On-The-Go Robot-to-Human Handovers with a Mobile Manipulator

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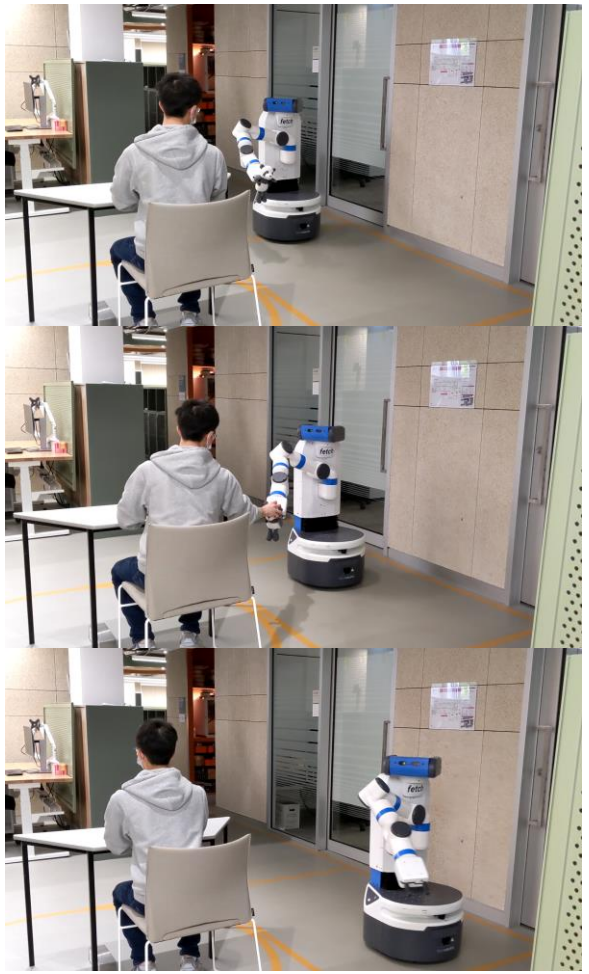
Introduction: Motivation

- Most handover research performed on **fixed-base manipulators**
- Handovers can also be performed on **mobile manipulators** which allow global access within a workspace
- Can we allow the base to **continue to move** while performing a handover?

Stop and deliver

On-the-go



Introduction: Related Work

Handovers w/ fixed-base manipulators:

- Yang et al., 2021
- Rosenberger et al., 2020
- Kupscik et al., 2018 – considers cases where human is moving

Handovers w/ mobile manipulators:

- Choi et al., 2009
- Quispe, Martinson, and Oguchi, 2017
- Mainprice et al., 2012

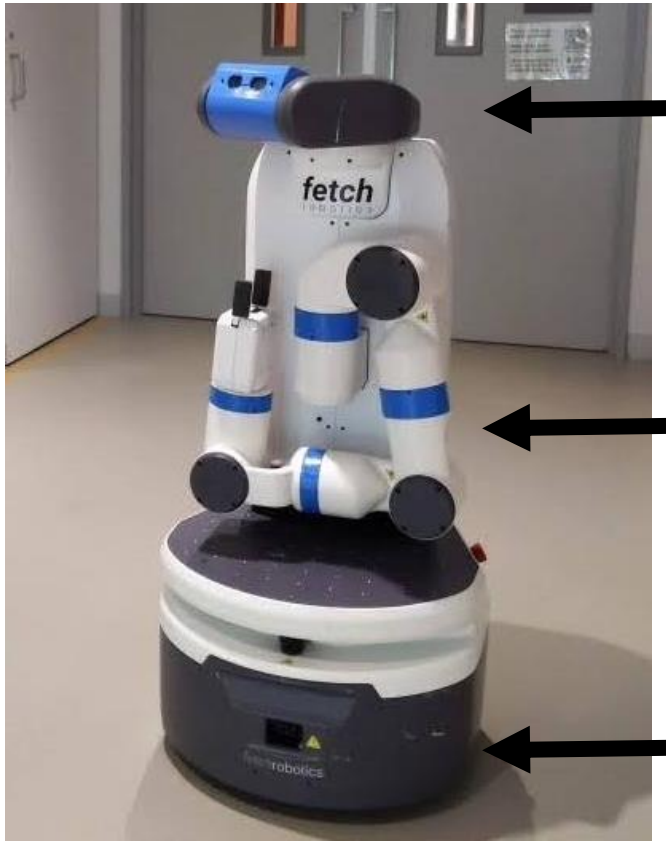
However, the robot always comes to a **full stop** at the object transfer point

Introduction: Contributions

- We propose **on-the-go** handovers for mobile manipulators
- Compare against standard **stop and deliver** handovers
- Perform user studies to investigate subjective perceptions of human receivers

Methodology: Robot Implementation

- Experiments conducted on a **Fetch Mobile Manipulator**
- Localisation and mapping via. default ROS SLAM packages
- Control of arm and base performed using **holistic optimization-based reactive controller** (Haviland, Sünderhauf, and Corke, 2022)



Methodology: Stop-and-deliver

Methodology: On-the-go

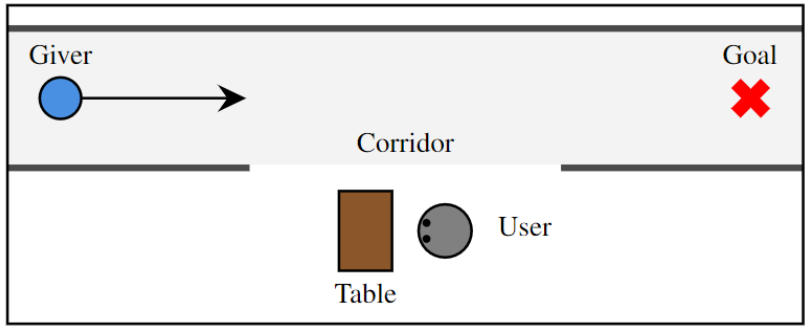
Methodology: On-the-go

Methodology: Experimental Design

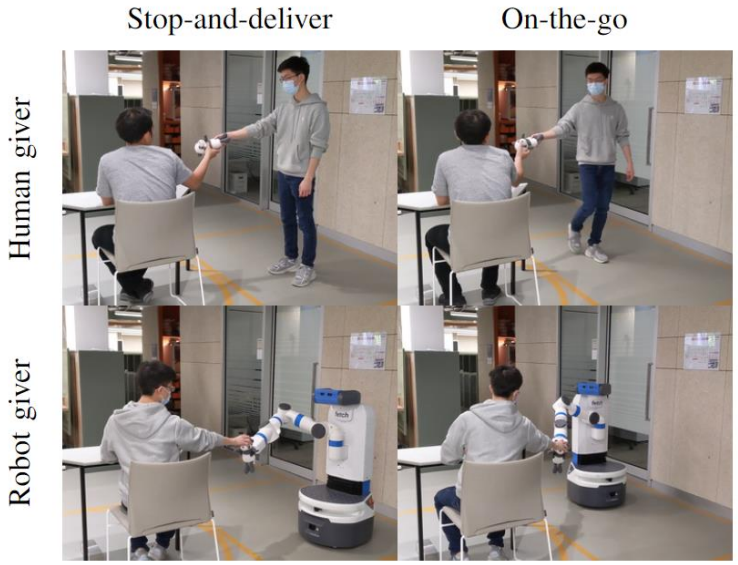
- Robot traverses down corridor towards goal
- Handover object is soft plushie

- Two independent variables:
  - Handover style (on-the-go vs. stop and deliver)
  - Giver (robot vs. human)
- Four handovers per participant, ran in randomized order

Experimental setup



Handover object



Methodology: Survey

After each handover, rate on 5-point Likert scale:

- The giver was **efficient** in completing the handovers
- The interaction with the giver felt **natural**
- The giver's **timing** was appropriate
- The giver was **competent** in giving objects to me
- I felt **safe** during the interaction
- I was able to **predict** what the giver was going to do

After all four handovers:

- Which **robot giver** handover did you prefer
- Which **human giver** handover did you prefer

Methodology: Survey

Recruited 15 participants from University premises

- 11 male, 4 female participants
- Aged 20 to 31 (μ=22.9, σ=3.56)

Hypothesis:

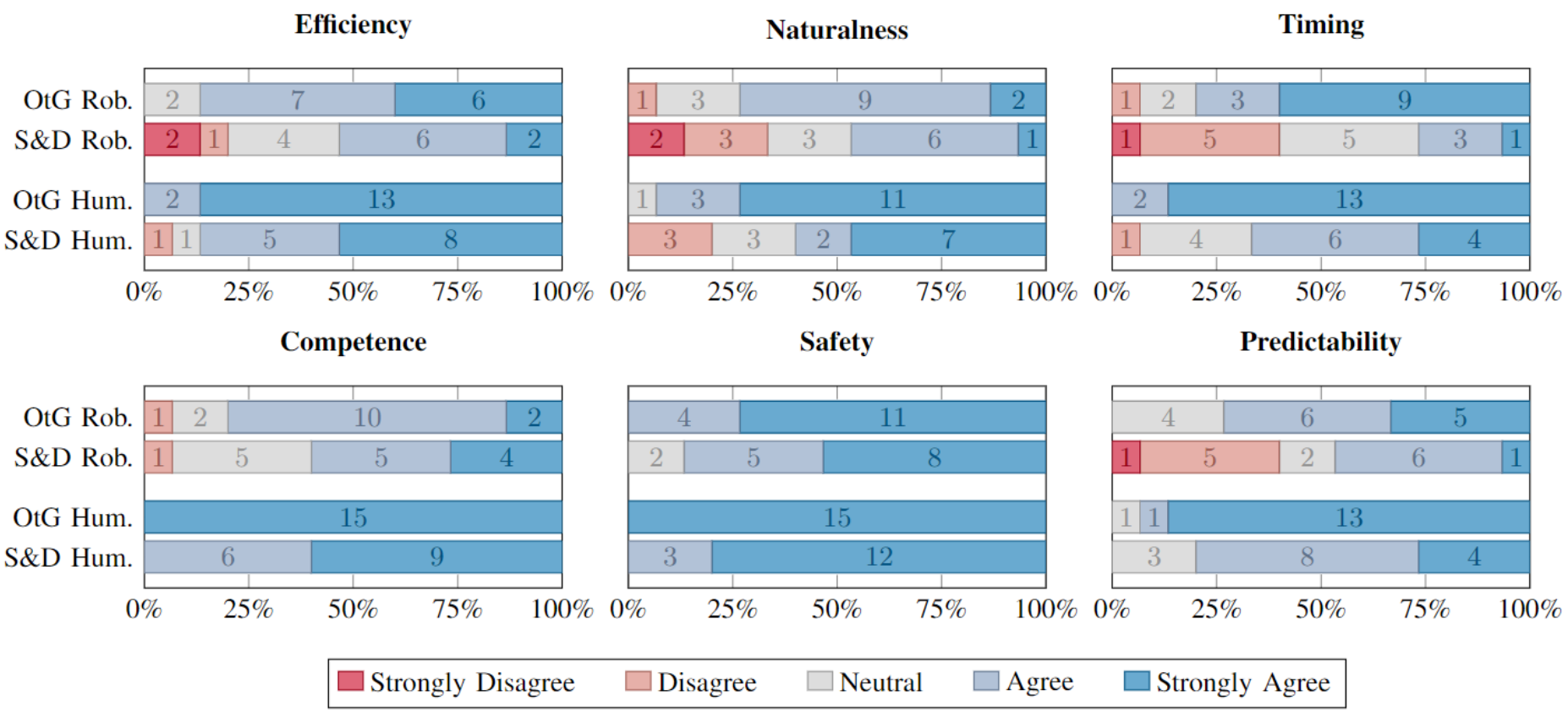
On-the-go handovers will be perceived **more positively** than **stop-and-deliver** handovers in all subjective measures.

Analysis:

- Single-tailed Pratt Modified Wilcoxon signed-rank test
- 5% significance level

Results: Analysis

Raw data



Hypothesis test summary

	H_a	Robot	
		W(15)	p
Efficiency	OtG>S&D	87.0	**0.021**
Naturalness	OtG>S&D	80.0	**0.020**
Timing	OtG>S&D	114.0	**0.001**
Competence	OtG>S&D	55.0	0.291
Safety	OtG>S&D	63.0	**0.049**
Predictability	OtG>S&D	90.5	**0.008**

	H_a	Human	
		W(15)	p
Efficiency	OtG>S&D	81.0	**0.016**
Naturalness	OtG>S&D	85.0	**0.041**
Timing	OtG>S&D	106.5	**0.002**
Competence	OtG>S&D	75.0	**0.007**
Safety	OtG>S&D	42.0	**0.042**
Predictability	OtG>S&D	101.0	**0.003**

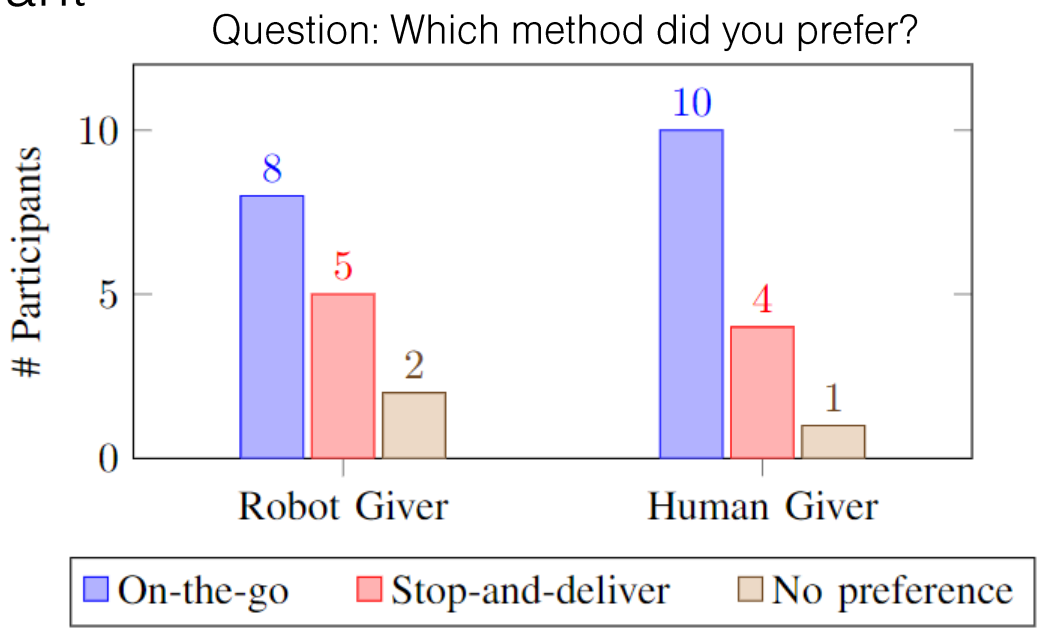
Results: Discussion

- On-the-go perceived as more **efficient**, **natural**, **safer**, **predictable** and have better **timing**
- However, not statistically significantly more **competent**

- Raw preferences do not show a clear preference of on-the-go
- Possibly due to preference being task-dependant

"[It] felt like each handover is good for a different purpose. [I] preferred [the on-the-go] handover for this particular [object]."

"If the robot was bringing me a plate of food, I would have preferred the [stop-and-deliver handover] since its safer."



Conclusion

- **Stop and deliver** is the standard way of performing handovers in existing literature

- However, **on-the-go** handovers can be more efficient and desirable in scenarios similar to ours

Future work:

- Better understand when and where on-the-go handovers are suitable

- Catching the attention of the handover receiver