Human-centered Benchmarking for Socially-compliant Robot Navigation

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1. Background and Motivation

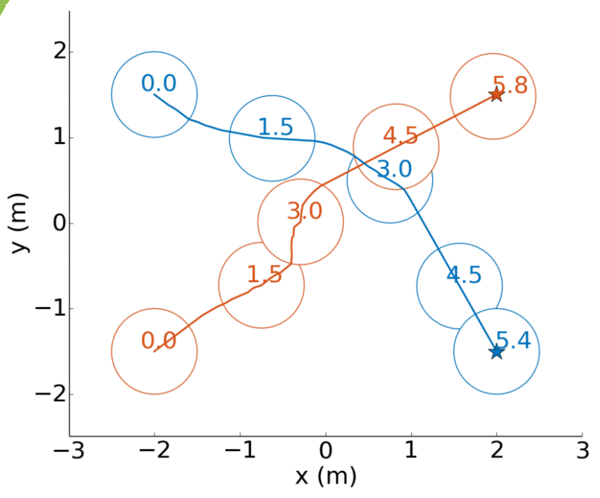


Fig.1. The example of RCM – agent's trajectory [1]


Fig.2. The experiment to measure HCM [2]

Evaluation of socially-compliant (SC) robot navigation by robot-centered metrics (RCM)

☑ The experiments with RCM can be done in a simulation

☑ RCM can be incorporated in the navigation algorithms

☒ RCM cannot represent the human feelings

Evaluation of SC robot navigation by human-centered metrics (HCM)

☑ HCM are the most accurate measuring of human feelings

☒ The HCM experiments require real participants

☒ HCM cannot be incorporated in the navigation algorithms

2. Aim and objectives


Fig.3. The experiment to evaluate SC robot navigation

Aim: improve the effectiveness of socially-compliant robot navigation evaluation

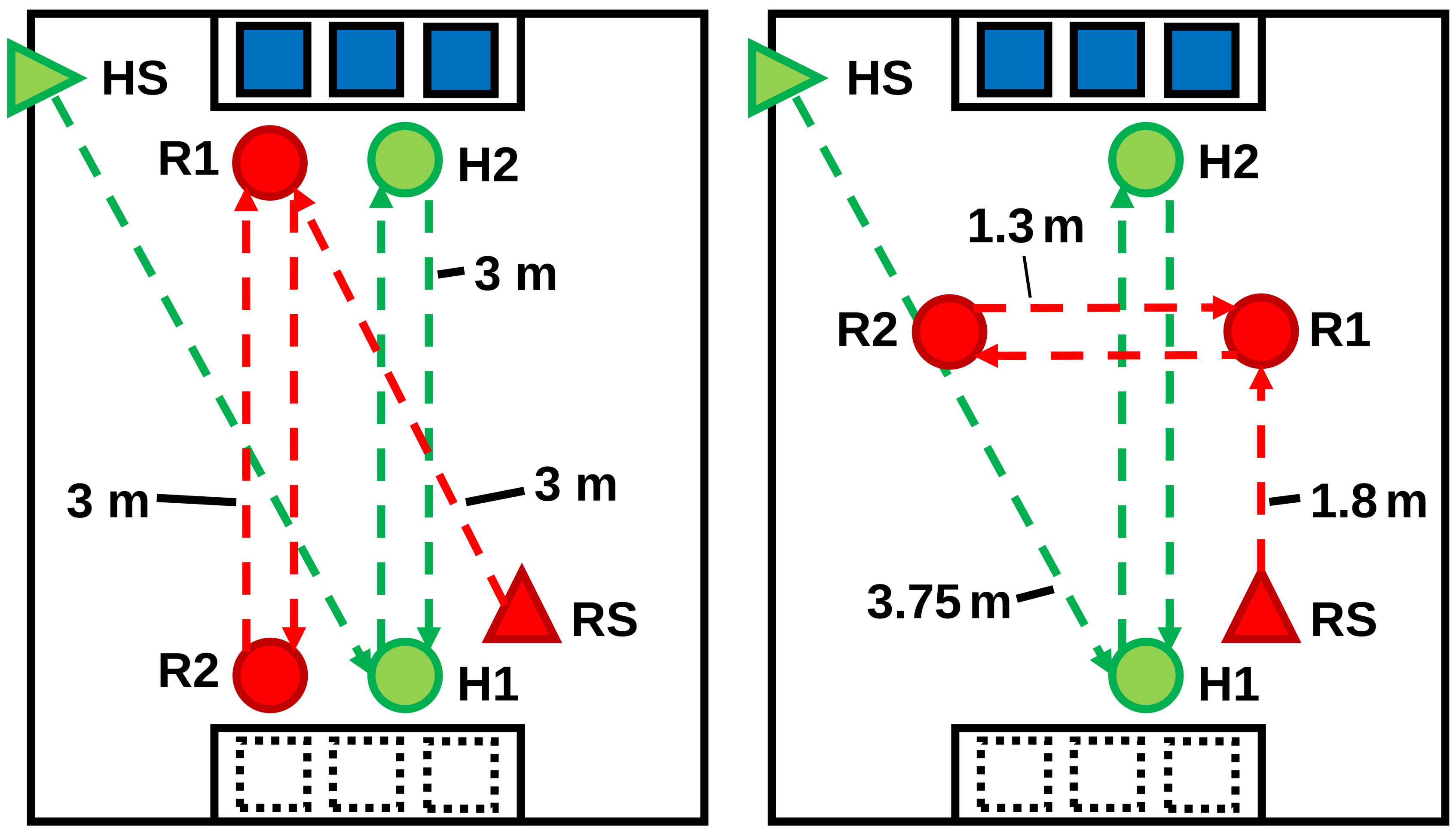
Objectives:

1) To develop an end-to-end human-centered benchmarking framework
2) To evaluate the correlation between HCM and RCM

3. Contributions

1) **The proposed reproducible end-to-end human-centered benchmarking** framework. The benchmark was tested with 2 SC and two regular robot navigation methods
2) **We found the correlation between some RCM and HCM**, which allows to judge the social part of human-robot interaction by RCM

3. Benchmarking Framework



▶ is the person's start position;
▲ is the robot's start position;
● is the person's goal position;
● is the robot's goal position;
■ is the box's start position;
⬚ is the box's finish position;
➔ is the person's trajectory;
➔ is the robot's trajectory.

4. Social Competence Metrics

HCM

The Robotic Social Attributes Scale (RoSAS) [3]

Warmth	Competence	Discomfort
Happy	Capable	Scary
Feeling	Responsive	Strange
Social	Interactive	Awkward
Organic	Reliable	Dangerous
Compassionate	Competent	Awful
Emotional	Knowledgeable	Aggressive

RCM

$$R^{r}_{extra} = T^{r}/T^{r}_{h} \qquad R_{succ} = N_{succ}/N$$

$$R^{h}_{extra} = T^{h}/T^{h}_{r} \qquad R_{haza} = \frac{1}{n} * \sum_{i=1}^{n}\left(\frac{T_i^{hazard}}{T_i^{social}}\right)$$

$$R_{dist} = D^{r}/D^{r}_{h} \qquad R_{dec} = \frac{1}{n_v} * \sum_{i=1}^{n_v}\left(\frac{V_i}{V_{max}}\right)$$

5. Experiments

Experimental setting:

- **20 participants**
- **4 methods:**

1) Social Navigation Layers (SNL) [4]
2) Time Dependent Planning (TDP) [5]
3) Collision Avoidance with Deep Reinforcement Learning (CADRL) [6]
4) Move base (MB) [7]

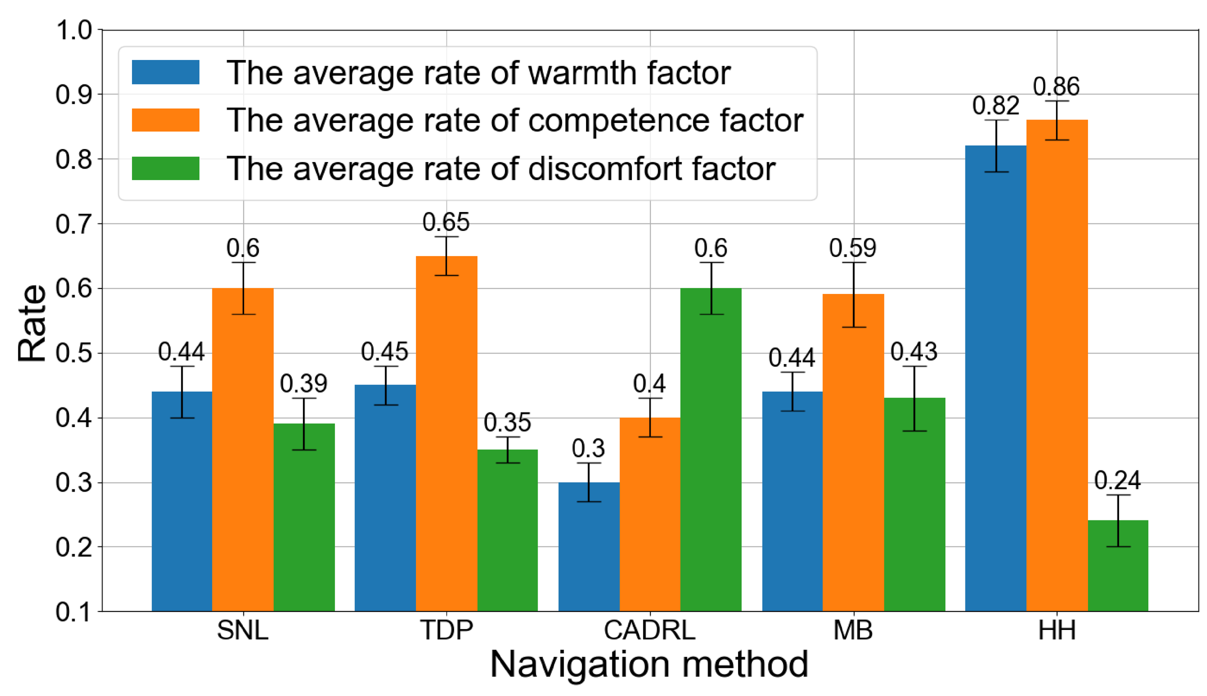


Fig.4. The mean values of HCM with standard error (N = 20)

The mean values of HCM and RCM

Metric	SNL	TDP	CADRL	MB
Warmth	0.44	0.45	0.30	0.44
Competence	0.60	0.65	0.40	0.59
Discomfort	0.39	0.35	0.60	0.43
R_{haza}	0.59	0.57	0.65	0.56
R^{h}_{extra}	0.9	0.88	0.94	0.87
R_{dist}	0.96	1.00	0.95	0.97
R_{dec}	0.56	0.58	0.17	0.61
R^{r}_{extra}	0.77	0.74	1.00	0.83
R_{succ}	0.92	0.85	1.00	0.8

Conclusion

The developed framework can be applied to evaluate the social element of robot navigation

TDP demonstrates the best HCM

R^{r}_{extra} and R_{dist} reflect the HCM and can be used to judge the social competence of navigation methods

The software-hardware integration scheme is available:
https://github.com/Nedzhaken/human_aware_navigation

References

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