Supplementary Information

Proactive Control for Online Individual User Adaptation in a Welfare Robot Guidance Scenario: Toward Supporting Elderly People

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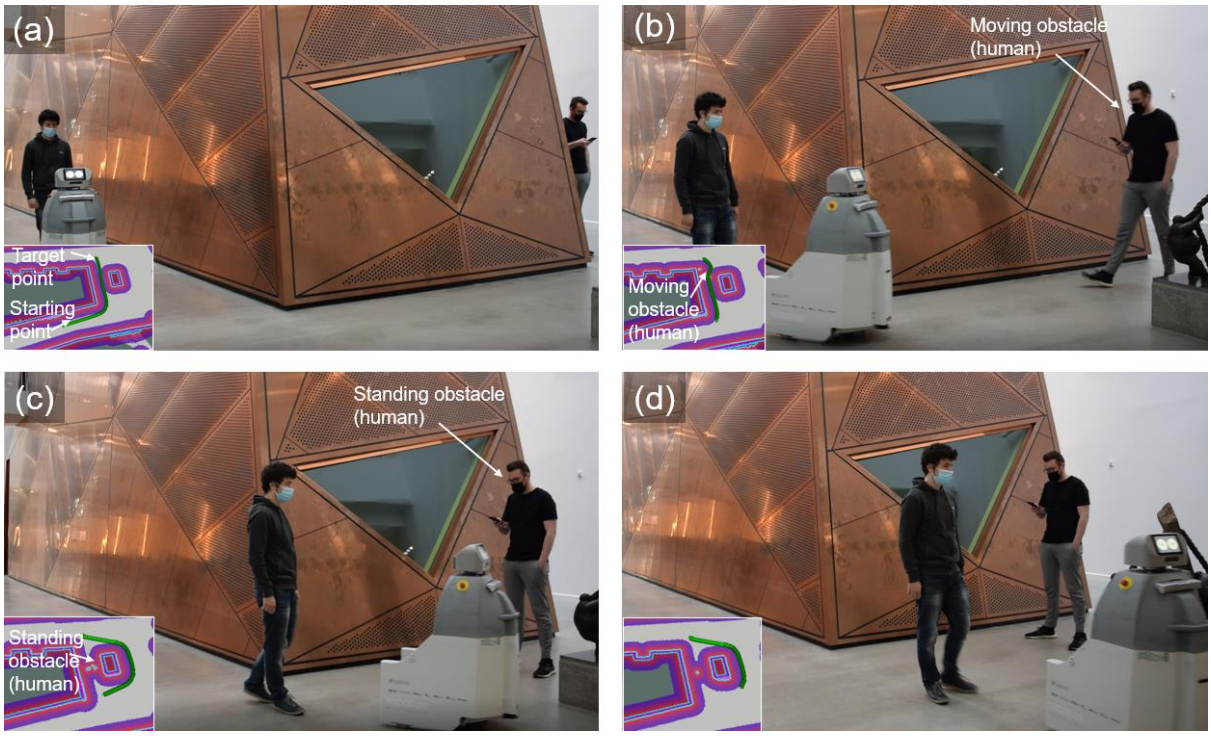
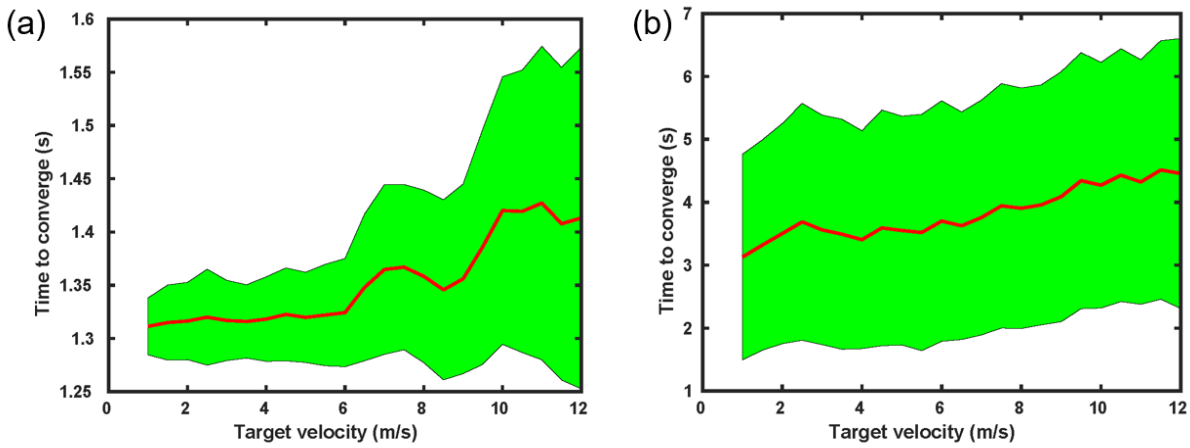
Supplementary Figure 1. SMOOTH robot successfully guiding a subject in a dynamic environment (situation 1). (a) It guided the subject from the starting point towards the target point. (b) A cafeteria tray cart was moved to block the planned path. The robot detected the cart and reactively adjusted its path to avoid the cart. (c) It successfully avoided the cart. (d) It continued to guide the subject to the target point. The experimental video of this experiment can be seen at http://www.manoonpong.com/ProactiveControl/video5.mp4 . The light condition during this experiment was approx. 250 lux. The inset of each snapshot shows the navigation map and trajectory (green line) of the robot.



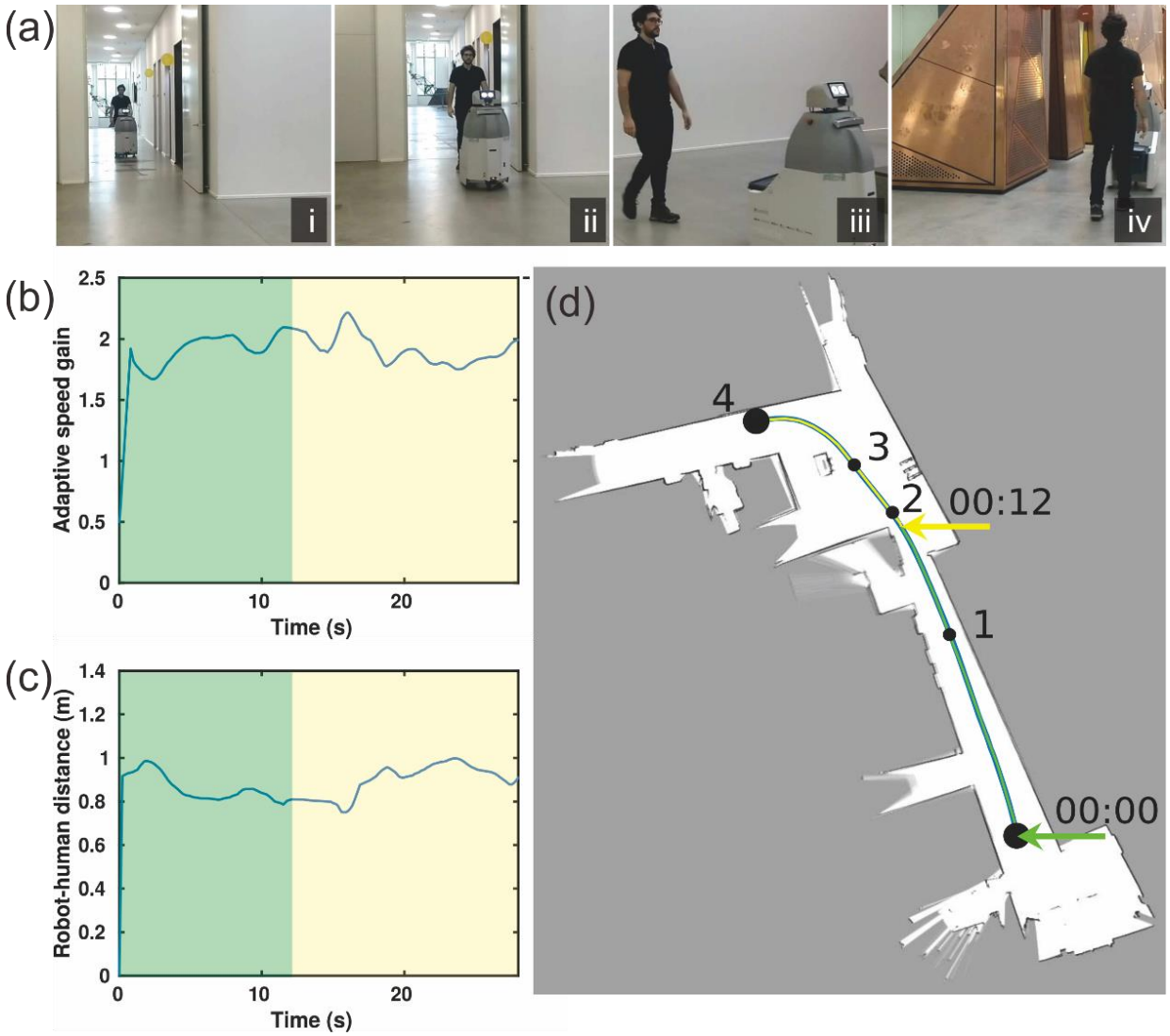
Supplementary Figure 2. SMOOTH robot successfully guiding a subject in a dynamic environment (situation 2). (a) It guided the subject from the starting point towards the target point. (b) During guiding, a person was walking on the planned path. (c) The person was standing on the path. The robot detected him and reactively adjusted its path. (d) It successfully avoided the person and continued to guide the subject to the target point. The experimental video of this experiment can be seen at http://www.manoonpong.com/ProactiveControl/video6.mp4 . The light condition during this experiment was approx. 250 lux. The inset of each snapshot shows the navigation map and trajectory (green line) of the robot.

Supplementary Figure 3. SMOOTH robot successfully guiding a subject in a dynamic environment (situation 3). (a) It guided the subject from the starting point towards the target point. (b) During guiding, a person was passing by the robot. (c) The robot detected him and reactively adjusted its path. (d) It successfully avoided the person and continued to guide the subject to the target point. The experimental video of this experiment can be seen at http://www.manoonpong.com/ProactiveControl/video7.mp4 . The light condition during this experiment was approx. 250 lux. The inset of each snapshot shows the navigation map and trajectory (green line) of the robot.



Supplementary Figure 4. The convergence times of the TEC learning mechanism at different target velocities [1-12 m/s] under different noise levels. (a) Gaussian-distributed noise with a standard deviation of 1% to the prediction error e_t (Eq. 1). (b) Gaussian-distributed noise with a standard deviation of 5% to the prediction error e_t (Eq. 1). Each target velocity was repeated 1000 times. The red lines show the average convergence times. The green areas show the variances.

Supplementary Figure 5. Examples of face recognition and tracking in two different subjects during guiding. (a) An elderly subject with an average walking speed of 0.2~m/s. (b) A young subject with an average walking speed of 0.8~m/s.



Supplementary Figure 6. SMOOTH robot guiding a subject over a distance of 30 m. (a) Snapshots of the robot guidance experiment (from left (i) to right (iv)). (b) Adaptive gain adapted according to the TEC learning rule. (c) Robot-human distance. (d) Navigation map and robot trajectory. Note that real experimental artifacts are considered as variability in human walking and path planning for robot navigation. The green and yellow colors in (b), (c), and (d) describe the different regions in the guidance map. The numbers depicted in (a) and (d) refer to the robot position during guiding. In this experiment, the adaptive gain was adapted online to adjust the robot speed to match the human walking speed of approximately 1.1 m/s. In the experiment, the robot experienced different light levels in a range of approx. 50 - 850 lux. We encourage readers to view a video of the experiment at

http://www.manoonpong.com/ProactiveControl/video8.mp4