A multi-objective optimization approach for socially aware robot navigation

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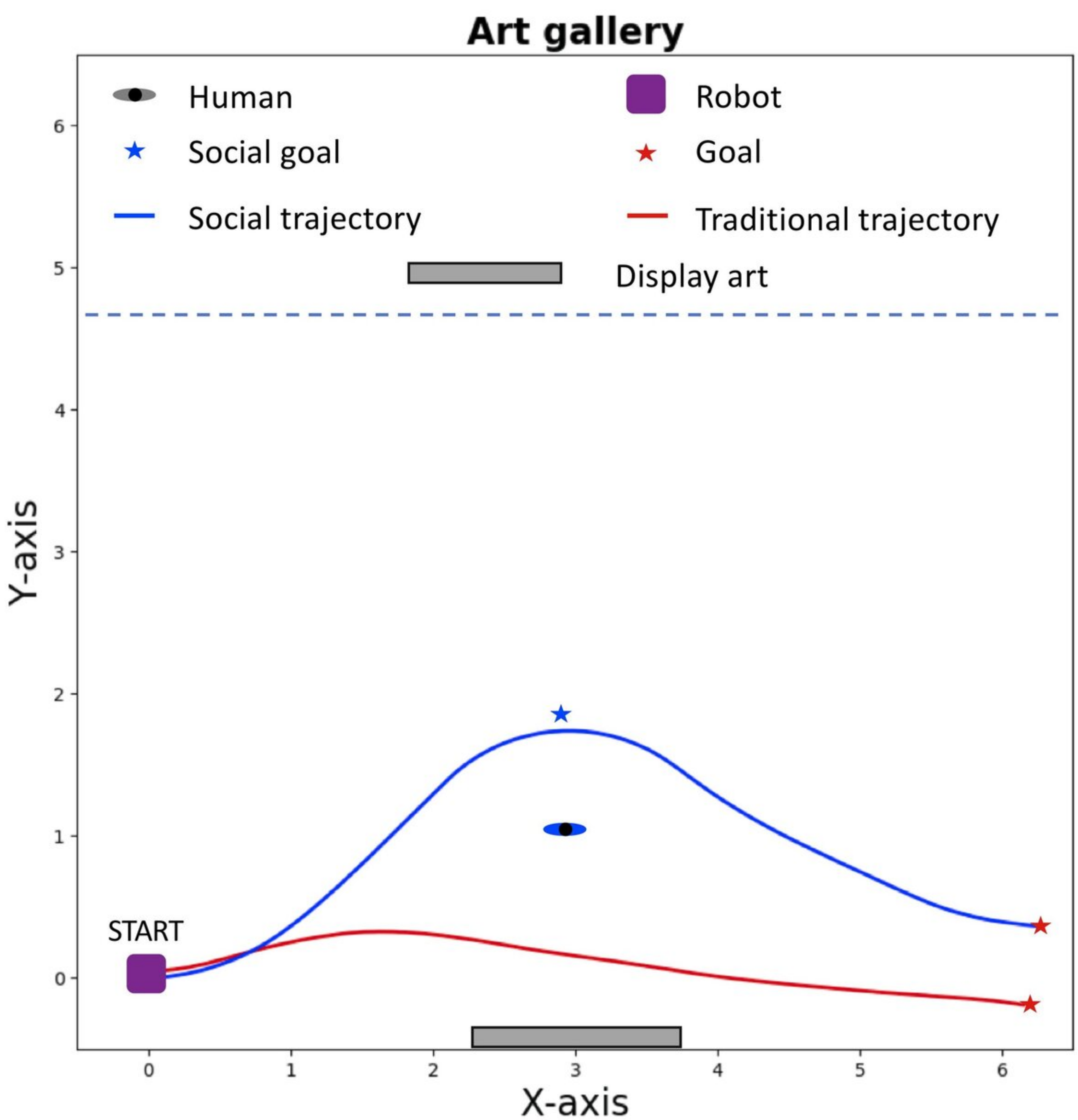


A mobile robot taking into account activity space in an art gallery where the robot with SAN planner avoids going into the activity space, represented by the blue trajectory. Credit: Banisetty et al.

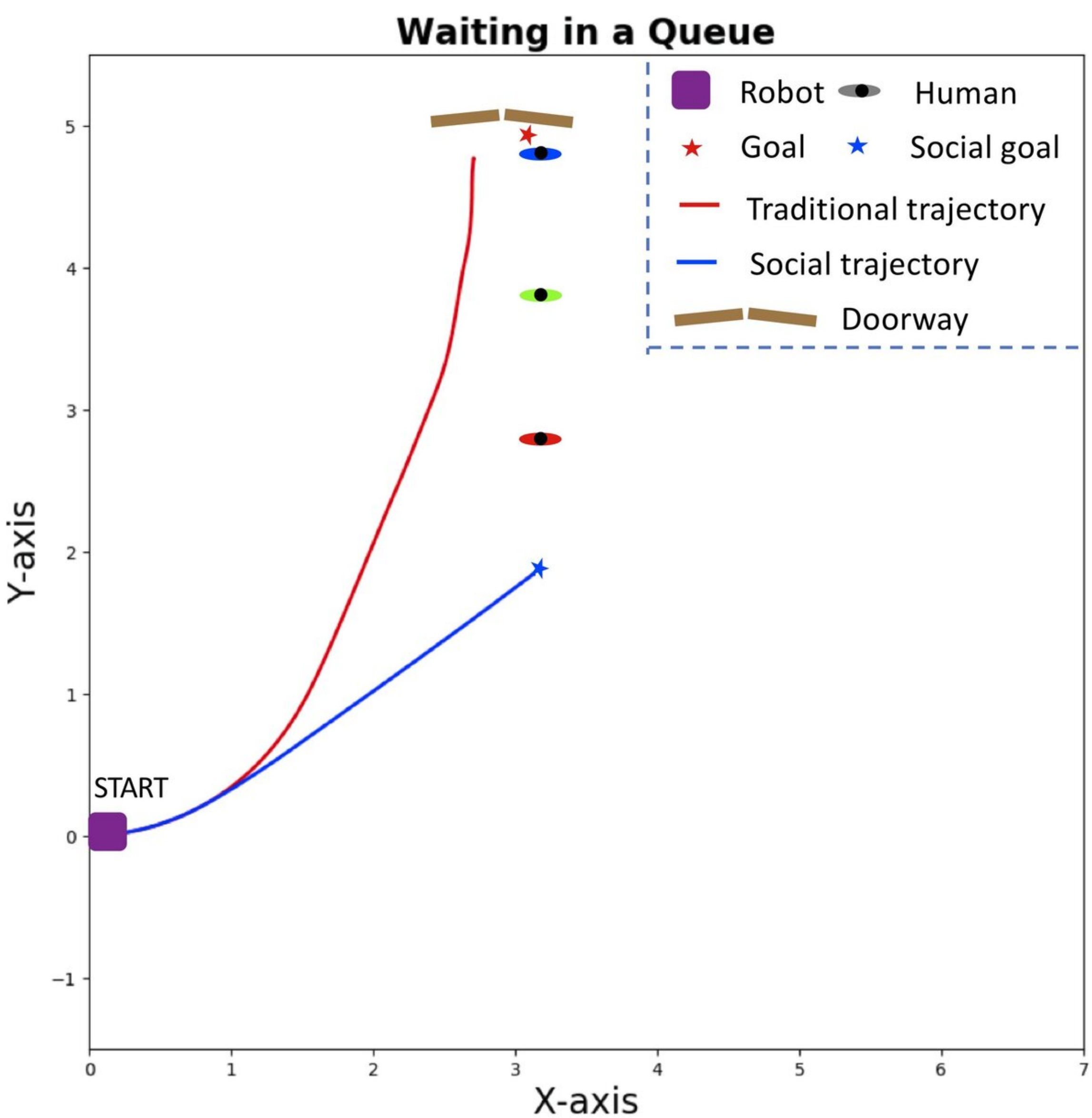
Mobile robots are gradually making their way into a number of human-populated environments, including hospitals, malls and people's homes. In order for these robots to interact with humans in their surroundings, they should respect a number of unspoken social norms that are associated with sharing a given environment with others.

With this in mind, researchers at the University of Nevada, Reno have recently developed a non-linear, multi-objective optimization approach that could enable socially aware navigation in mobile robots. This approach, first outlined in a paper presented at the 2018 International Conference on Robots and Systems (IROS) and now published on arXiv, ensures that robots do not invade the personal space of humans in their surroundings, while also enabling more effective human-robot interactions (HRIs) in several scenarios.

"This research initially began as part of my dissertation work with robots and children," David Feil-Seifer, one of the researchers who carried out the study, told TechXplore. "Earlier work involved developing a robot for environments where we wanted a robot to interact with children. In this case, we had the robot take the most 'efficient' path by the metrics that are commonly used in robot path planning (minimizing the time for a movement, minimizing the distance traveled, not hitting anything)."

In a previous study published in the *Journal of Human-Robot Interaction*, Feil-Seifer and his colleagues tried to develop robot navigation behaviors for environments populated by children. Pilot work showed that the robot was effective in reaching its desired location without hitting anything, but the researchers observed that the children typically reacted poorly to the robot.

In fact, the robot used in their experiments would generally turn away from children and move as fast as possible toward its desired location. As a consequence of this behavior, the children thought that the robot did not want to interact with them.



A mobile robot is joining a cue, formed in front of a doorway scenario. The traditional planner generated the red trajectory, guiding the robot to a location beside the first person(inappropriate), cutting the line. The blue trajectory, our proposed approach, leading the robot to join the line (appropriate). Credit: Banisetty et al.

"We observed the robot and saw that it wasn't really moving the way a person does, taking in social information and using that to help its path planning," Feil-Seifer said. "We thus decided to make a navigation planner that can use social distance information in order to execute socially appropriate movements."

In the same previous study, Feil-Seifer and his colleagues successfully allowed the robot to determine whether a planned movement was socially appropriate using a simple mathematical method called Gaussian mixture models (GMMs). This method worked well in situations where social factors could be easily understood and represented using a simple linear mathematical model.

As most real-world social interactions involve several factors that are hard to fit in a linear model, however, the simple method they developed would not generalize well across different social situations, and in many instances, it would not work at all. In their new study, the researchers thus decided to update the planner they previously developed in order to optimize the robot's planned movements, accounting for the non-linear relationships between the various social properties that they wanted the robot to consider. This involved using a Pareto concavity elimination transformation (PaCcET)-enabled planner.

"The key advantages of our approach is that it can take these non-linear relationships between the various social factors (i.e., where you are in a hallway, where you are in relation to other people, how close you are to your goal, etc.) into account," Feil-Seifer said.

Feil-Seifer and his colleagues applied their non-linear optimization approach to several scenarios in which a robot had to respect social norms, for instance, by not invading people's personal space. They found that their approach worked well in many of these scenarios, including interactions in a hallway, in an art gallery or while waiting in a cue.

"We have not yet done a direct comparison to other socially aware navigation planners; that is planned for the future," Feil-Seifer said. "However, compared to a traditional planner that does not consider social dynamics, the robot gives a person much more room when passing them in the hallway, while also continuing to proceed toward a desired goal."

In their recent study, the researchers evaluated their approach in 2-D simulations on a simulated [PR2 robot] and in the real world on a pioneer-3DX mobile robot. Their findings suggest that their approach can handle multiple interaction scenarios involving both holonomic and non-holonomic robots.

"Practically, this initial paper demonstrates that this method can work, at least in a simulated environment," Feil-Seifer said. "Later work has demonstrated this in the real world and a wide range of social scenarios that consider both other people and factors related to the robot's environment (i.e., places of interest, such as paintings on a wall) that also relate to being socially aware."

Overall, the work carried out by Feil-Seifer and his colleagues highlights the need to develop tools to make robots more socially aware in order to ensure that they don't make people uncomfortable and thus facilitating their integration into society. In the future, the non-linear optimization approach they developed could ultimately simplify the adoption of mobile robots in offices, hospitals and a variety of other environments.

"We are now continuing to extend the capabilities of our socially aware navigation (SAN) planner to include a wider range of social interactions to understand the social context better so that it can properly decide what objectives to prioritize, and to make the system perform more robustly," Feil-Seifer said. "We are also planning to study the direct effects that socially aware navigation has on people observing the interaction and how it affects their perceptions of the robot, as this would help to validate the necessity for socially aware navigation."

More information: Socially-aware navigation: a non-linear multi-objective optimization approach. arXiv:1911.04037 [cs.RO]. arxiv.org/abs/1911.04037

Distance-based computational models for facilitating robot interaction with children. DOI: 10.5898/JHRI.1.1.Feil-Seifer. dl.acm.org/citation.cfm?id=3109684