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Schweinfurt, den 7. März 2025

Bachelor's Thesis: Development of a Virtual Reality Interactive Laboratory Testbench for Socially-Aware Robot Navigation

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In the context of service robotics, the social acceptance of robots plays a crucial role for successful interaction with humans. To this end, socially-aware robot navigation algorithms [1], including social cues, signals and proxemics [2], can enhance the way how mobile robots interact with humans in environments such as hospitals, factories, highways, etc. by providing socially compliant behavior.
The goal of this thesis is to create a testbench for social robot navigation that allows to be employed both for research and teaching purposes: a virtual laboratory experiment that can a) demonstrate a variety of off-the-shelf social navigation algorithms, b) show the effect of user-defined custom cost functions and/or evaluation metrics used in the navigation algorithms, c) modify the human behavior simulation, and (optionally / ideally) d) run custom social navigation algorithms.

The thesis topic consists of several tasks:

- Literature review on social robot navigation, as well as state-of-the-art benchmarking environments such as [3], [4]
- Proposal of a concrete experiment to demonstrate the difference between socially-aware navigation algorithms and standard, non-social navigation
- Design of the software architecture, including
    - Derivation and documentation of the requirements
    - Comparison and selection of the simulation backend, e.g. Unity, Gazebo, Isaac Sim
    - Containerization technology and required middleware / interfaces, e.g. Docker, ROS
    - Environment for algorithmic development of social navigation algorithm, e.g. ROS, Matlab/Simulink
    - Definition of the interface between virtual environment and user-defined algorithm
    - Deployment to allow for 3D real-time interactive simuation and VR / AR / XR capability
- Implementation of a prototype setup
    - Laboratory experiment
    - Ideally including some custom social navigation planner, e.g. based on Model Predictive Control or Reinforcement Learning
- Experimental evaluation of the setup, ideally using one the VR glasses available at CERI
- Detailed documentation of the work steps carried out and the software created, including its limitations
- Recommendations for further investigations

References

[1] R. Möller, A. Furnari, S. Battiato, A. Härmä, and G. M. Farinella, “A survey on human-aware robot navigation,” Robotics and Autonomous Systems, vol. 145, doi: 10.1016/j.robot.2021.103837.

[2] J. Rios-Martinez, A. Spalanzani, and C. Laugier, “From Proxemics Theory to Socially-Aware Navigation: A Survey,” Int J of Soc Robotics, vol. 7, no. 2, pp. 137–153, Apr. 2015, doi: 10.1007/s12369-014-0251-1.

[3] L. Kästner et al., “Demonstrating Arena 3.0: Advancing Social Navigation in Collaborative and Highly Dynamic Environments,” in Robotics: Science and Systems XX, Robotics: Science and Systems Foundation, Jul. 2024. doi: 10.15607/RSS.2024.XX.074.

[4] J. Holtz and J. Biswas, “SocialGym: A Framework for Benchmarking Social Robot Navigation,” in 2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Kyoto, Japan: IEEE, Oct. 2022, pp. 11246–11252. doi: 10.1109/IROS47612.2022.9982021.