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Human-Aware Robot Behavior in Healthcare Facilities

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***Abstract*— In this paper, we propose a method for building sophisticated costmaps based on spatio-temporal world information. This enables mobile robots to gain adequate movement behaviors in unconstrained environments, such as hospitals and other healthcare facilities. Here robots needs to be extra cautious as they encounter some of the most fragile members of society, who are likely unfamiliar with robots. We show that our method improves standard navigation methods by keeping a larger distance to people, by predicting people's future trajectories and acting appropriately to these. Also, we use f-formations to group people who are likely interacting socially, thereby enabling the robot to avoid interrupting them.**

I. INTRODUCTION

Mobile robots are successfully solving logistic tasks in constrained industrial environments emancipating humans from heavy logistic tasks. With the success experienced in constrained environments, it is only natural that logistic tasks in unconstrained environments – such as healthcare facilities and hospitals – are attempted to be solved with mobile robots. In these types of unconstrained environments a mobile robot encounters completely different scenarios than seen in any industrial setting. The hallways are busy with staff, patients, and visitors whom all are walking at different speeds and with various objectives. Unlike in an industrial setting, robots are encountering people that are both unfamiliar with robots while being some of the most fragile members of society – requiring extra cautiousness. As part of the Health-CAT project[1] we have analyzed how robot technology can create value in the healthcare sector. We identified different use cases by analysing how societal challenges affect healthcare facilities in Denmark and Germany. These challenges were investigated together with the end users during a needs analysis. We conducted interviews, observations and workshops with a extensive involvement of end users in the form of patients and different types of employees at healthcare facilities. We ended up developing a mobile robot (see fig. 1) which task is to deliver small equipment to individual patient rooms when requested by a nurse. We did multiple iterations of mock up tests at a hospital ward to verify the need for this robot and to evaluate technical challenges. Our robot mock up was part of the daily routine for the nurses on the test day. The final iteration of testing consisted of the actual robot concept. We tested the robot on fig. 1 for 5 consecutive days, where it was an integrated part of the workflow at a hospital ward. Navigating around the busy hallways – full of people and equipment while nurses interacted with it – gave insight to the limitations of the standard navigating methods available for mobile robots, such as the ROS navigation stack [1]. In the standard methods, the robot navigates around an environment by following the cheapest costs of a movement within a costmap. The costmap receives information about the environment from the laser range sensors and/or 3D cameras on the robot. In the standard methods every obstacle in the environment is considered equal, meaning no semantic nor spatio-temporal information about detected obstacles is used in the costmap. Therefore, this prevents a planning algorithm from making any sophisticated decisions, resulting in clunky and none adequate movement behavior in our test environment with a lot of humans and non-static objects. In this paper, we present a spatio-temporal human-aware navigation system, which detect humans and their properties and uses them to deduce certain social interactions between people. We hypothesize that building a temporally consistent costmap from this information will make the robot able to do sophisticated decisions which will lead to adequate movement behaviors.

Fig. 1: The Health-CAT robot at a hospital ward.

II. METHOD

Navigating a robot in a people rich environment requires that the robot can detect people and their properties in order to follow certain social norms. These properties includes their current position, the direction they are facing, as well as their current speed. In [2] we describe a detection and tracking

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[1]https://www.healthcat.eu/da/

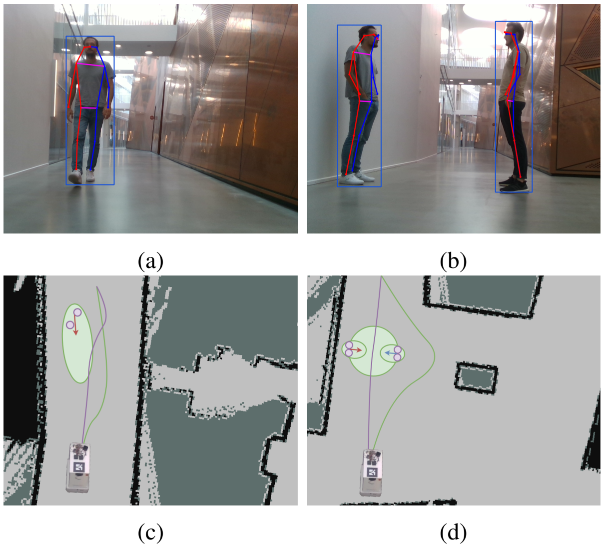

Fig. 2: Detections by the framework and corresponding costs and planned trajectories.

framework for mobile robots, which can be used to extract those properties and more. The framework uses CenterNet [3] to detect the 2D pose of each person in the image from an RGB-D sensor. Hereafter the depth information is used to find the 3D position of each person, as well as the normal vector to their torso thereby giving the facing direction.

In order to obtain temporal consistency the framework uses a multi-object tracker – as described in [2]. The main purpose of this is to assign unique IDs to each detected person, enabling the robot to update the corresponding peoples placement in the map instead of adding the detections as new people. In addition to assigning IDs, the tracker is also used to correct the detected peoples position and orientation using a Kalman filter. The Kalman filter is also used to predict the speed of the people.

Once the people has been detected and tracked, their properties can be used to derive socially acceptable behaviours for the robot – such as in [4]. In this paper the detected people are projected to the robots map such that the information can be used for navigation. A cost is assigned around each person such that the robot does not move too close to anyone, infringing on their personal space. By incorporating the information about the people's speed, it is possible to predict where they will be when the robot comes near them. In this way the cost can be assigned to where the person is likely to be, which improves the path planning. Using the detections it is also possible to deduce certain social interactions, which a socially aware robot should not disrupt. One such interaction is the formation of groups. A group is defined as an entity of two or more people either moving together or engaging in a common activity [5]. In our framework we focus on free standing conversational groups which are common- or jointly-focused – as defined in [6]. Using the estimated facing direction, f-formations [7] and the o-space (the common space shared exclusively by the group) can be detected.

III. RESULTS

Figure 2 shows two scenarios. Figures 2a and 2b show the detected people and figs. 2c and 2d represent the cost given to the detections. The standard method [1] is shown with purple and our method with green. The two lines starting from the robots front is the robots planned trajectory made from this snapshot detection. The purple line is the robot trajectory created by the standard method and the green line the robot trajectory created by our method.

In scenario 1 (figs. 2a and 2c) we see that our method creates an elongated cost around the person in the direction of the persons predicted trajectory. By doing this the robots trajectory will be shifted to the right to avoid a future coalition and movement correction. Predicting peoples future trajectory makes us able to react to potential changes in the environment preemptively and by that avoid clunky robot movement while in the vicinity of people.

In scenario 2 (figs. 2b and 2d) we see that by analyzing social interactions between detected people we can create a cost within the o-space of a group. In this way we ensure that the robot does not enter the space shared exclusively by the members of the group.

IV. CONCLUSION

We proposed a method for building sophisticated costmaps based on spatio-temporal world information. We show that the movement behaviors of a mobile robot can be improved over using standard navigation methods.

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