WE CAN
DO SO
MUCH
TOGETHER

Observing Human Assembly: Lessons Learned

Anthony Remazeilles, Irati Rasines,
Asier Fernandez, Julius Klein, Joseph McIntyre

Medical Robotic group, Health Division
Tecnalia Research & Innovation, San Sebastian
name.surname@tecnalia.com

Smart Cooperative Robots for Agile Assembly Workshop
14 March 2018

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EUROPEAN ROBOTICS FORUM
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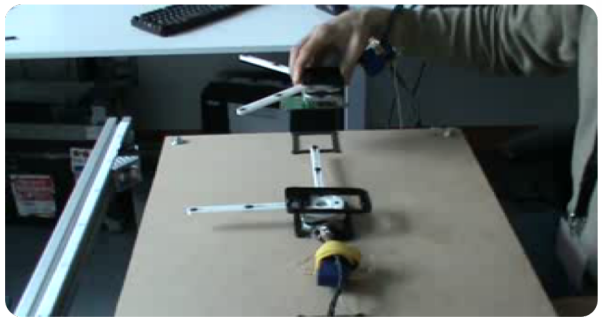
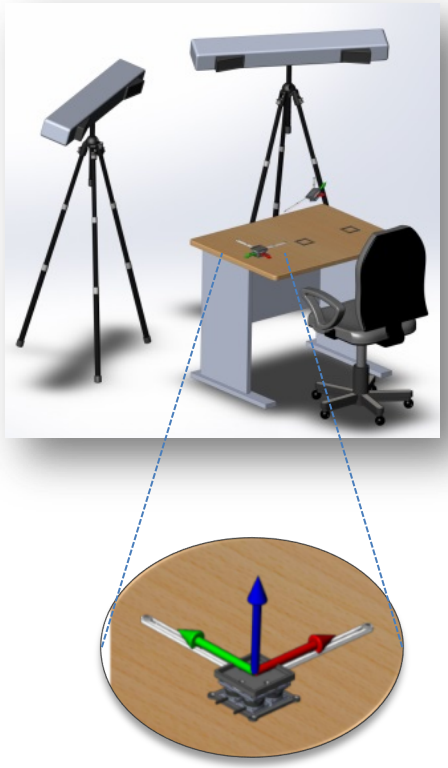
Human observation

- Observation setup
  - Object pose: visual markers
  - Manipulation wrenches: optoforce sensors

Insertion (sliding + folding)

Phone folding

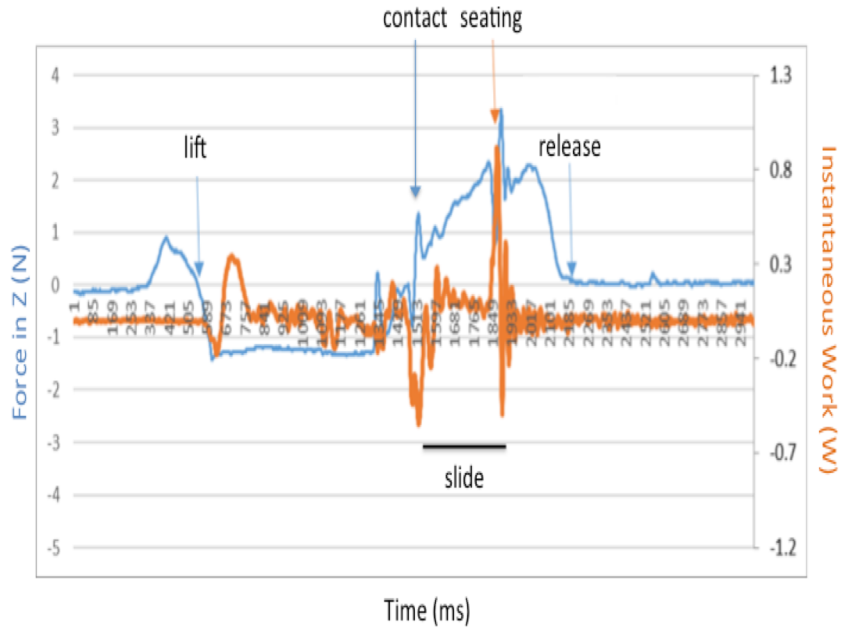




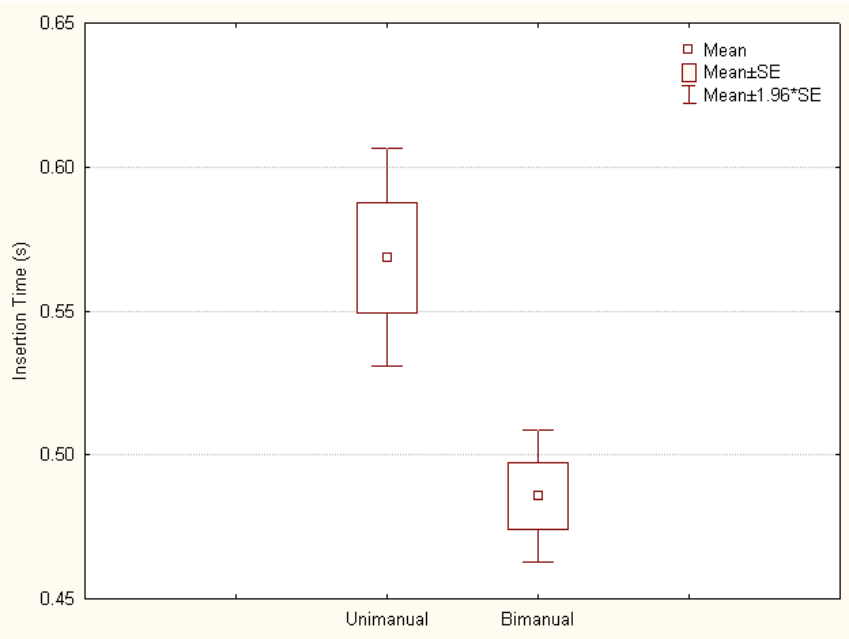
Analysis of Human Sliding Insertion

Time required from initial contact until seating.

Segmentation



Statistical Analysis

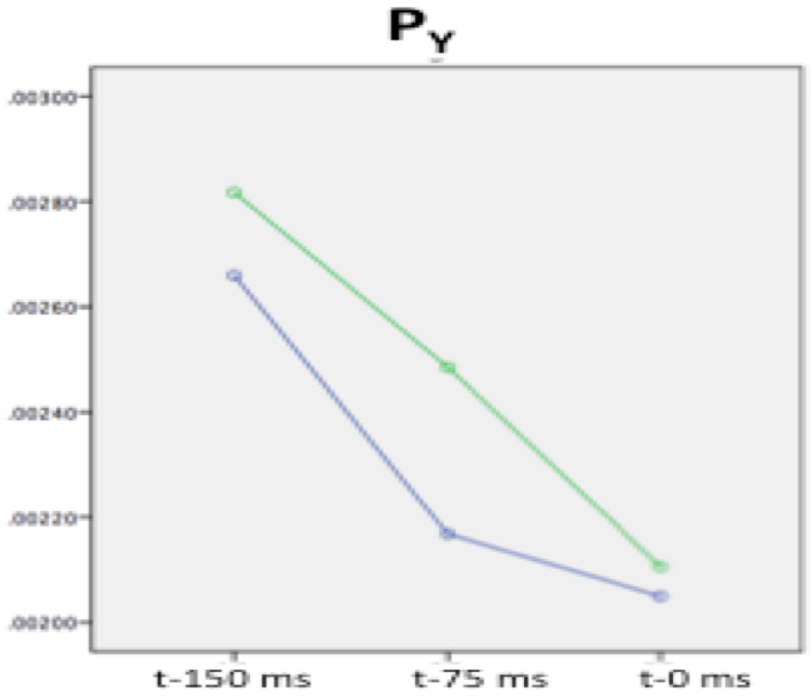


Unimanual assembly takes 17% longer, on average, compared to bimanual assembly.

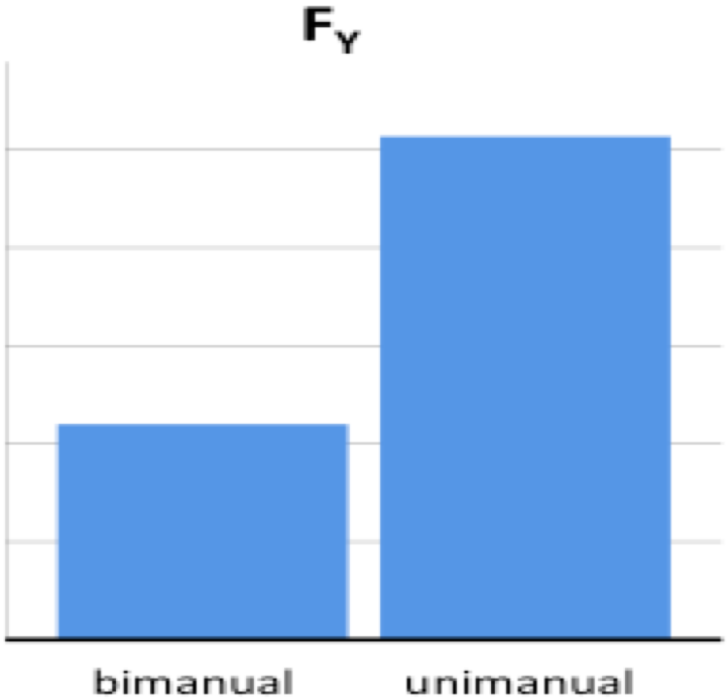
Analysis of Human Sliding Insertion

Adjustments during approach and contact.

Variation of approach position



Variation of contact forces



Position during approach is less variable during bimanual assembly, resulting in a reduced need for adjustments during the sliding contact.

Analysis of Human Sliding Insertion

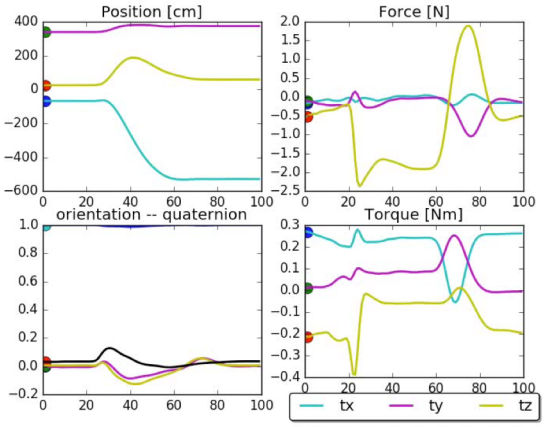
Hypotheses to explain empirical observations.

- H1: Impedance Modulation
  - The human may modulate the impedance of the receiving hand to facilitate insertion.
- H2: Improved Sensory Feedback
  - When working bimanually, the CNS has both visual and kinesthetic information about the location of the receptacle.
- H3: Improved Manipulability and Observability
  - Humans may perform the bimanual insertion in an optimal location for manipulability of the end effector or to maximize precision of visual pose estimation.
  - With bimanual assembly, movements may be shared across the manipulators, further increasing manipulability.

From the human to the robot

DMP vs robotic skills

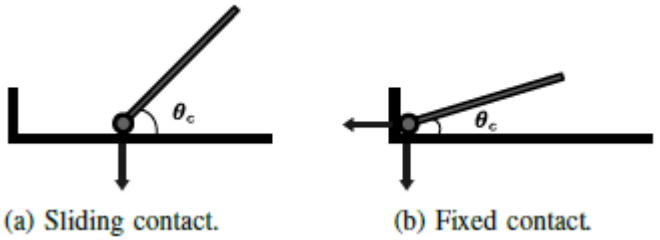
DMP learning of Assembly task [Abbu-Dakka2015]



- Kinematic modelling with GMM
- Reproduction feasible using DMP framework

[Abbu-Dakka2015]: Abu-Dakka et al: Adaptation of Manipulation Skills in Physical Contact with the Environment to Reference Force Profiles Fares, Autonomous Robot 2015.

Manipulation Skills for insertion [Almeida2016]



- Robot with predefined skills
- Skill instantiation: task frames, manipulation magnitudes

[Almeida2016]: Almeida, Viña, Karayiannidis: Bimanual Folding Assembly: Switched Control and Contact Point Estimation, IROS 2016

From the human to the robot

Data segmentation : manipulation transitions

- Detection with the derivative of instantaneous work

$$\delta \mathrm{W} = V_c . F_c$$

- Independent of the measurement site

$$\delta \mathrm{W} = V_c . F_c = V_b . F_b = V_b . \left(Ad_{bs}^{\mathsf{T}} F_s \right)$$

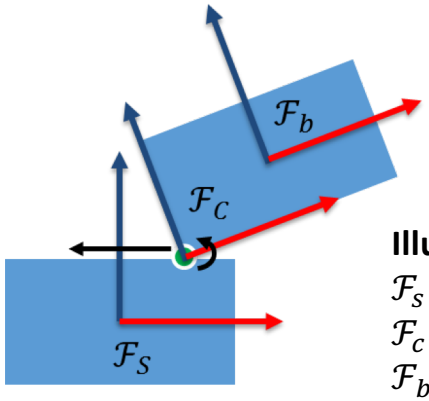


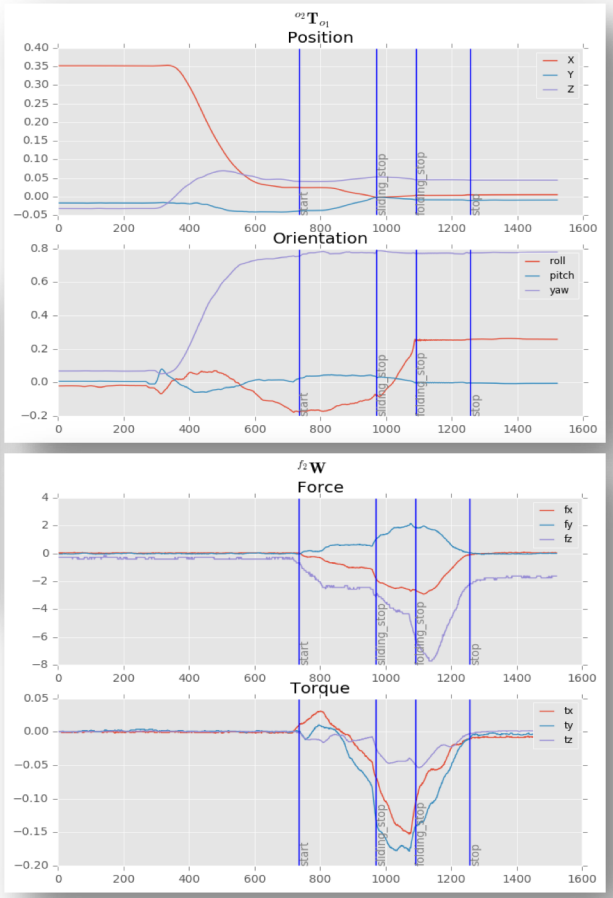
Illustration on sliding exp.:
$\mathcal{F}_s$: static object frame
$\mathcal{F}_c$: moving contact frame
$\mathcal{F}_b$: moving object frame

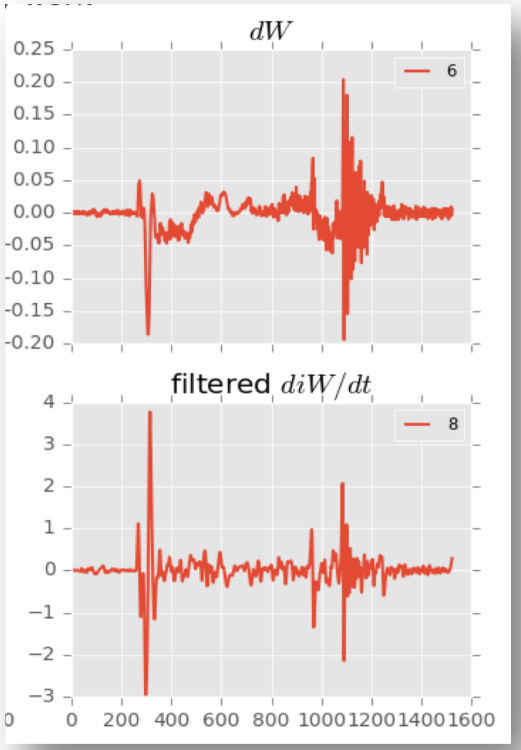
Insertion exp.

Phone exp.

From the human to the robot

Validation of the instantaneous work metrics: unaligned sensor



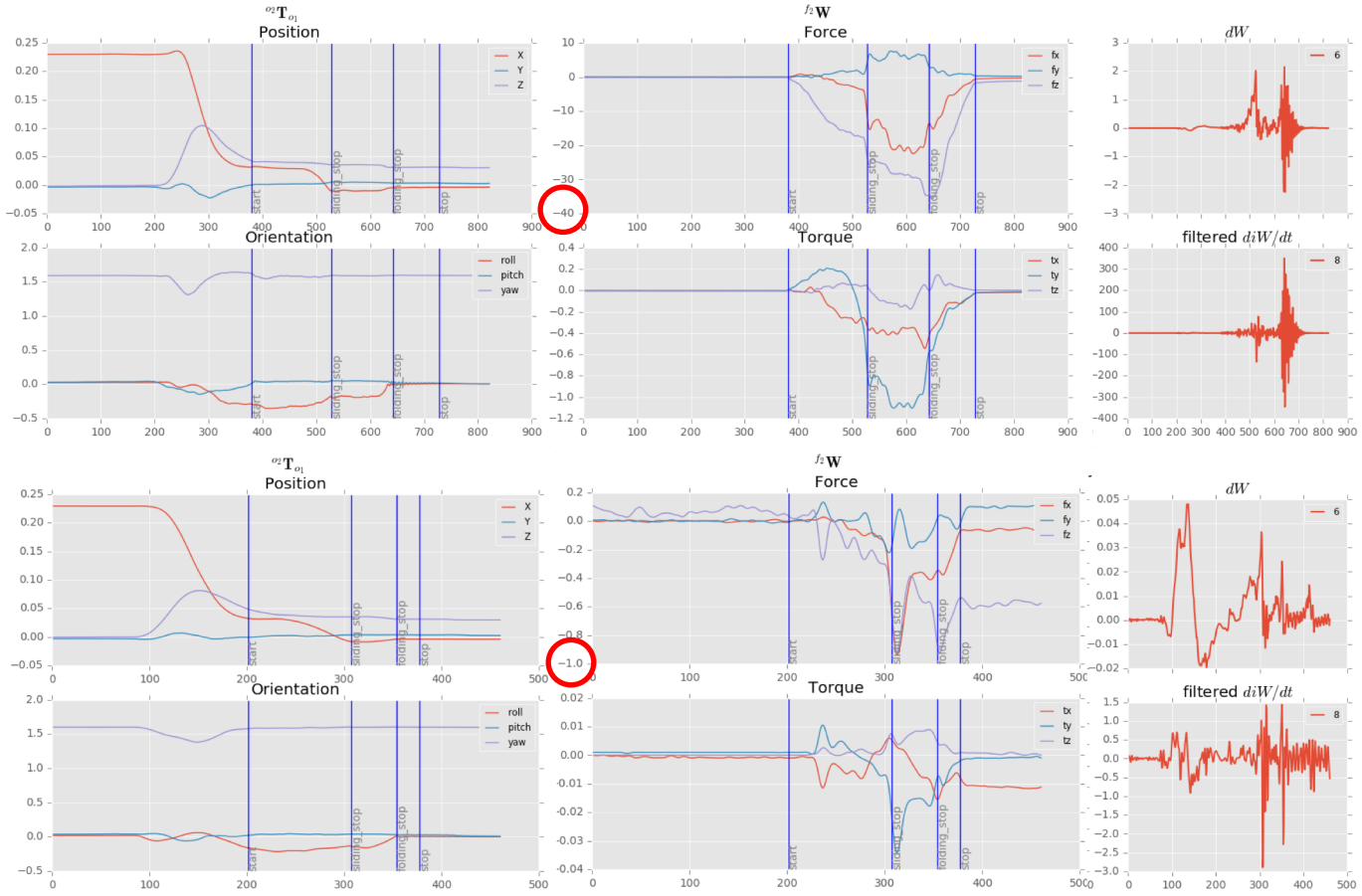


From the human to the robot

Validation of the instantaneous work metrics: Force variation

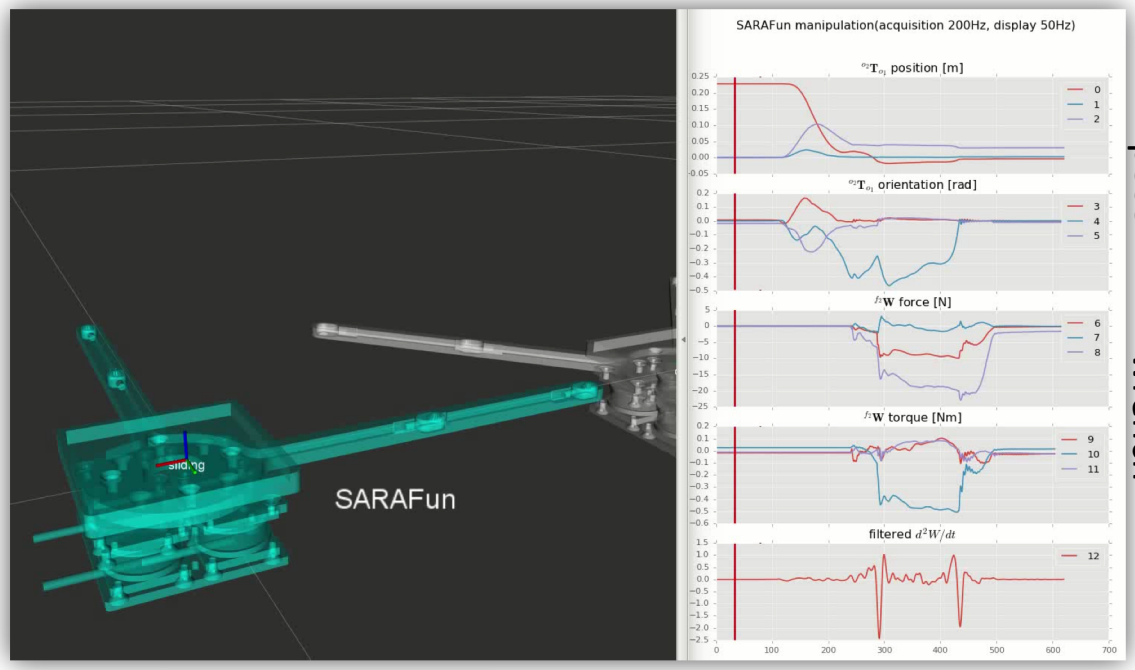
High forces (35N)

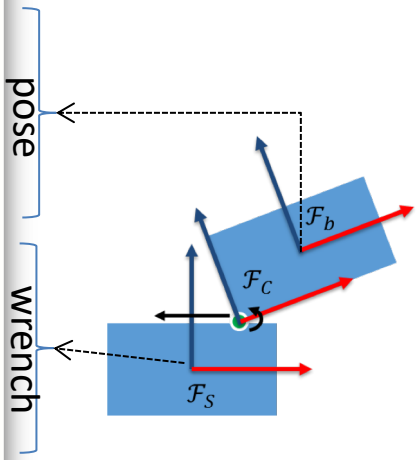
Low forces (1N)



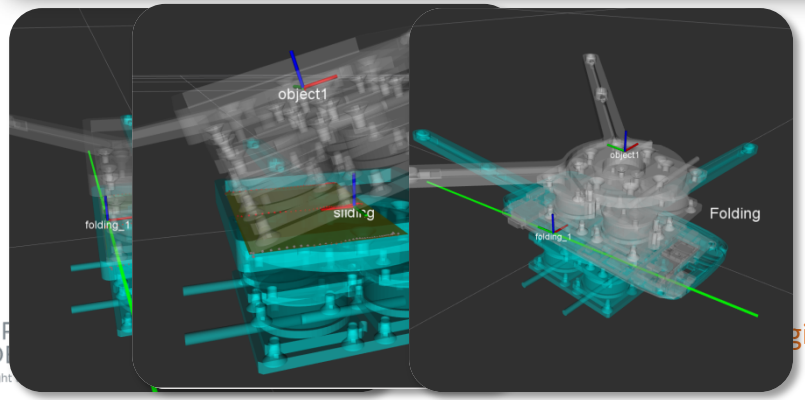
From the human to the robot

- From segmentation to task characterization





Inst. work derivative



Sliding manipulation

1. Rotation axis & anchor point
2. Frame aligned with motion axis

Folding manipulation

1. Rotation axis & anchor point
2. Frame aligned with motion axis

Conclusions

- Human observation:
  - Significant reduction of manipulation time in bi-manual configuration wrt unimanual.
  - Several hypothesis proposed and currently investigated

- Robotic skill adjustment
  - Instantaneous work metric for tansient detection
  - Independent of measurement frames
  - Task frames extraction based on kinematic information

Thank you!
Kiitos!

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This work was supported by the SARAFun project, funded by the EU under H2020 under grant agreement No. 644938

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