Optimal Velocity for Handover Trajectories

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Outline

Motivation

- Handover key part in human robot collaboration
- Industry 4.0
- Eldercare
- Service Robots
- Nursing

Video

Related Works

- Vannucci et al.[1] investigated effect of aggressive and gentle behavior of the robot giver
- Expressed through vocal commands and motion
- Vocal instructions increased human peak velocity compared to actions
- Aggressive actions and instructions increased human peak acceleration


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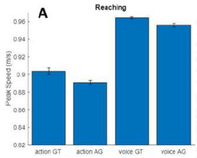

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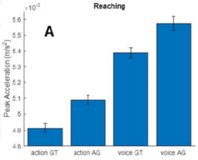

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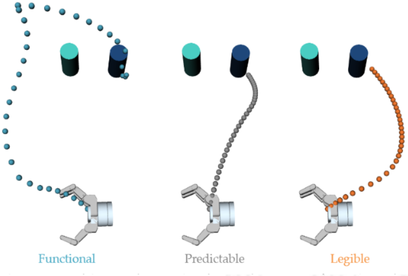
[1] [Vannucci et al., 2018]

- Dragan et al.[2] studied difference between functional, predictable and legible trajectories
- Legible motions performed best for coordination task



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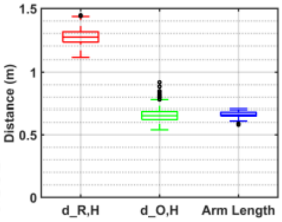
[2] [Dragan et al., 2015]

Related Works

- Nemlekar et al. [3]proposed an object transfer point (OTP) estimation method
- Initial OTP estimation is static, based on both agents orientations, midpoint between them and reachability
- dynamically refined with an Probabilistic Movement Primitives based approach



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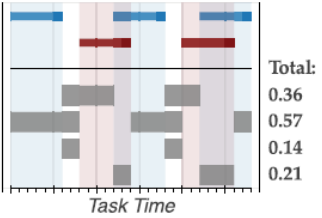
[3][Nemlekar et al., 2019]

Related Works

- Hoffman [4] made a survey of fluency evaluation methods for human robot collaboration
- did a study correlating objective fluency measures with subjective measures
- Objective measures: H-IDLE, R-IDLE, C-ACT, F-DEL



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[4] [Hoffman, 2019]

Hypotheses

H1:

Faster robot trajectories lead to shorter overall handover time.

H2:

Object type affects the overall handover time.

H3:

Faster robot trajectories make humans act slower.

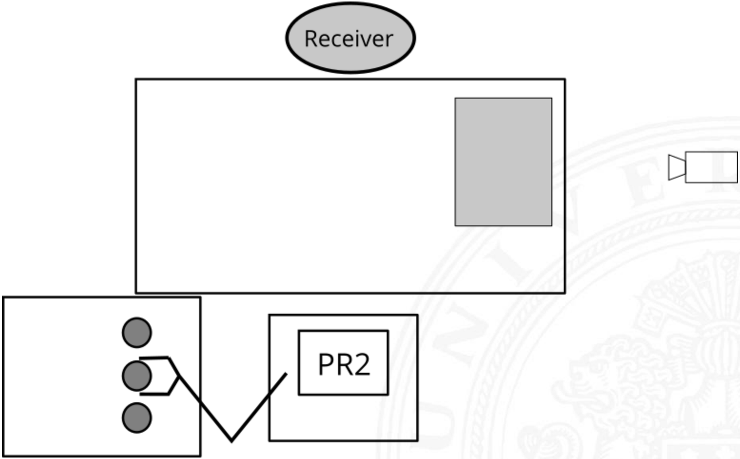
H4:

Faster robot trajectories reduce fluency.

Procedure

- One Handover
  - Robot picks up an object
  - Executes a trajectory with a specified Cartesian end-effector velocity towards receiver
  - Human receiver grasps object from the robot's gripper
  - Receiver places object onto the table
- Three different objects per velocity
- After each three objects are handed over, a questionnaire is filled out
- Objects are setup again

Setup



Objects

Study

- Pre-Study
  - Tested tcp velocities [0.2-1.3]m/s in steps of 0.1
  - $4 \cdot 3 objects \cdot 12 velocities = 144 handovers$
  - No questionnaire
- Study
  - ca. 20min
  - Tested tcp velocities: [0.4-1.2]m/s in steps of 0.2
  - $3 participants \cdot 3 objects \cdot 5 velocities = 45 handovers$
- Velocity order is randomized

Evaluation Methods

- Total handover time
- Human activity time
- H-IDLE, R-IDLE, C-ACT, F-DEL [5]
- Questionnaire (fluency, trust, robot contribution ...)

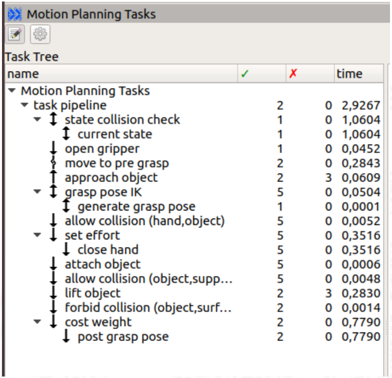
[5] [Hoffman, 2019]

Pick

- Robot picks up an object
- Executes a trajectory with an specified velocity towards receiver
- Receiver grasps object from the robot's gripper
- Receiver places object onto the table

Pick - MoveIt! Task Constructor[6]

- Objects at fixed location
- Gripper effort is fine tuned for each object



[6] [Görner et al., 2019]

Trajectory

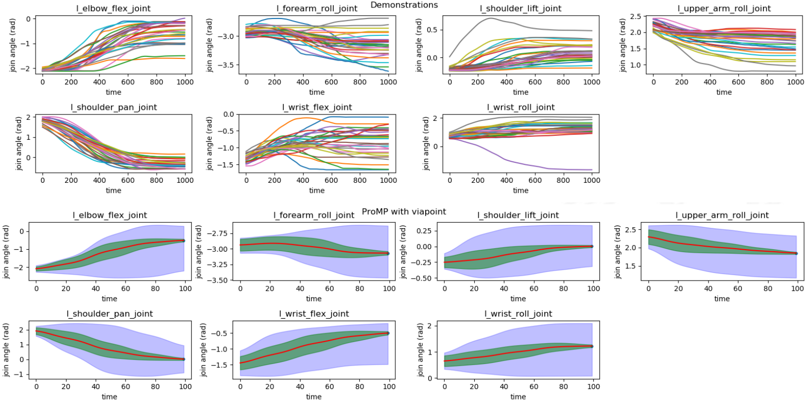
- Robot picks up an object
- Executes a trajectory with an specified velocity towards receiver
- Receiver grasps object from the robot's gripper
- Receiver places object onto the table

Trajectory - ProMP[7]

- Kinematically similar movements
- Ability to specify endpoint of trajectory
- Implemented in C++ and Eigen
- Learned from demonstrations (29 in total)

[7] [Paraschos et al., 2017]

Trajectory - ProMP



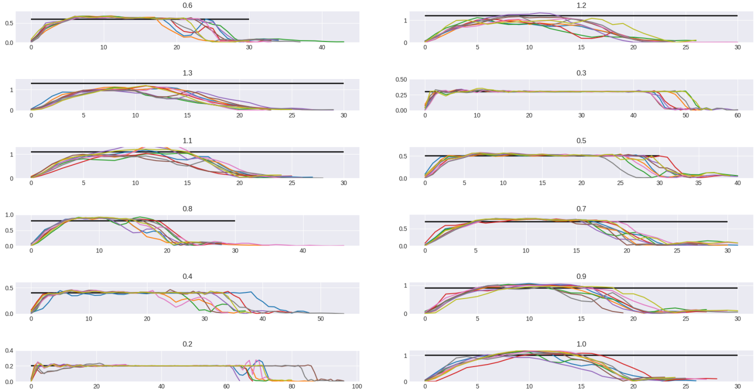
Physical handover detection

- Robot picks up an object
- Executes a trajectory with an specified velocity towards receiver
- Receiver grasps object from the robot's gripper
- Receiver places object onto the table

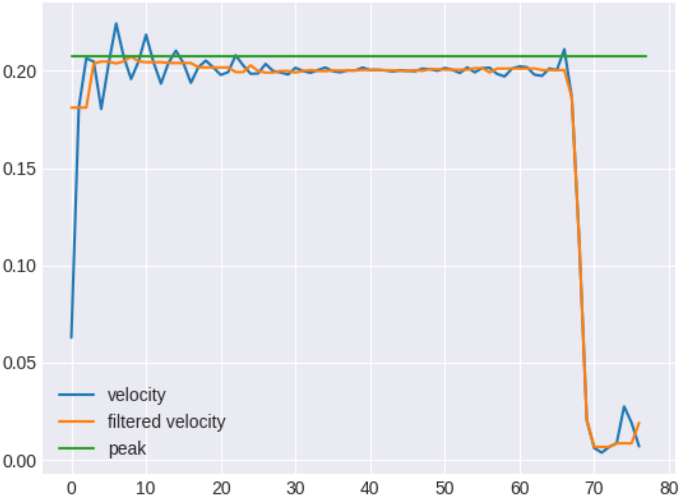
Human activity annotations

- Robot picks up an object
- Executes a trajectory with an specified velocity towards receiver
- Receiver grasps object from the robot's gripper
- Receiver places object onto the table

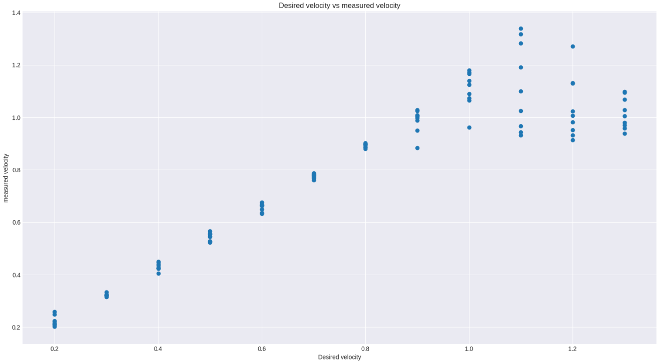
Velocity Accuracy



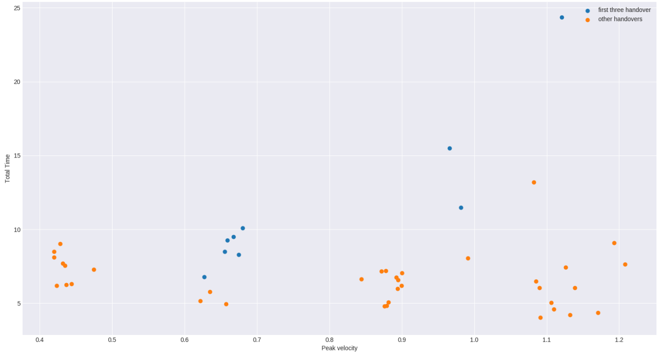
Velocity Accuracy



Velocity Accuracy



Learning Effect

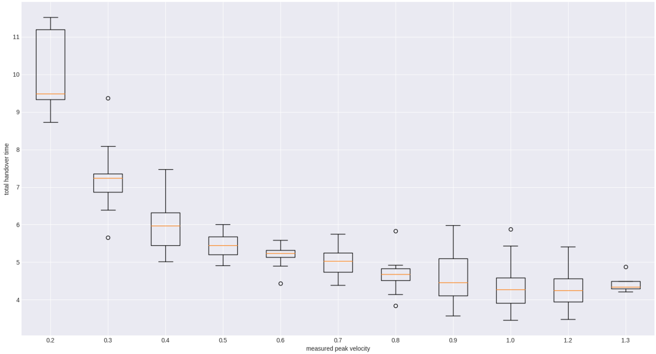


Remove first three handovers $\rightarrow$ 36 total handovers

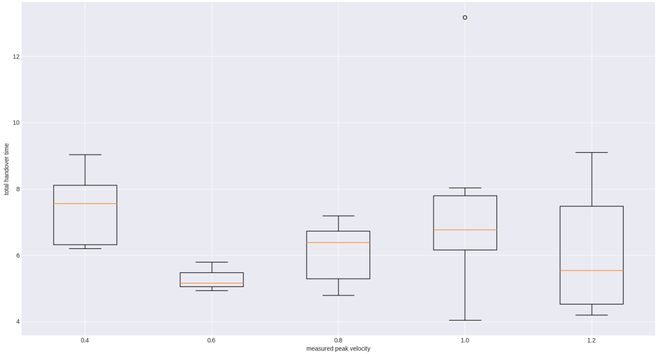
H1:

Faster robot trajectories lead to shorter overall handover time.

H1 - Prestudy - Total handover time



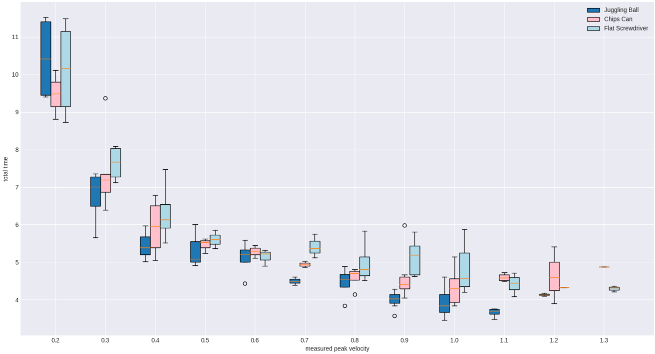
H1 - Study - Total handover time



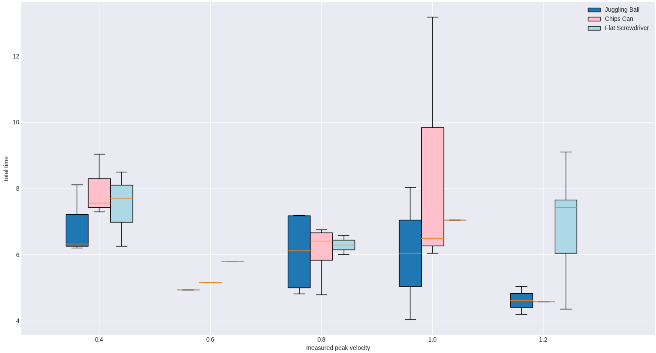
H2:

Object type affects the overall handover time.

H2 - Prestudy - Total handover time



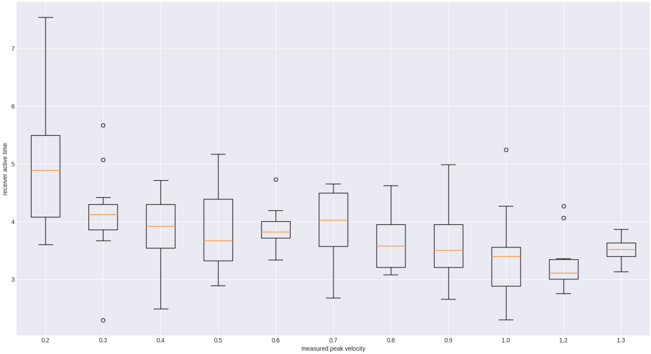
H2 - Study - Total handover time



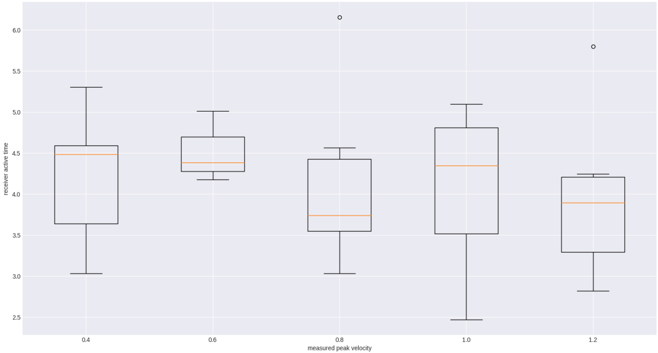
H3:

Faster robot trajectories make humans act slower.

H3 - Prestudy - Human active time



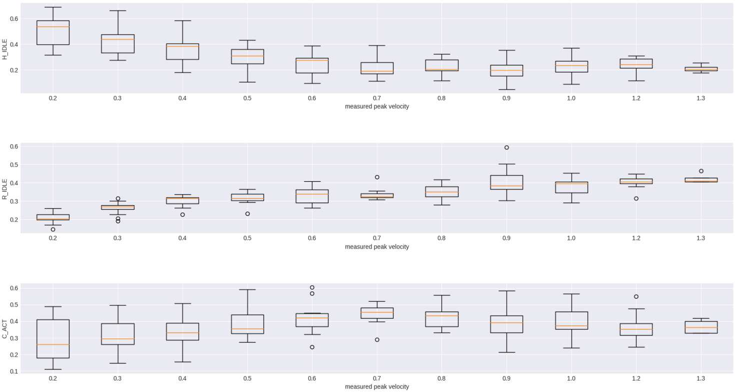
H3 - Study - Human active time



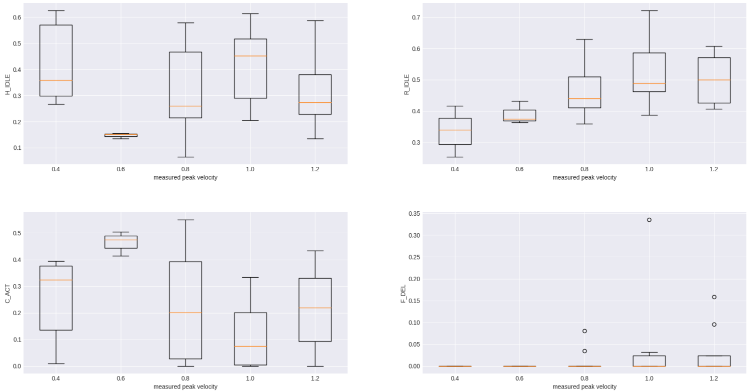
H4:

Faster robot trajectories reduce fluency.

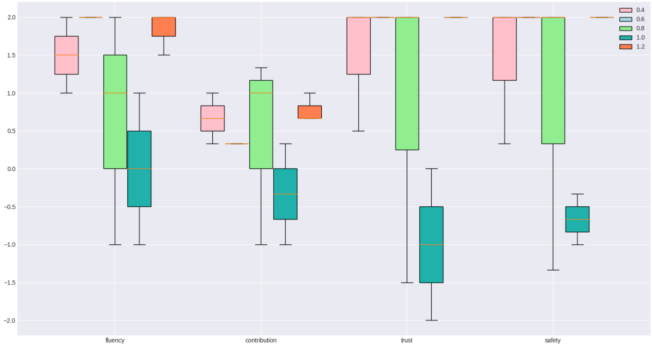
H4 - Prestudy - H-IDLE, R-IDLE, C-ACT



H4 - Study - H-IDLE, R-IDLE, C-ACT, F-DEL



H4 - Study - Questionnaire



Conclusion

- Number of participants too small for significant results
- There is some evidence, that faster trajectories lead to a less fluent interaction
- Faster trajectories do not increase the time the receiver is active
- Faster trajectories do reduce the overall handover time
- Object type does affect the overall handover time

Future Work

- More participants
- Faster robot (e.g. UR5)
- Include training phase
- Heavier or more complex objects
- Shorter questionnaire

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