FLUIDITY in Human-Robot Interaction

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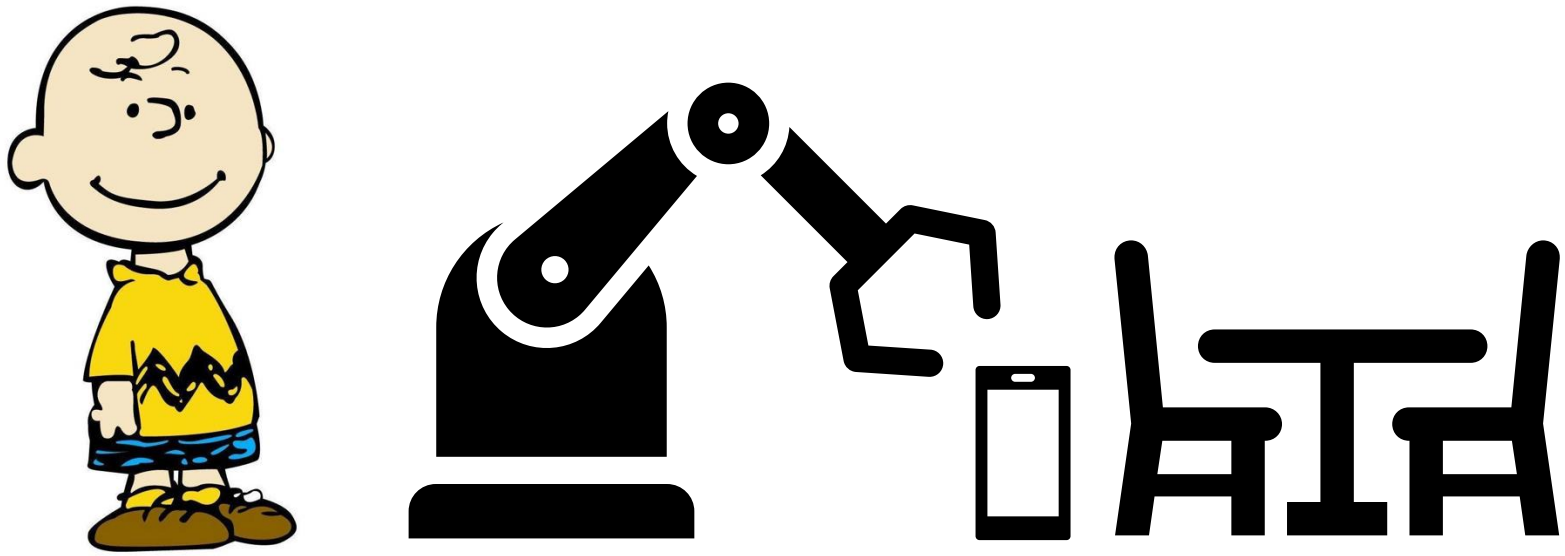
EPSRC
Engineering and Physical Sciences Research Council

Swansea University
Prifysgol Abertawe

A problem with current robots…



A problem with current robots…

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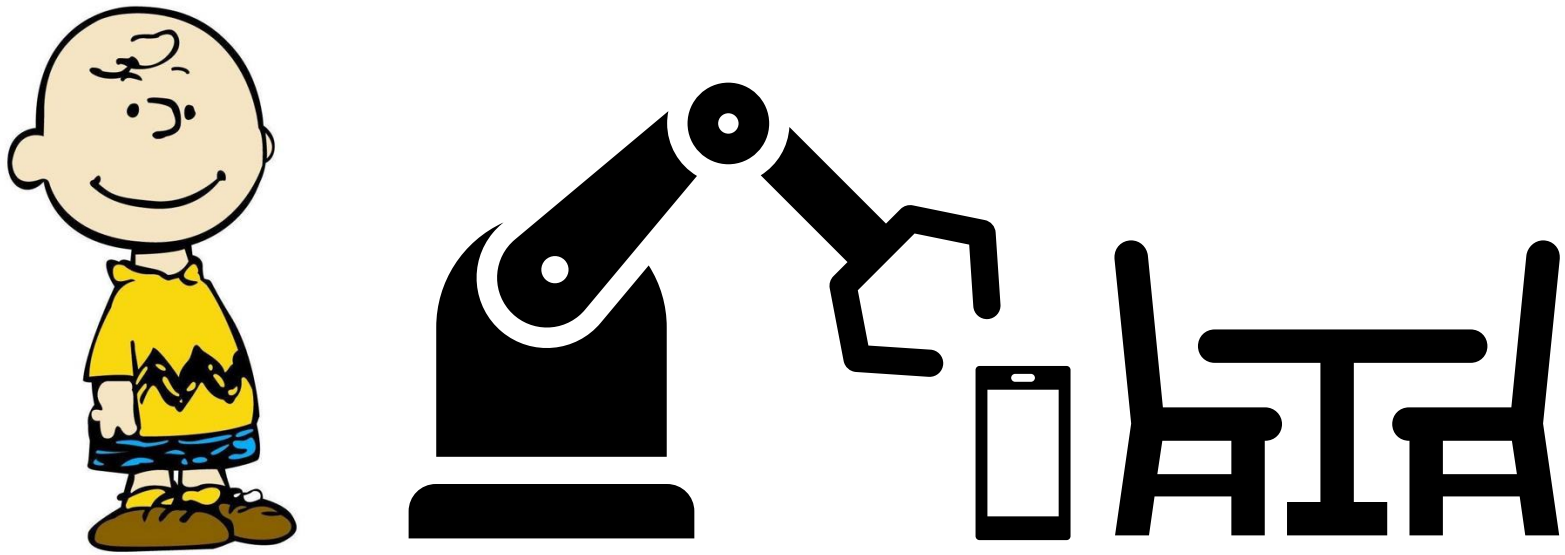
Some time later…



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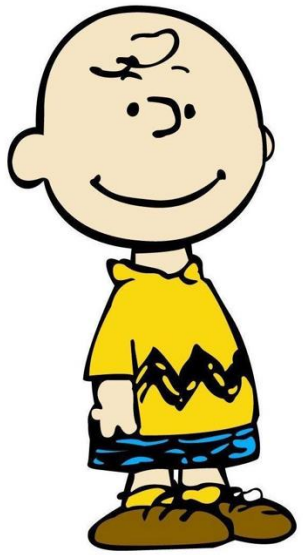
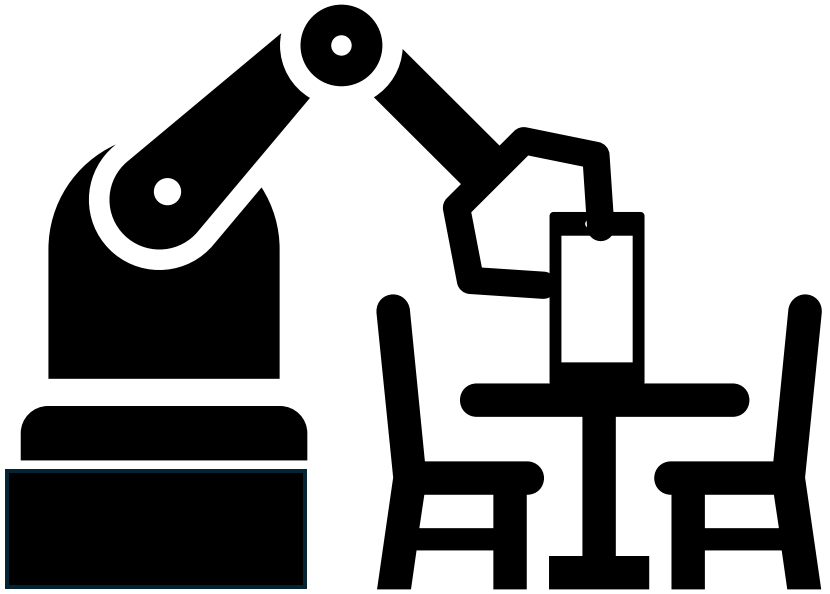
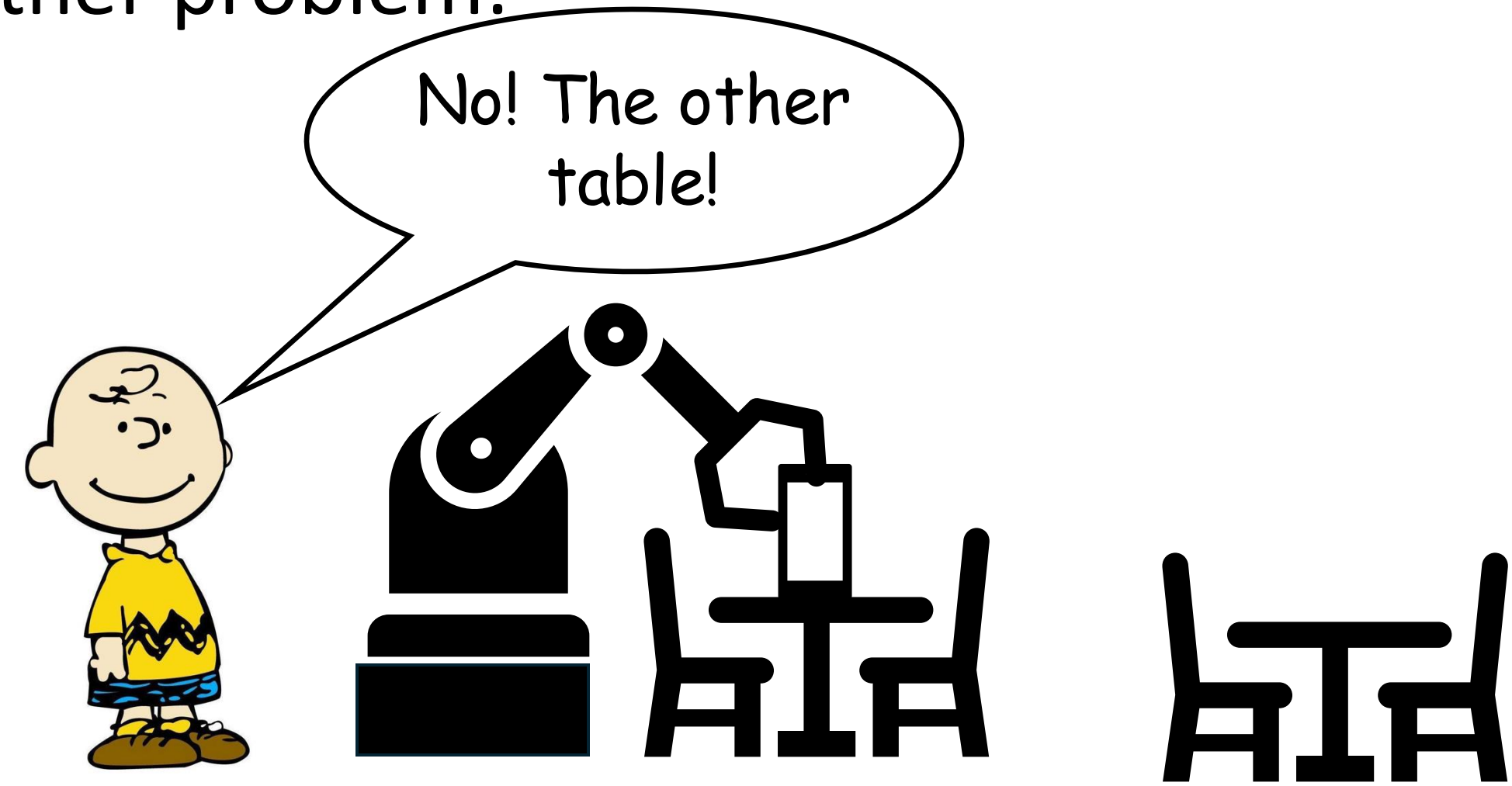
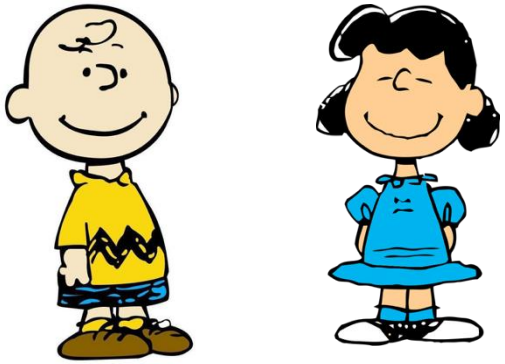




Another problem:



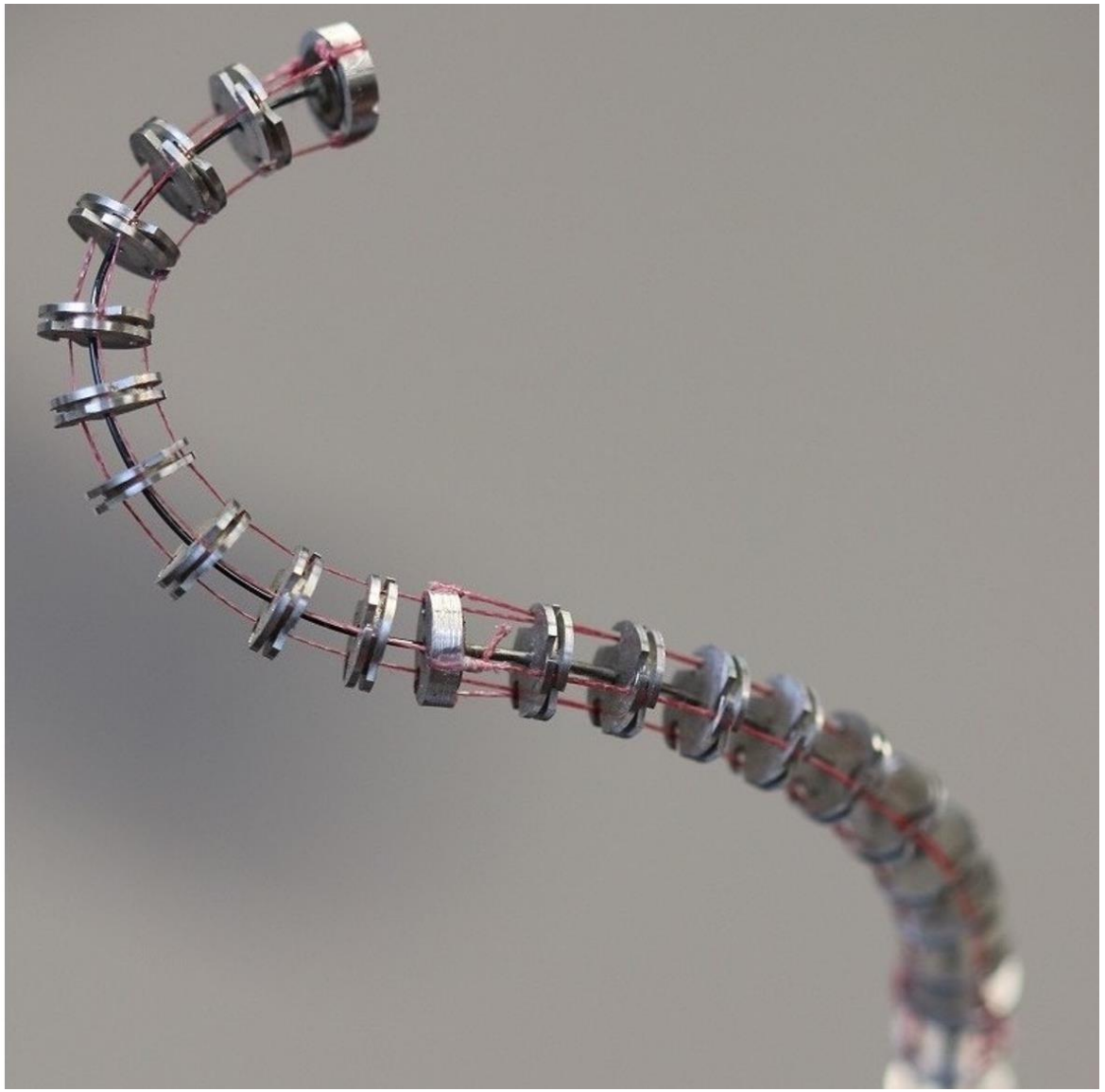
Problems which humans don't have…



- In face-to-face conversation, turn-taking is **seamless** and **predictive.**
- Average turn transition 0-200ms (De Ruiter et al., 2006; Heldner and Edlund, 2010)
- Same applies **multi-modally** (Hough et al., 2015) – people move/gesture during speech continuously!
- **Repairs** and **recovery from misunderstanding** still allow rapid response times (Brennan and Schober, 2001).
- That is, the interaction feels **fluid.**

Fluidity

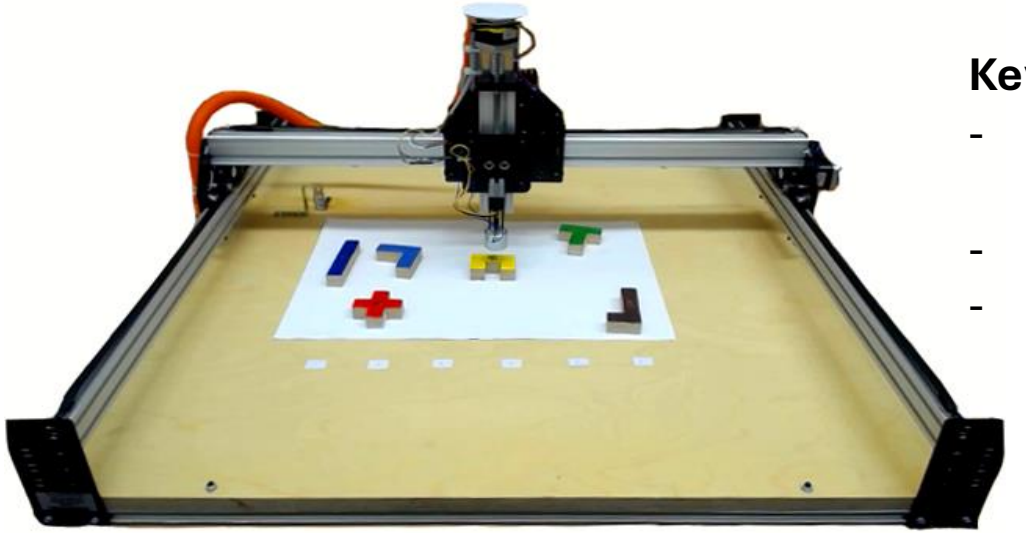
- Even if we have more fluid and continuously operating hardware…
- And indeed better and faster computer vision and speech recognition.
- And indeed bigger and better LLMs!
- These are not enough to achieve fluid interaction.



Improving Interaction Fluidity

- In HRI we have non-fluid, laboured interactions.
- Hough and Schlangen (SigDial 2016) proposed a fluid control model for a simple pick-and-place robot PentoRob.

PentoRob



Key methods:

- **Incremental speech processing (word-by-word)**
- **Continuous intention modelling**
- **Real-time communicative grounding management**

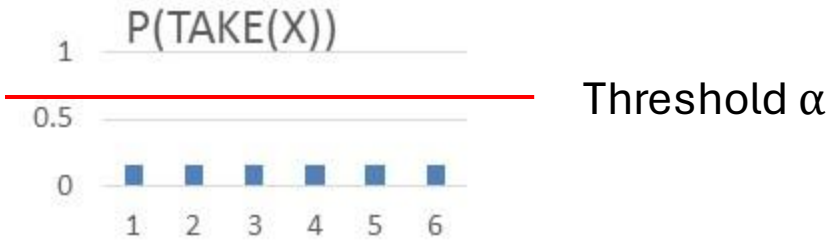
“take the red cross and move it to box 2”

“right” “no the other cross”

Improving Interaction Fluidity

Hough and Schlangen, SigDial 2016

Ev(UserGoal) = intention recognition confidence



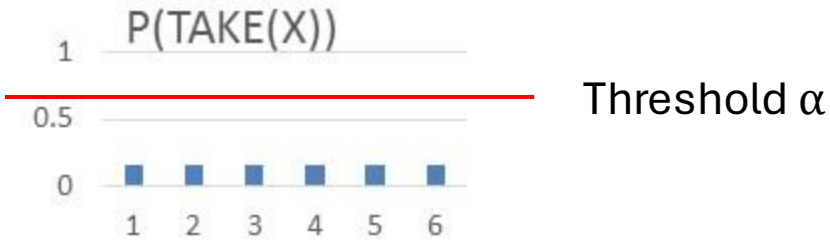
Threshold α

Improving Interaction Fluidity

Hough and Schlangen, SigDial 2016

Ev(UserGoal) = intention recognition confidence

take



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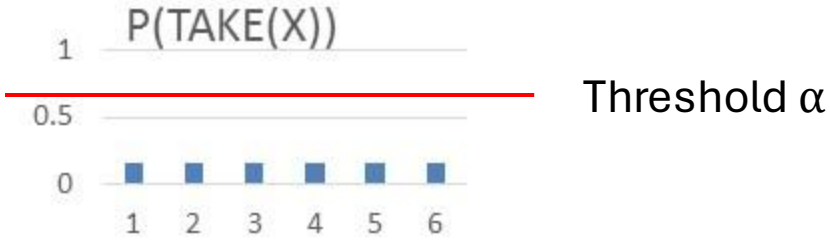

Threshold α

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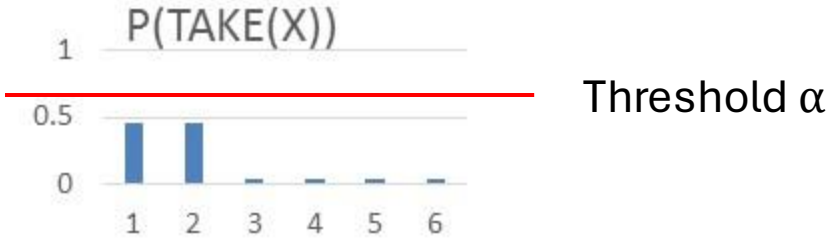
take | the | blue



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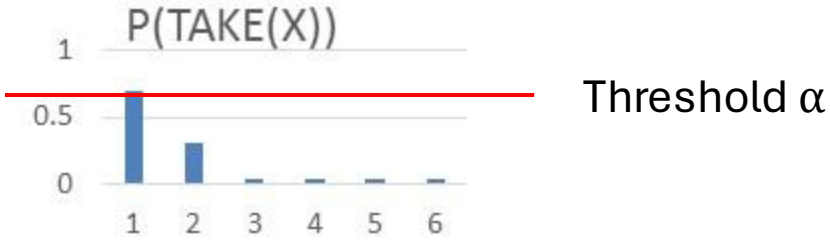
take | the | blue | L



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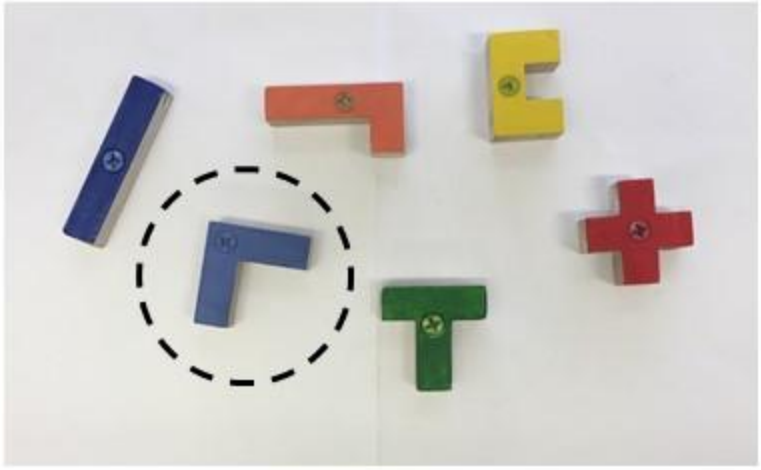

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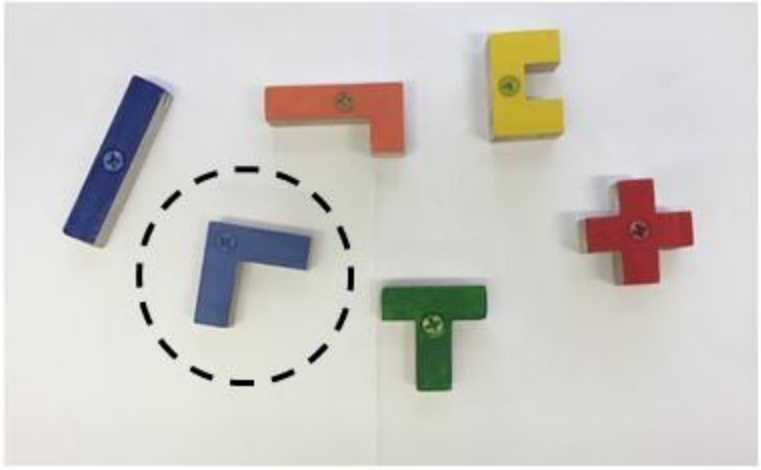

Higher Threshold α - safe, but non-fluid

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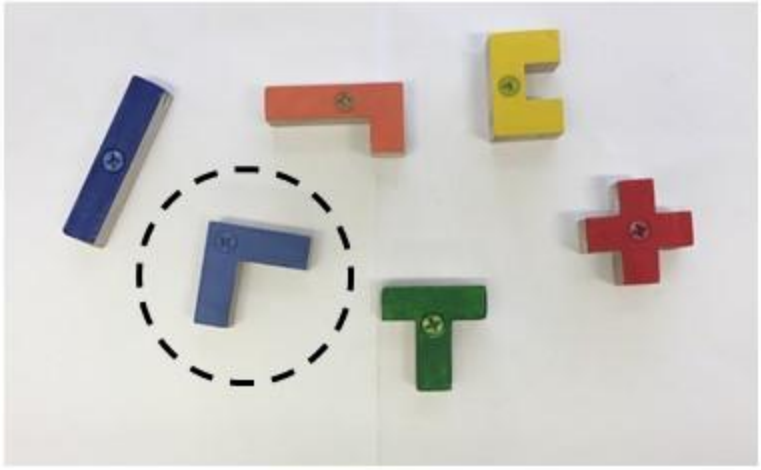
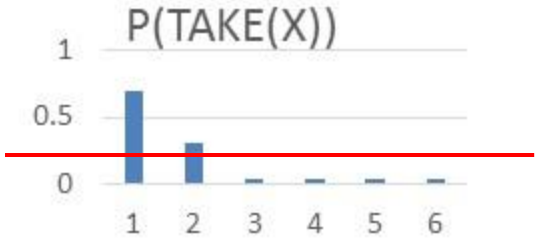


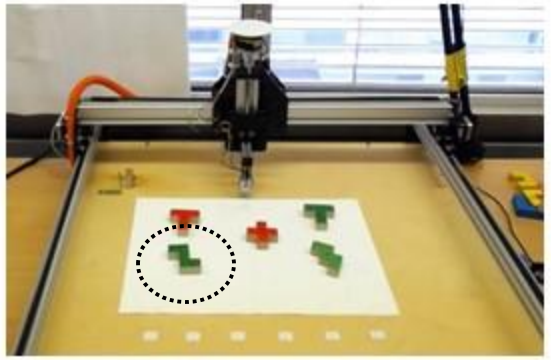


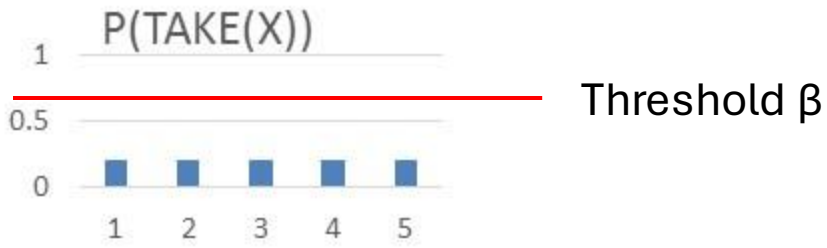
Lower Threshold α - less safe, but fast/fluid

Improving Interaction Fluidity

Hough and Schlangen, SigDial 2016

Ev(RobotGoal) = **legibility** of action (Dragan et al, 2013)





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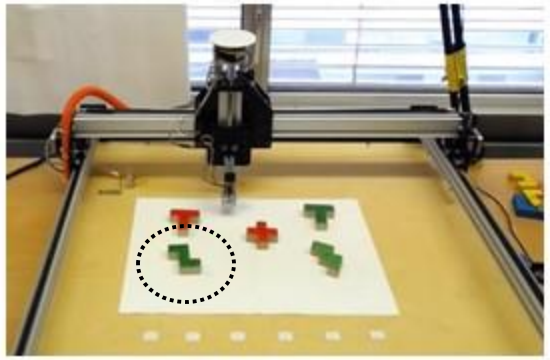

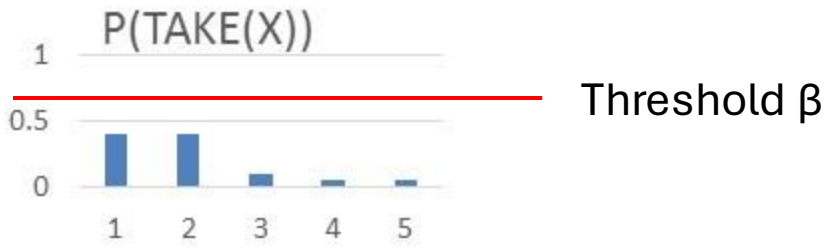

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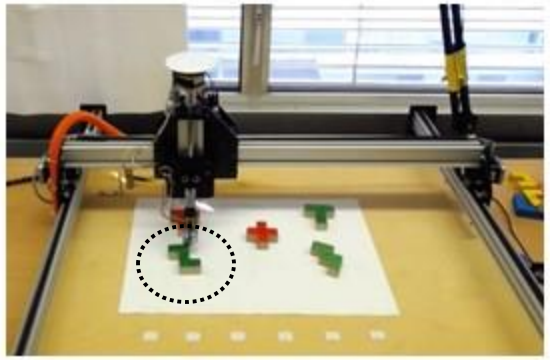

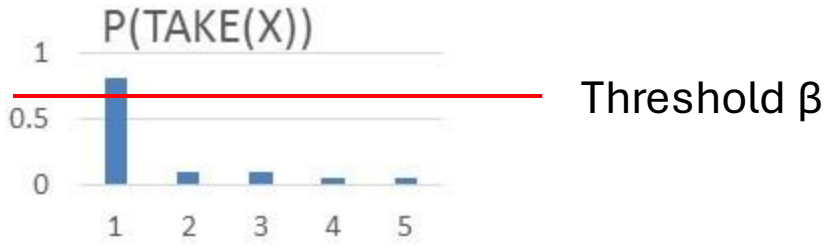

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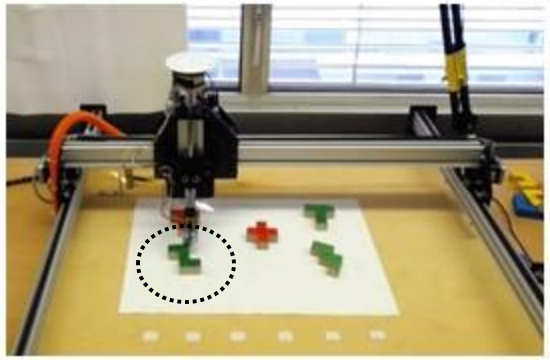
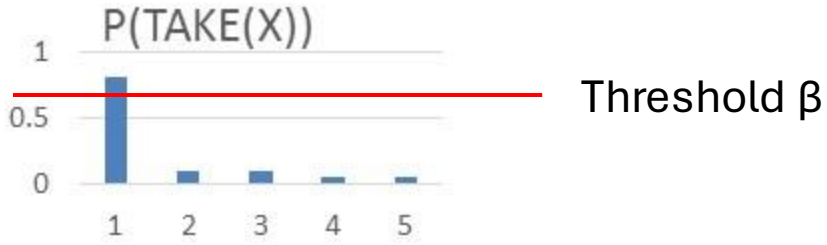


Grounded yes



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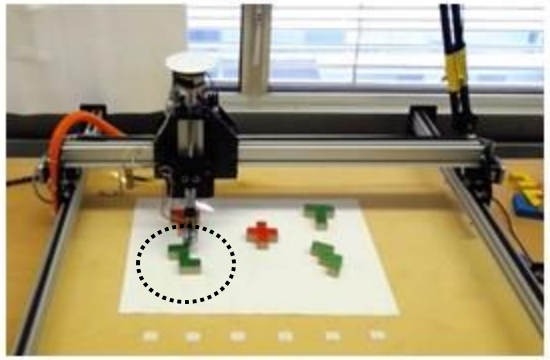

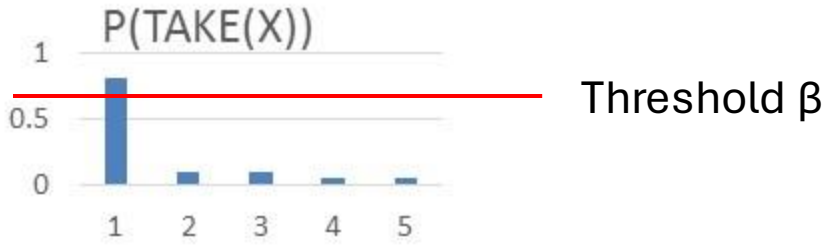

Repair

no

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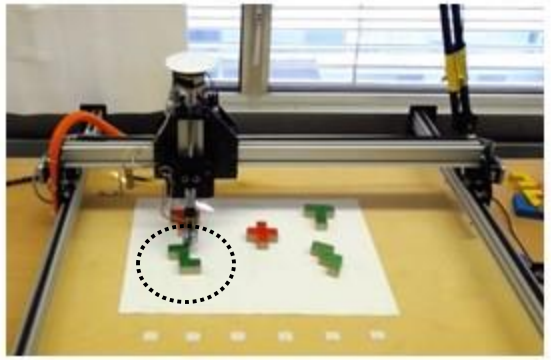

Higher threshold β – safe, but slow/non-fluid

Improving Interaction Fluidity

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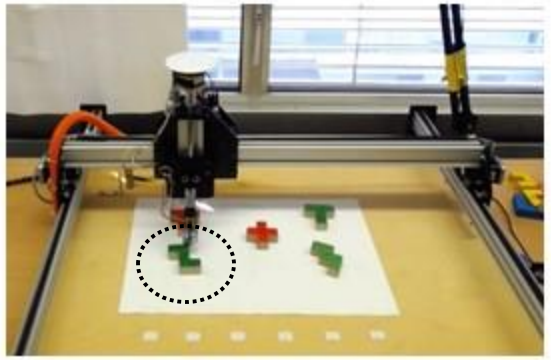
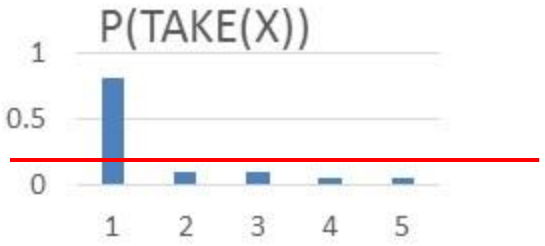
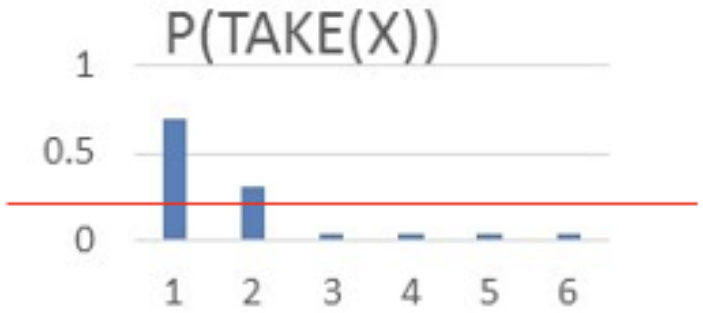




Lower threshold β – less safe but faster/more fluid

Improving Interaction Fluidity

- Fluidity: manipulation of **intent confidence thresholds** for action for different responsiveness vs safety trade-off:



Lower Threshold α - less safe, but fast/fluid

Higher Threshold α - safe, but non-fluid

Improving Interaction Fluidity

Hough and Schlangen (2016, SigDial)

- **Experiment 1:** By increasing fluidity with lower threshold for **Ev(RobotGoal)** we can improve users' perception of the robot's *understanding* according to user ratings.

- **Experiment 2:** We can increase fluidity with lower threshold for **Ev(UserGoal).** Higher repair rates from user but no effect on task success.

Improving Interaction Fluidity

TAKE-AWAYS:

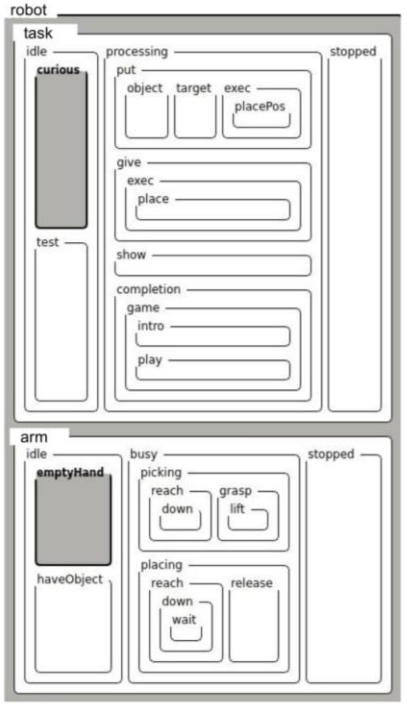
Even if individual components fail in different ways, with effective control which increases fluidity we can make more successful, pleasant interactions.

Users may prefer fluid corrections and repairs over slower and laboured interactions, even if they have less accurate first-time predictions.

FLUIDITY in Simulated Human-Robot Interaction with Speech Interfaces

FLUIDITY project
(EPSRC, Swansea/UHerts 2023-2026)

- Aims to generalize fluidity
- With incremental parsing and legibility
- Uses VR Unity Fetch robot simulation (Baptista De Lima et al., 2024)
- Wizard-of-Oz data collection
- Comparison to real-world robot



classifier	1	2	3	4	5	6	7	8	9	10
Remote	0.99	0.05	0.30	0.43	0.32	0.57	0.48	0.89	0.60	0.87
Basket	0.10	0.99	0.04	0.90	0.45	0.45	0.40	0.25	0.40	0.40
Spherical	0.30	0.00	0.92	0.91	0.85	0.97	0.90	0.30	0.88	0.20

“put the mug on the table… in the dishwasher”

$$i = \left[human : \left[intention : \left[\begin{array}{ll} goal & : \left[\begin{array}{ll} landmark & : obj\_2 \\ rel\_location & : INTO \end{array} \right] \\ objects & : \{obj\_1\} \\ action & : PUT \end{array} \right] \right] \right]$$

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Thank you...

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https://fluidity-project.github.io/