATION

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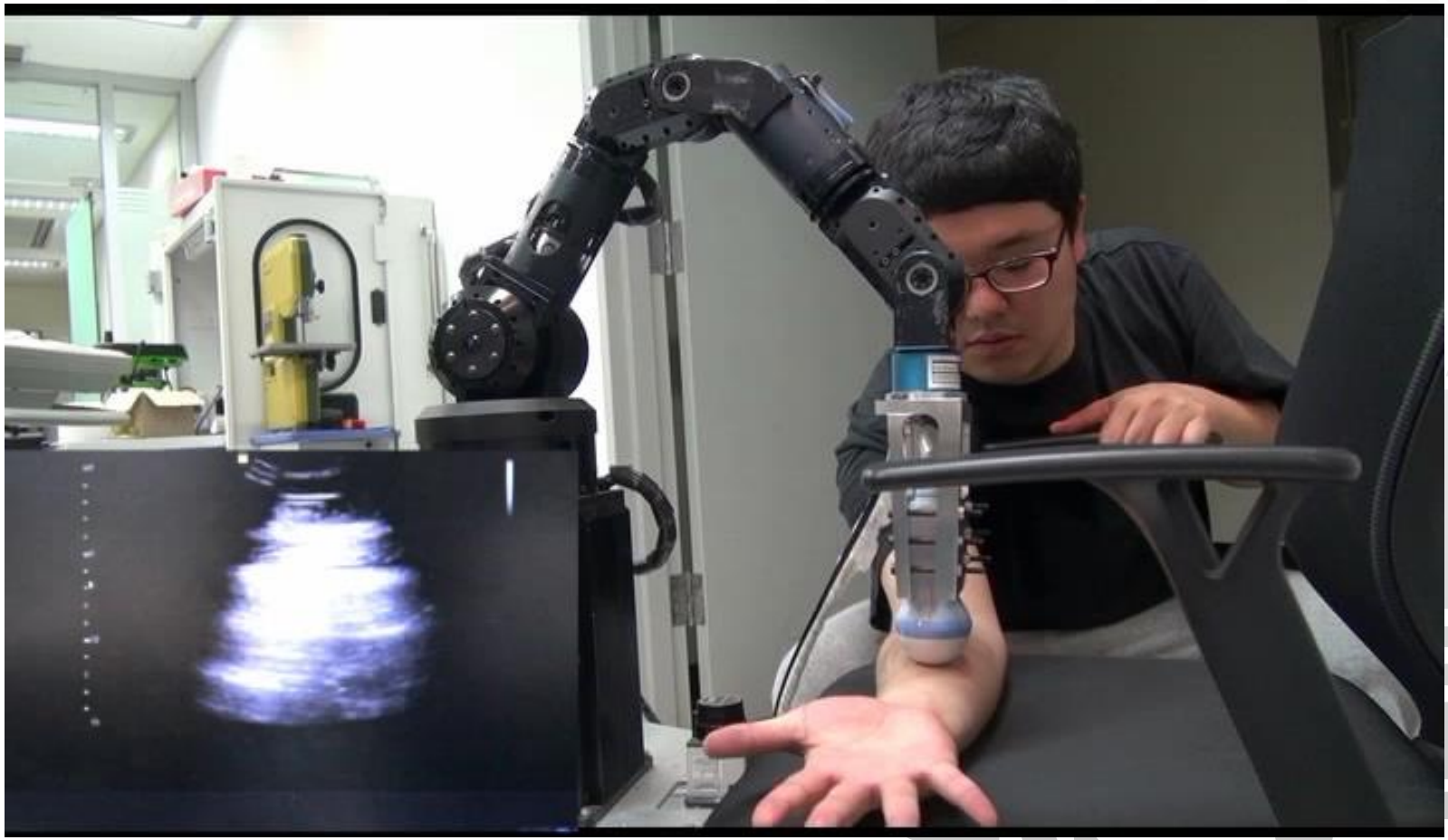
ACTIVE SENSING: CONTACT ESTIMATION



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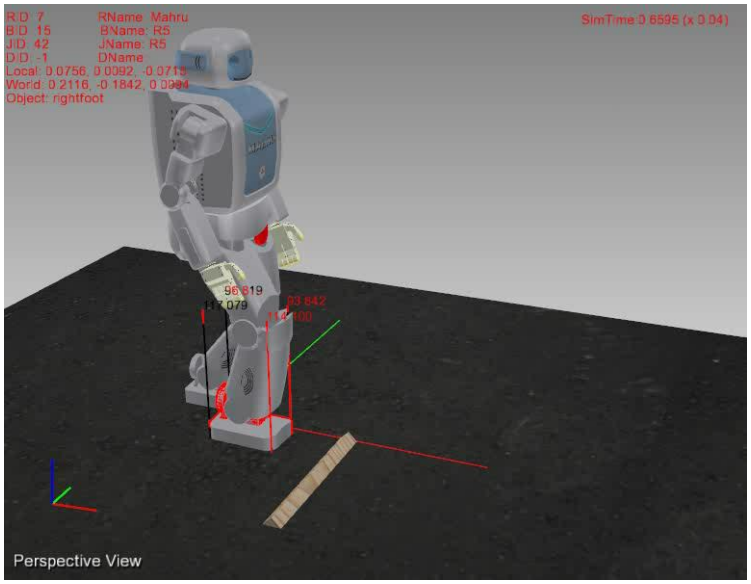
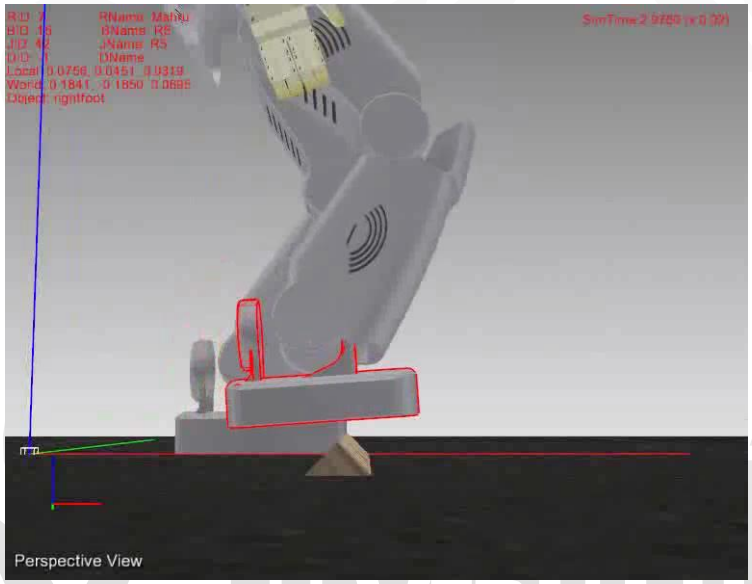
ACTIVE SENSING DURING BIPEDAL WALKING





- Whole-body control framework for walking
  - COM, Trunk Orientation, Foot Position/Orientation
- Estimate contact condition during one foot stance
  - Contact type (line) and location is estimated through compliant control
- Maintain ZMP on the contact line and update COM trajectory

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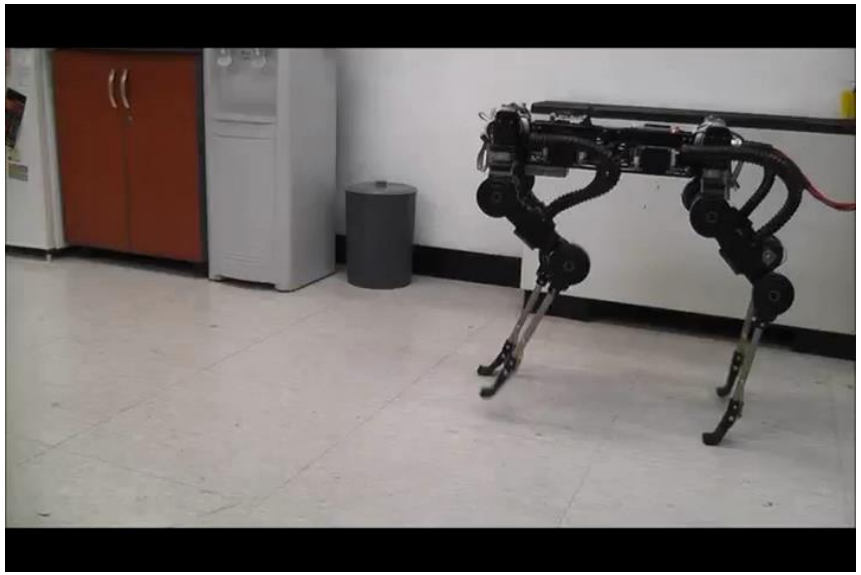
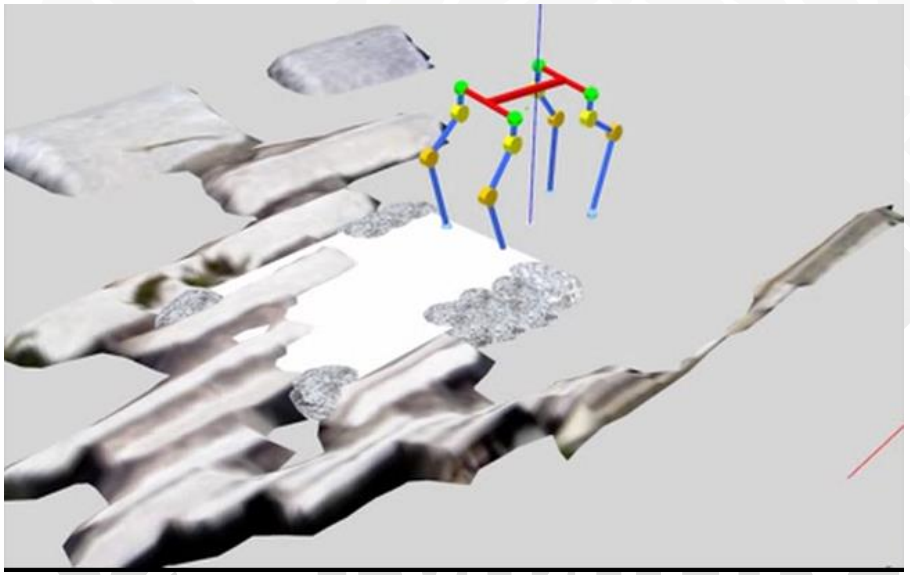
ACTIVE SENSING: QUADRUPEDAL WALKING

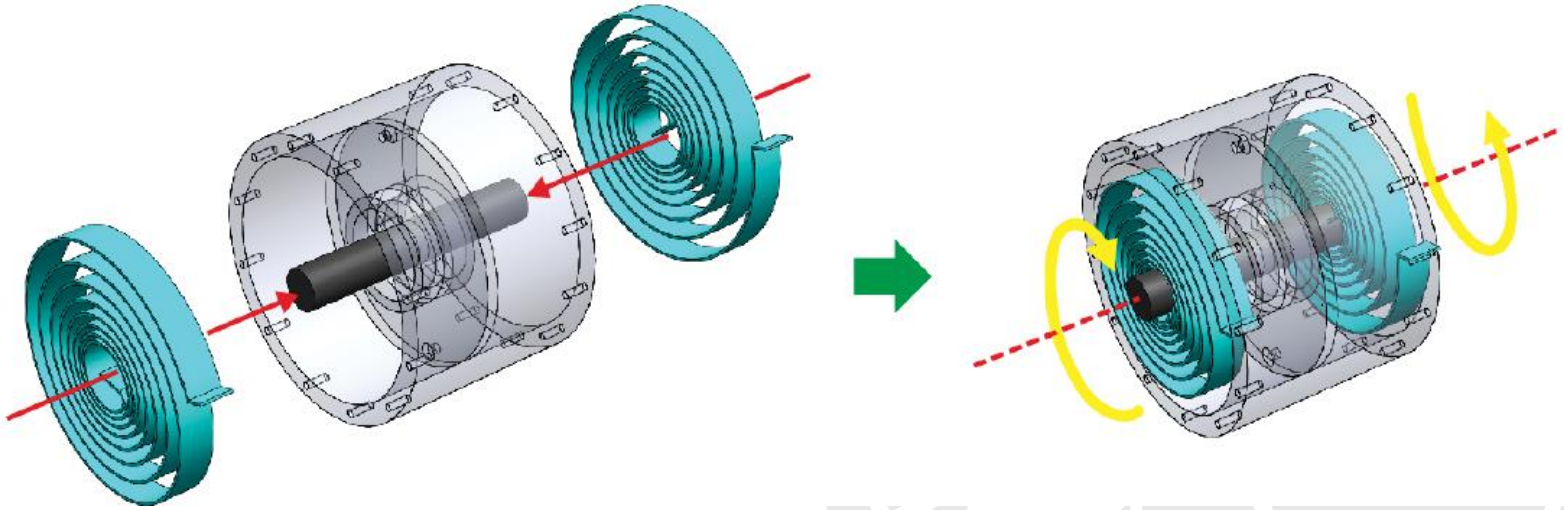


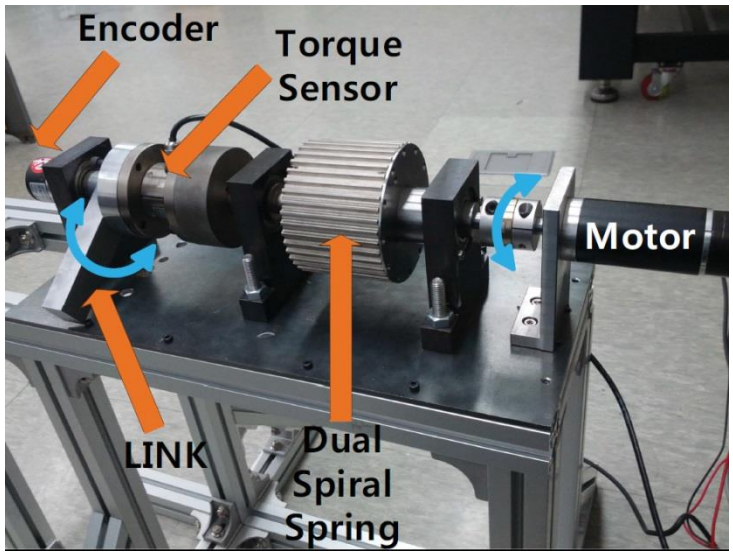


- SQ1 by Simlab
- Planning & Control of quadruped robot using whole-body control and contact estimation

OTHER ACTIVITIES

DUAL SPIRAL SPRINGS





- Large Compliance
- Large Displacement

KINETIC XYLOPHONE

- Robotics and Art

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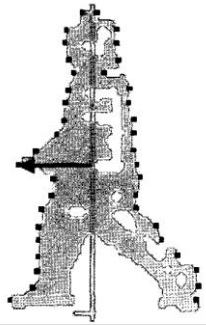
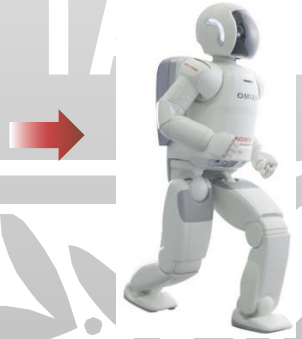
GAIT RECOGNITION & GENERATION

- of the different people on different conditions

Human Recognition System for Different Human Conditions



Humanoid Robot Control Representing Human Conditions



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THANK YOU !