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Navigating without Intruding Humans' Social Space

A cost-based Approach

Carolin Schindler | 07.07.2022 | Project Autonomous Systems

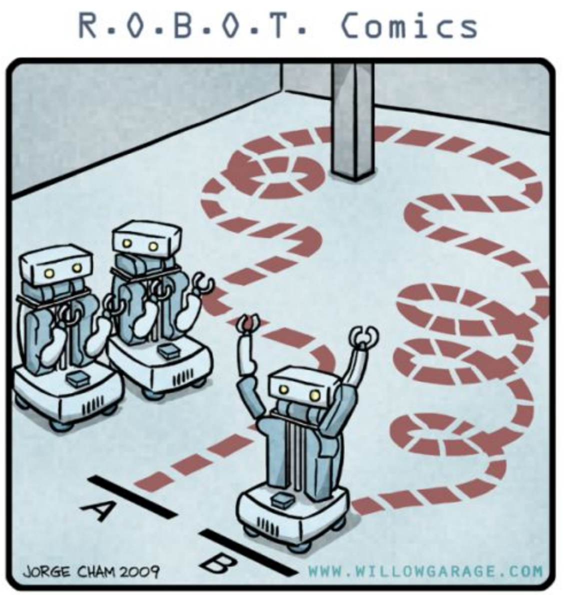
Motivation

Robots employed in human environments should conform to social values and norms.

Basic task of navigating to a given goal

- no explicit interaction but sharing space with humans
- can cause misunderstandings, discomfort or even insecurity, e.g., when intruding people's social space

→ navigation should not treat people as obstacles but consider their social space

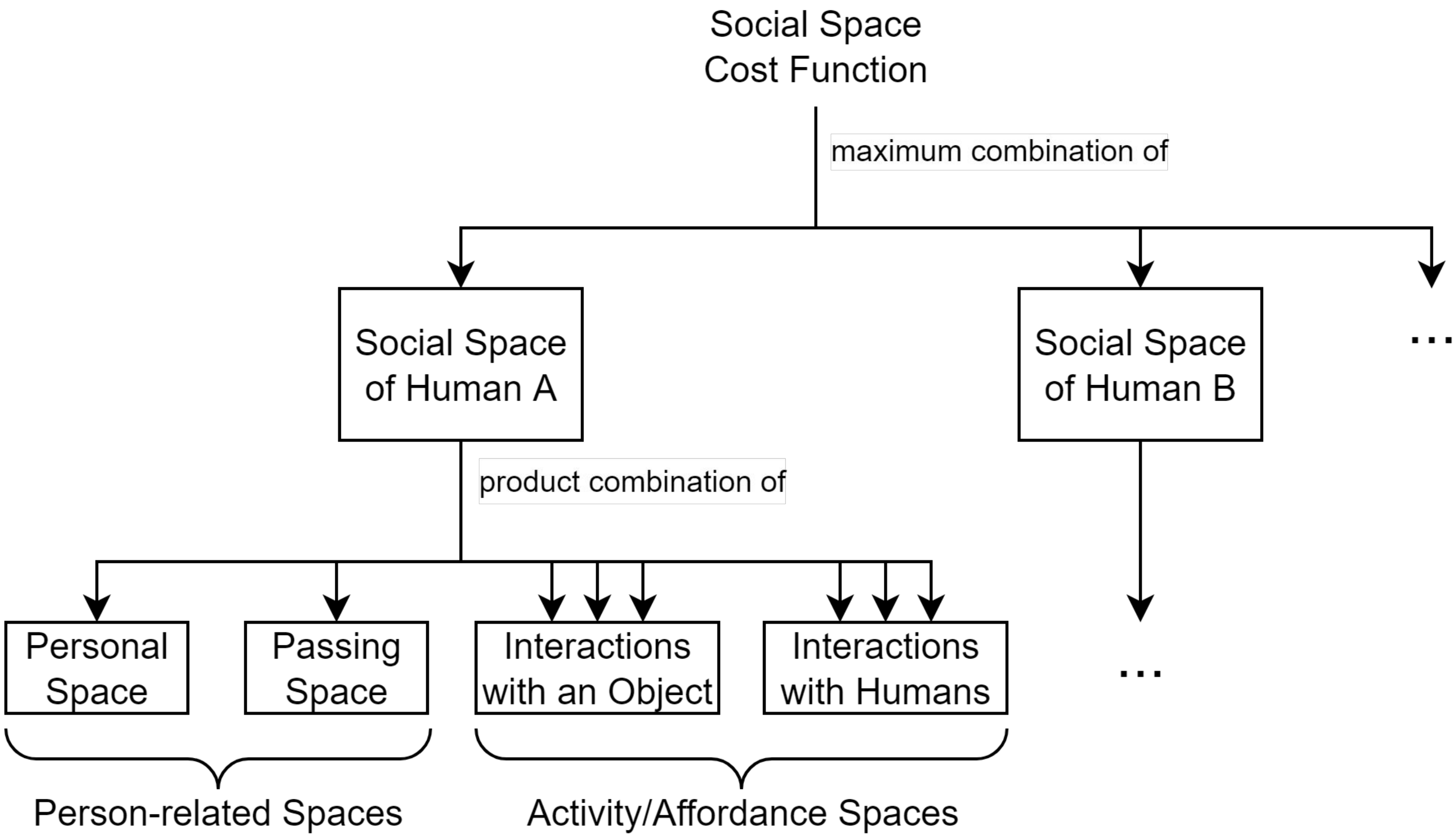


"HIS PATH-PLANNING MAY BE SUB-OPTIMAL, BUT IT'S GOT FLAIR."

Modular Cost Function for Modelling Humans’ Social Space

Methods

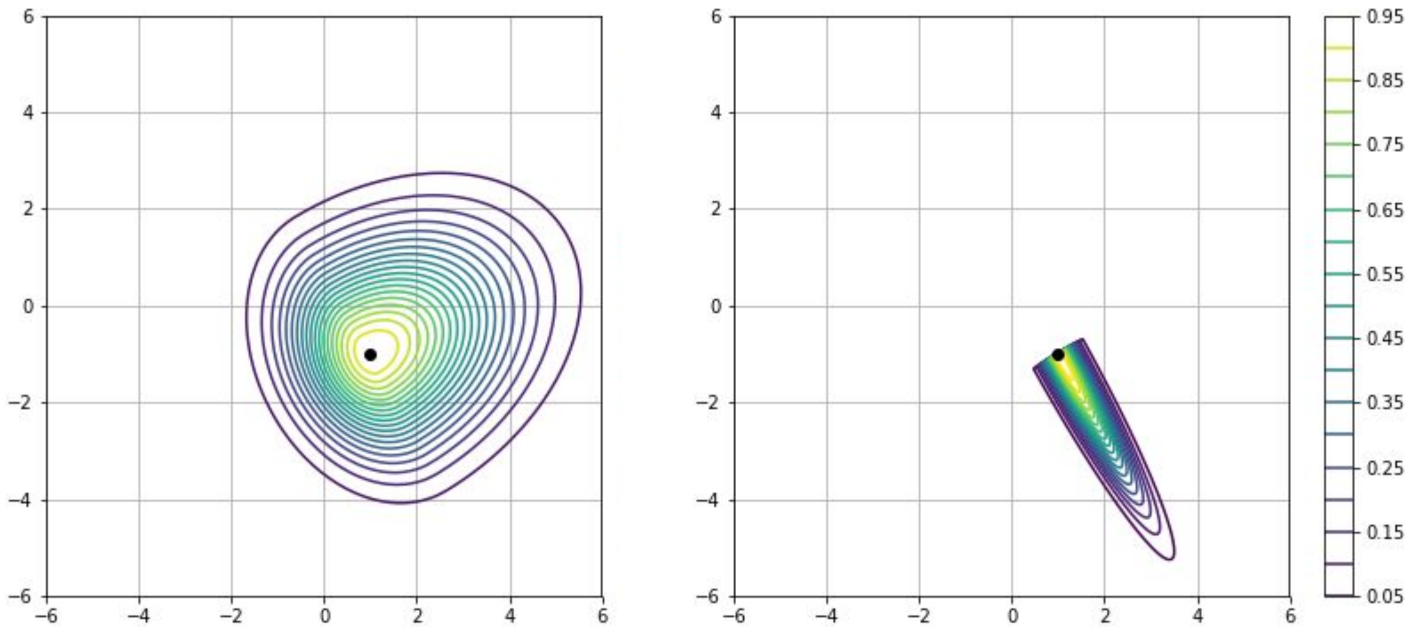
Social Space Cost Function



Felix Lindner and Carola Eschenbach. 2011. Towards a formalization of social spaces for socially aware robots. In Spatial Information Theory, pages 283–303. Springer Berlin Heidelberg.

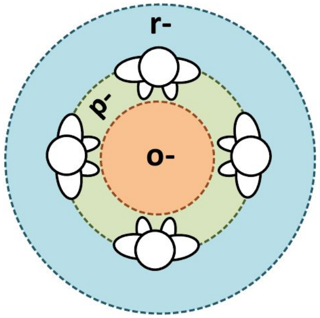
distance zones		distance from person [m] from	to
intimate distance	close	0	0.15
	far	0.15	0.46
personal distance	close	0.46	0.76
	far	0.76	1.22
social distance	close	1.22	2.13
	far	2.13	3.66
public distance	close	3.66	7.62
	far	7.62	∞

Person-related Spaces

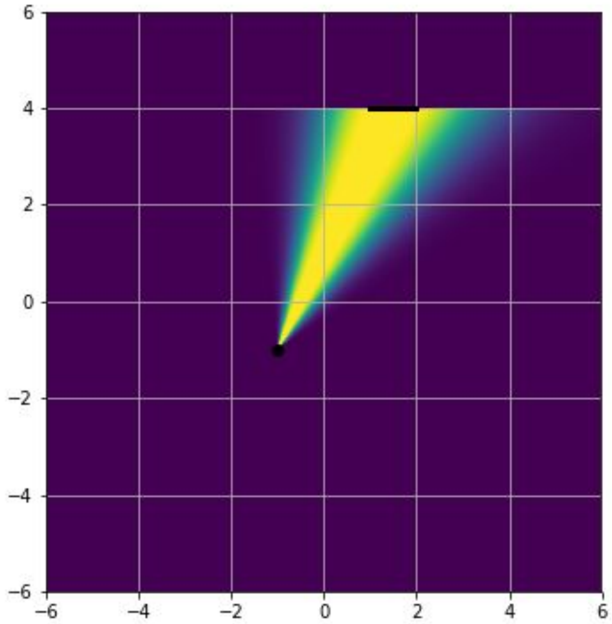


Personal Space Passing Space

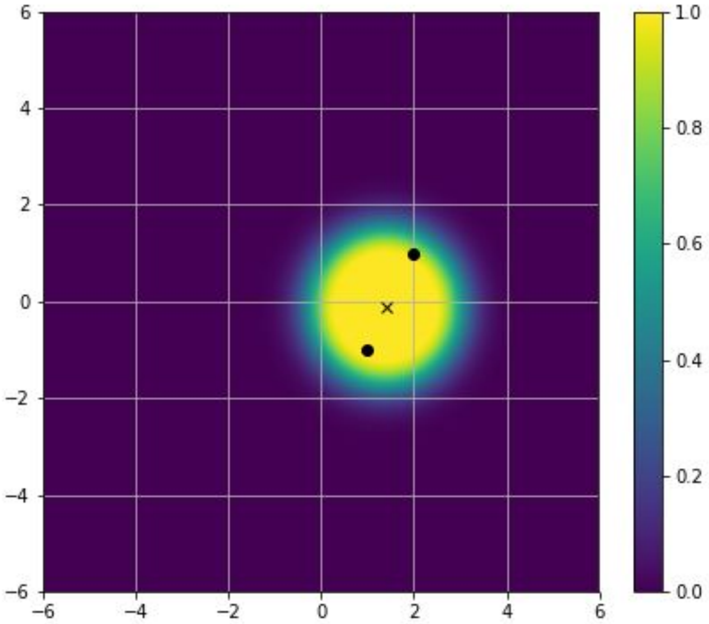
Rachel Kirby. 2010. Social Robot Navigation. Ph.D. thesis, Carnegie Mellon University, Pittsburgh, PA.
Edward Twitchell Hall. 1969. The Hidden Dimension. Doubleday, New York.



Activity / Affordance Spaces



with an Object



with Humans

James Jerome Gibson. 1979. The theory of affordances. In The ecological approach to visual perception, chapter 8. Houghton Miffin, Boston.
L. Bai. 2018. Merging human-object interaction behavior into a personal space model: for social robot navigation. Master's thesis, Industrial Engineering and Innovation Sciences, Eindhoven University of Technology.
Adam Kendon. 2010. Spacing and Orientation in Co-present Interaction, pages 1–15. Springer Berlin Heidelberg.
Francesco Setti, Chris Russell, Chiara Bassetti, and Marco Cristani. 2015. F-formation detection: Individuating free-standing conversational groups in images. PLOS ONE, 10(5):1–26.

Combining the individual Sub-Spaces

Product Combination

- in the inverted cost-space
- $\mathrm{prod}(s_1, s_2, \ldots, s_n) = 1 - \left(\prod_{i=1}^{n} (1 - s_i) \right)$
- effect on costs
    - no overlap: costs stay the same
    - overlap: increased costs

Maximum Combination

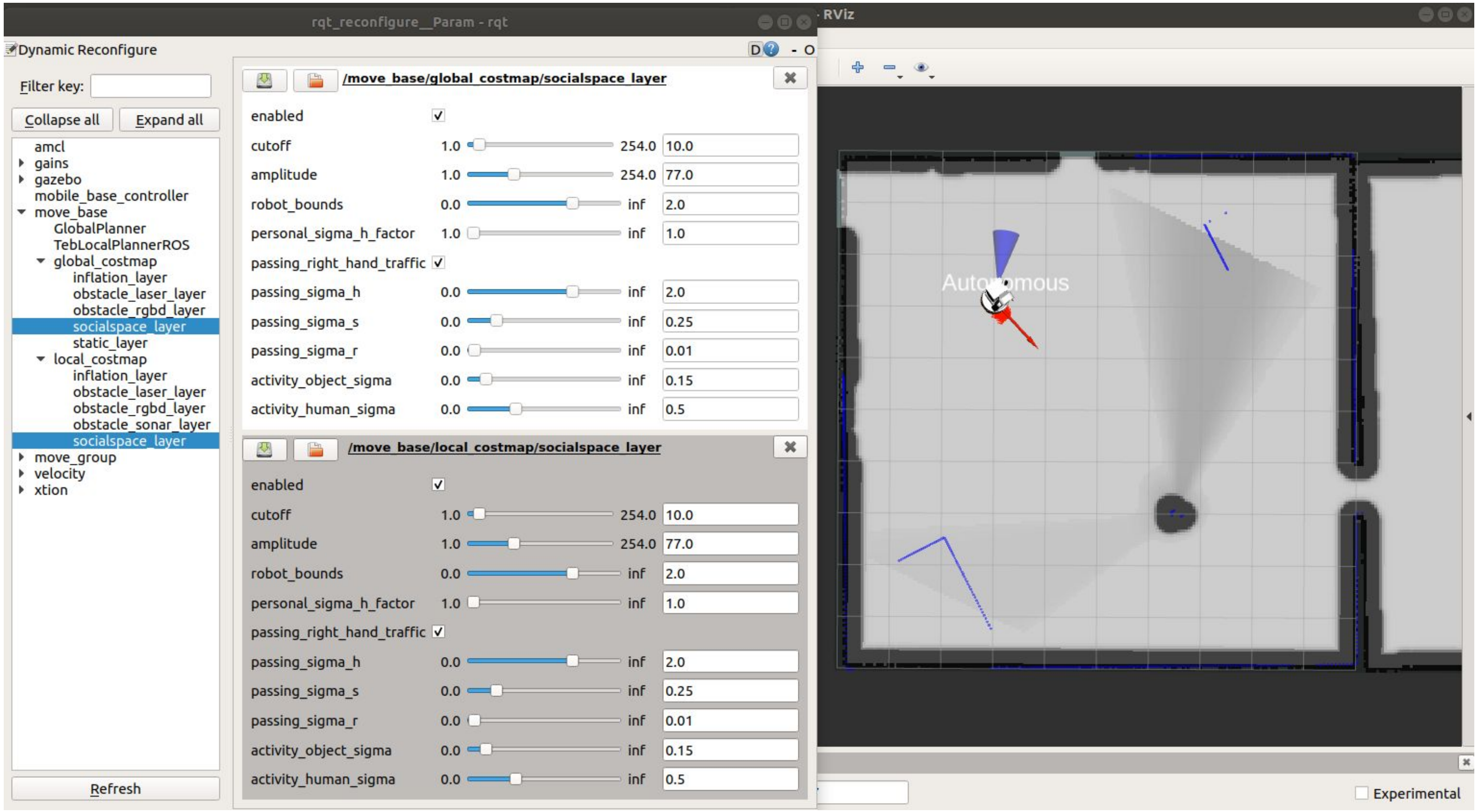
- effect on costs
    - no overlap: costs stay the same
    - overlap: maximum of the costs → no increase of costs possible

L. Bai. 2018. Merging human-object interaction behavior into a personal space model: for social robot navigation. Master's thesis, Industrial Engineering and Innovation Sciences, Eindhoven University of Technology.
J. Rios-Martinez, A. Spalanzani, and C. Laugier. 2014. From proxemics theory to socially-aware navigation: A survey. International Journal of Social Robotics, 7(2):137–153.

Employment as a Navigation Layer in ROS

Methods

Social Space Navigation Layer



David V. Lu, Dave Hershberger, and William D. Smart. 2014. Layered costmaps for context-sensitive navigation. In 2014 IEEE/RSJ International Conference on Intelligent Robots and Systems, pages 709–715.
rqt_reconfigure Documentation: http://wiki.ros.org/rqt_reconfigure

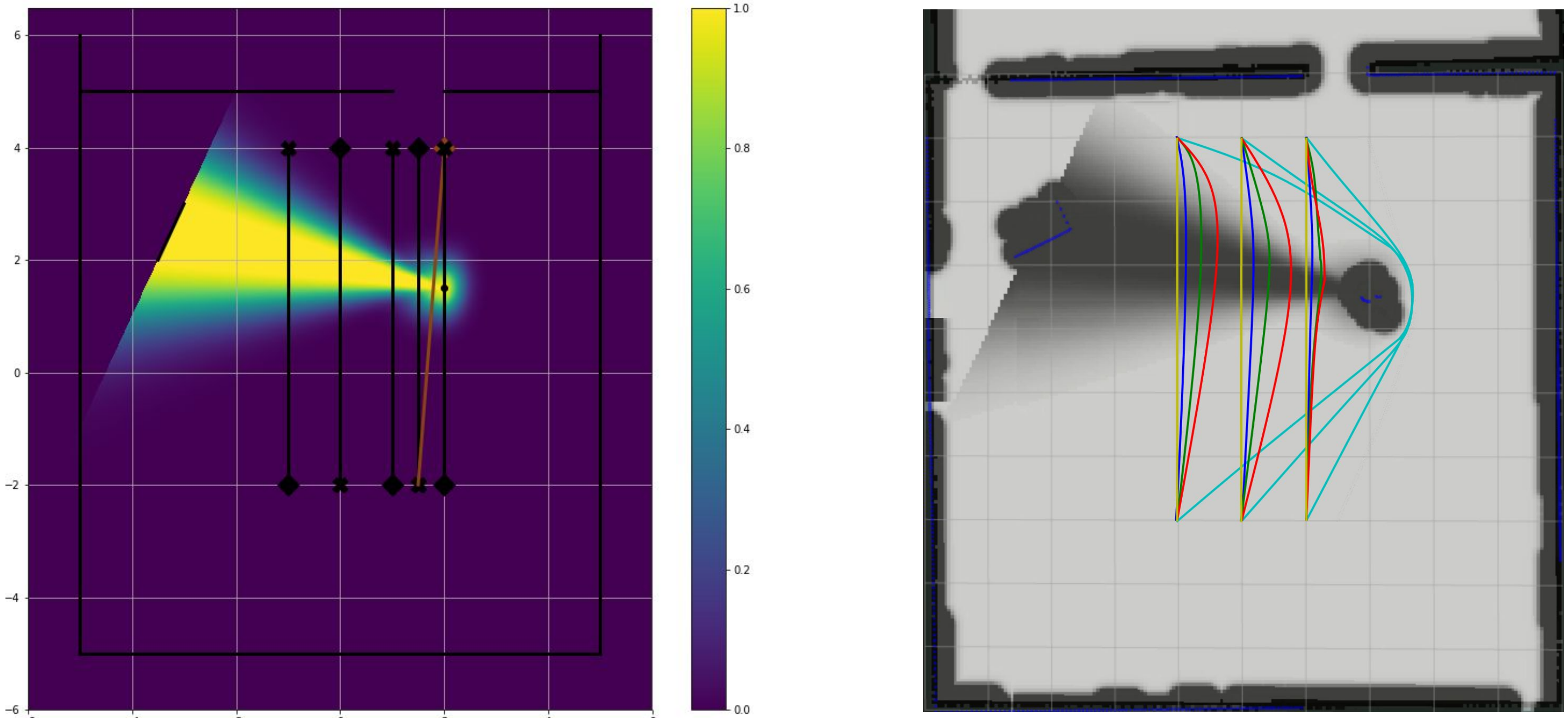
navigation performance
- reaching the goal
- path efficiency

behavioural naturalness
- trajectory smoothness

human comfort
- no collisions
- no intrusions of social spaces

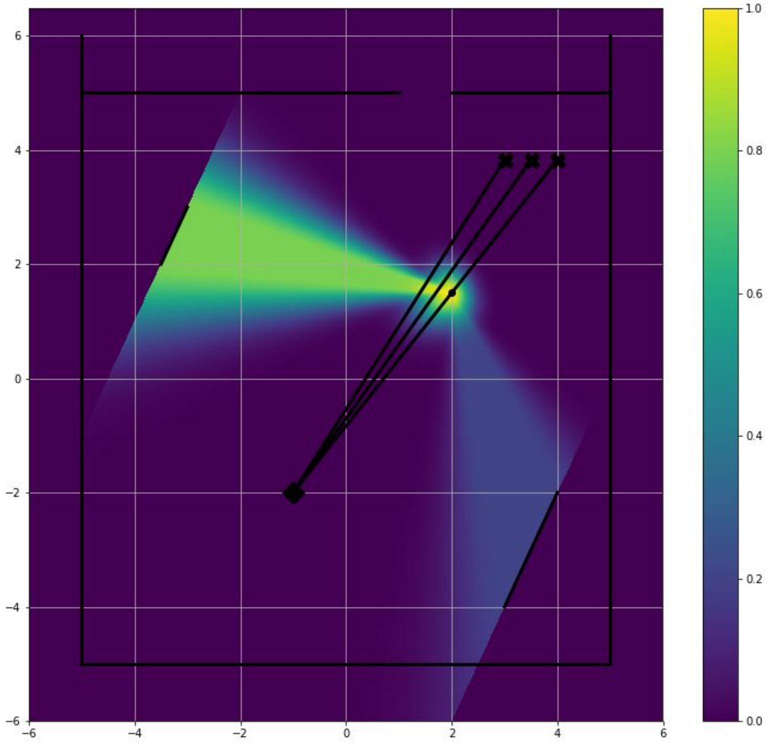
Results and Discussion

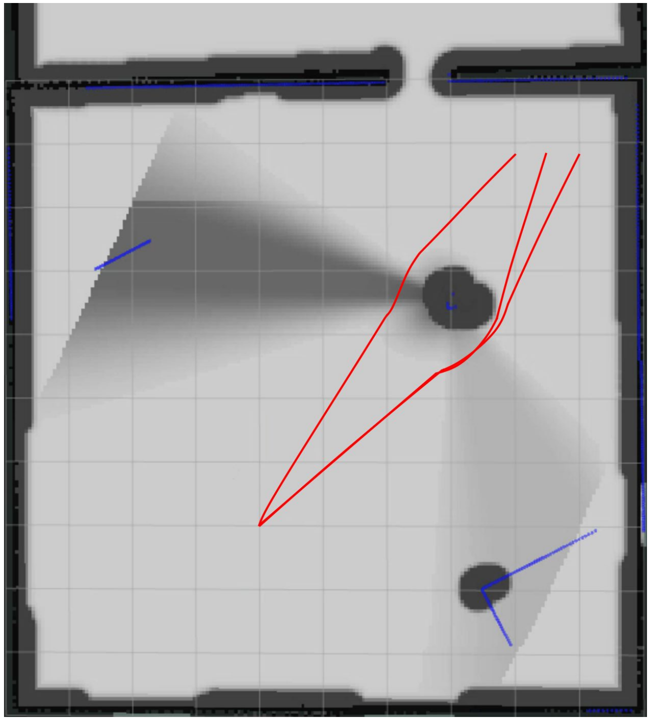
Scenario1: Interaction with an Object



socialSpace-77
socialSpace-154
socialSpace-231
socialSpace-253
socialSpace-253-local

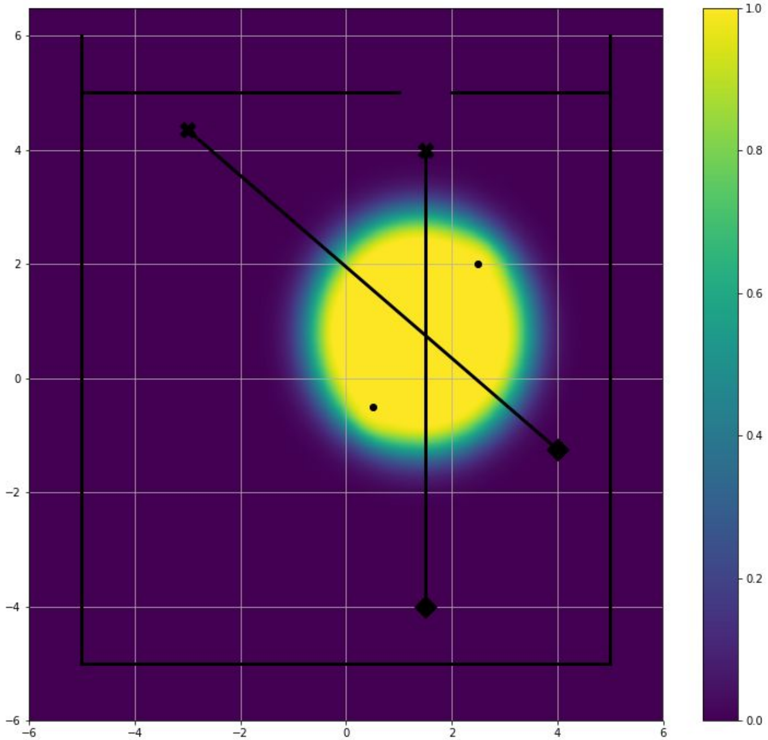
Scenario2: Activity vs Affordance Space

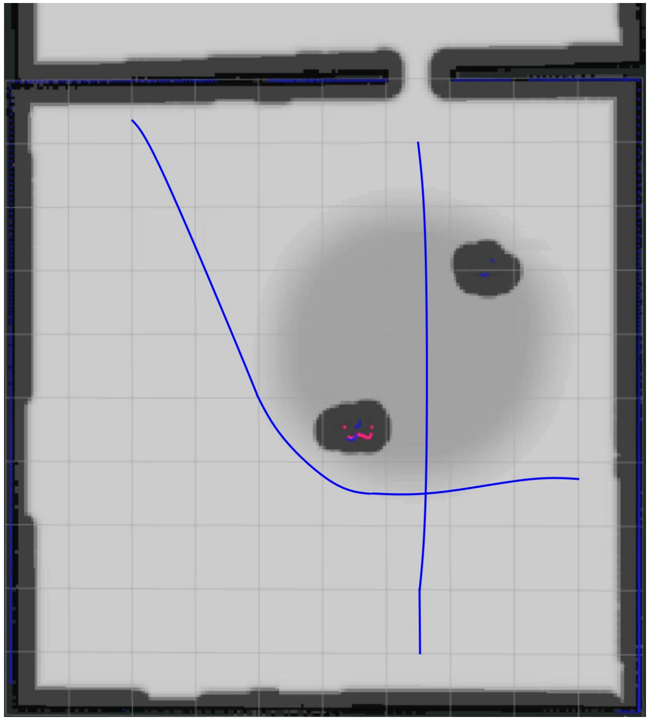




socialSpace-231

Scenario3: Interaction between two Humans





socialSpace-77

Discussion

Social Space Navigation Layer

- tuning of the complete navigation stack
- socially accepted and human-like behaviour of the robot

Social Space Cost Function

- combination of the costs
- robot's personal space
- further kinds of activities

Other Aspects

- dynamic scenarios, time-dependent costmaps
- socially accepted destinations

Kaiyu Zheng. 2017. ROS navigation tuning guide. CoRR, abs/1706.09068.
Felix Lindner. 2016. How to count multiple personal-space intrusions in social robot navigation. In What Social Robots Can and Should Do, 2016, volume 290 of Frontiers in Artificial Intelligence and Applications, pages 323–331. IOS Press.
Rachel Kirby. 2010. Social Robot Navigation. Ph.D. thesis, Carnegie Mellon University, Pittsburgh, PA.
Santosh Balajee Banisetty, Scott Forer, Logan Yliniemi, Monica Nicolescu, and David Feil-Seifer. 2021. Socially aware navigation: A non-linear multi-objective optimization approach. 11(2).

Social Space Cost Function & Social Space Navigation Layer

Conclusion

Conclusion

Modular Cost Function for Modelling Humans' Social Space

- person-related spaces: personal space, passing space
  → existing social navigation layers in ROS
- activity and affordance space: interaction with objects and humans

Social Space Navigation Layer

- employs the above cost function as a navigation layer in ROS
- potential to improve the social behaviour of the robot
  → requires application-specific tuning

Benefits

- can be easily added into the navigation stack of existing robots
- can serve as a more holistic baseline