

SOCIALMAP: A MAP FOR THE SAFE CONTROL OF CARE ROBOTS

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Received August 2021; revised November 2021

ABSTRACT. *The consideration of social influence will be of great assistance for improving the service quality of care robots. Still, how social influence can be integrated into the current robotic systems is yet to be investigated. In this work, in addition to the widely used layered costmaps, we propose a Socialmap that will not lay upon the existing costmaps directly for obstacle avoidance but be a reference to change the behavioral patterns (e.g., maximum acceleration and speed) of the robots. As a result, human-friendly and socially acceptable robotic behaviors can be expected during care services, which will increase the passive safety of the robotic care system. The presented approach has been proved to be effective through simulation and will be applied to our care robot for further evaluation.*

Keywords: Care robot, Socialmap, Social influence, Costmap

1. Introduction. Navigation of a care robot is not only about moving the robot from one location to another without colliding with an obstacle. Intelligent and trusted care delivery requires consideration of various types of additional factors, the most important of which is safety. Here, safety refers to two aspects: (i) avoid active collisions; and (ii) reduce the risk and damage of passive collisions. While various types of path planning and obstacle avoidance approaches [1-3] have been proposed considering (i), in this work, we focus on (ii), aiming at achieving passive safety [4] considering the effect of social influence.

Passive safety is not only about obstacle avoidance because in some cases, detection, avoidance action generation, and action execution may reach the limits of the robot when the object moves in an unintended way (e.g., a person suddenly waves his hand when a robot passed by). Normally, people walk faster and more efficiently when passing stationary objects; however, if they find people or objects that may move, they will slow down in advance to reduce the potential injury from a possible collision.

Social influence can refer to an individual’s behaviors being influenced by others [5]. The reason that social influence is important to passive safety for care robots can be explained with a simple example in Figure 1. Figure 1(a) shows our care robot capable of providing daily care services considering its object manipulation and navigation capabilities. As demonstrated in Figure 1(b), while conducting navigation inside a household domain, people (including the care recipients and possible families or visitors) should be considered not only about their existence as obstacles. Additionally, the robot should try to keep quiet and careful while being close to the care recipient yet more normal passing through other people, and more efficient while no movable or highly valuable objects are nearby.

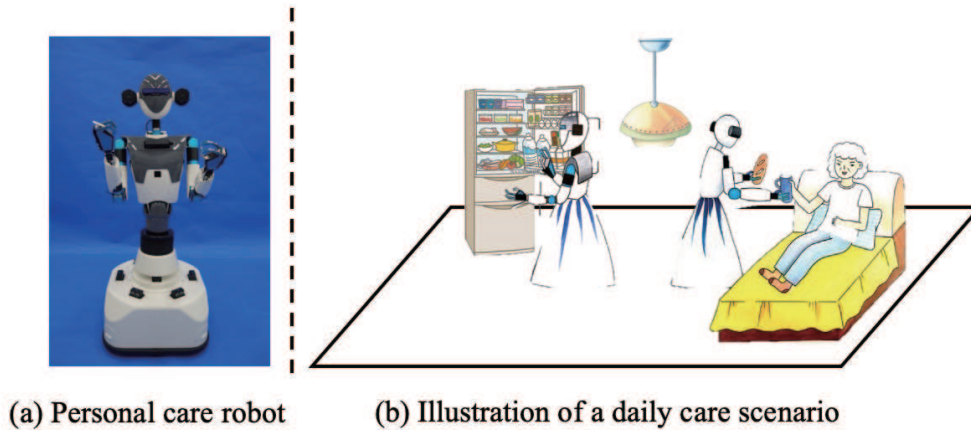


FIGURE 1. Care services considering social influence

In the existing work, layered costmaps [6,7] have played an important role in navigation for mobile robots considering path planning and obstacle avoidance. In layered costmaps, each layer tracks one type of obstacle or constraint, and then modifies a master costmap which can be used for applications such as path planning [8]. While the costmaps focus on the influence of objects considering the shape and size, additional effects such as social influence should be considered [9]. Therefore, a way to formally describe and evaluate such influence is required.

In this work, by defining and overlaying the social influences from different people or other types of objects, we propose a method to evaluate the influence and thus generate a Socialmap. Based on such a Socialmap, applications including safety control and other context-aware behaviors can be performed.

The rest of the paper is organized as follows: Section 2 describes the definition of the Socialmap and how it can be integrated into a robotic system; Section 3 presents simulation results; and Section 4 concludes the paper.

2. Socialmap. Socialmap is a type of robot-centric map for tracking the social influence of people or other objects within the perceptual range of a robot. In this section, we first compare it with the widely used costmap’s inflation layer, then give its formal definition, and finally, explain how it can be used in robotic applications.

2.1. Inflation layer and Socialmap. The inflation layer as one type of layer used for a costmap can be used to model the influence of obstacles considering additional influence range [8]. Figure 2 illustrates the inflation layer (as on the left) and Socialmap (as on the right). While they both focus on “influence”, there are two key differences:

- 1) **Sharpness of the Border:** borders around objects in an inflation layer are typically sharp while the Socialmap uses faded borders (as D_1 and D_2 indicate). Faded borders allow continuous evaluation of the influence;
- 2) **Distinction of Different Types of Objects:** both two types of description can distinguish different types of objects, yet inflation layers need to be layered up (each layer corresponds to one type) while Socialmap calculates and “layered” different types of objects (different radiuses) within only one layer. As demonstrated, r_1 and r_2 can be different in a Socialmap.

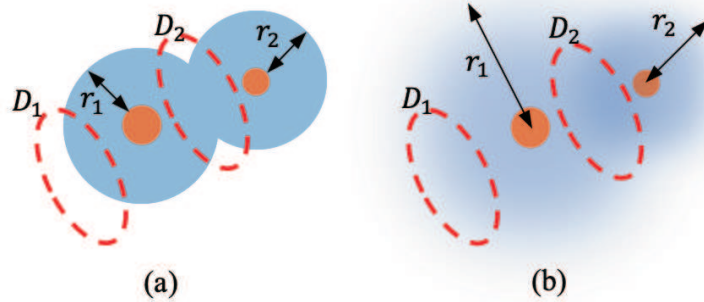


FIGURE 2. Inflation layer vs. social influence layer

2.2. Definition and formalization. The influence of an object is related to its type, specifically; for each type of object, it is necessary to define the maximum influence value $\emptyset_0\{\varphi_i\}$ and decreasing parameter $\lambda\{\varphi_i\}$, where $i = 1, \dots, n$ is the index of different types of objects that are pre-defined in a database. And the m objects that are currently detected in the environment are denoted as \emptyset_j , where $j = 1, \dots, m$. Therefore, the influence \emptyset_j from the object (with a distance of d) whose type is φ_i can be denoted as

$$\emptyset_j\{\varphi_i\} = \emptyset_0\{\varphi_i\}e^{-\lambda\{\varphi_i\}d} \quad (1)$$

When multiple targets are considered, the sum of the influences is

$$\emptyset = \sum_1^m \emptyset_j\{\varphi_i\} \quad (2)$$

$\emptyset_0\{\varphi_i\}$ and $\lambda\{\varphi_i\}$ can be decided as desired considering actual applications for each type of object, so that objects with different influence power can be well modeled.

2.3. Usage of Socialmap robotic systems. The construction of meaning-rich maps for robotic applications considering the social influence or semantic factors has been widely studied [10]. Unlike the traditional focus on avoiding obstacles, various types of factors are taken into account, resulting in more rational and safe robotic motions. In this section, we introduce how Socialmap can be integrated into robotic systems.

In our previous work [11], a context-aware motion planning method has been proposed. A configurable DWA (Dynamic Window Approach) controller was introduced to conduct navigation tasks considering different behavioral patterns from “very careful” to “not careful” by adjusting the available maximum speed and accelerations during motion planning. The behaviors patterns are chosen based on various types of trigger conditions. One of the conditions is when a care robot is near the patient or other people, the robot should slow down to prevent possible damage by the unexpected motion of both the robot and people. However, in that case, the trigger condition is simply a distance-based strategy, where

only an on/off can be adopted. While the strategy is effective in producing context-aware behaviors, the performance is less reasonable and unnatural.

Based on this work, a continuous evaluation of the social influence can be obtained, which can be further used by the context-aware control so that the motion performance can be closer to human behaviors. As shown in Figure 3 which is a complete robotic system, the Socialmap is not intended to replace the costmap, but performs as an additional module in the robotic system. On the one hand, “active safety” is achieved with path planning methods considering the costmap. On the other hand, the “passive safety” is realized by changing the behavior patterns with the pattern selector considering the Socialmap. In other words, the Socialmap does not provide a reference for path planning, but rather helps the robot execute the path in a more human-friendly and safe manner.

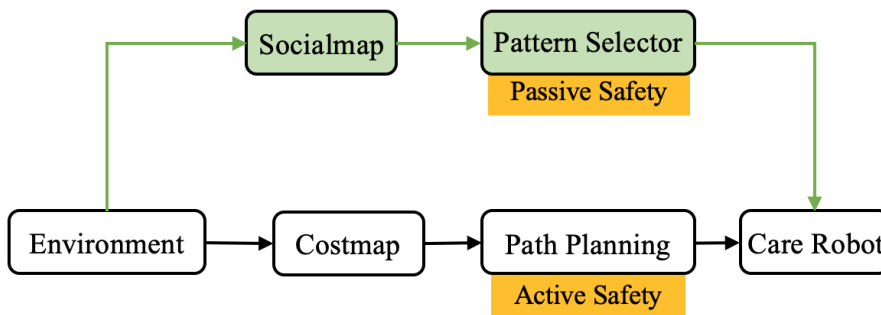


FIGURE 3. Workflow of a robotic system considering a Socialmap

3. Experiments. In this section, we demonstrate how a Socialmap can be used for the evaluation of safety concerns during the navigation of mobile robots in a simulated environment.

3.1. Scenario and results. Figure 4(a) shows a household environment with a bed (where a bedridden care recipient is) A, a family member B, and a table C. A series of footprints of the robot is shown to indicate how a robot navigates towards the care recipient in the room for necessary services.

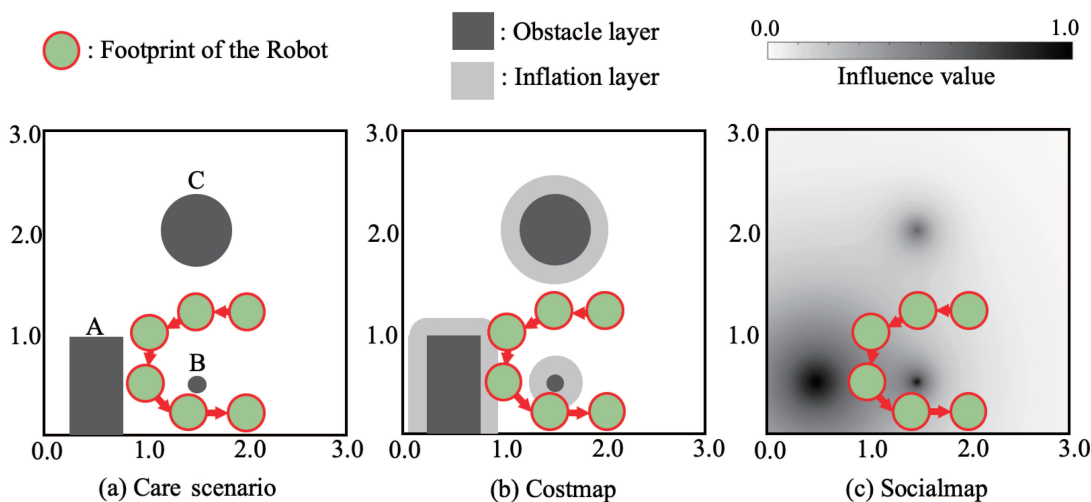


FIGURE 4. A simulation of the Socialmap

Figure 4(b) shows a cosmap established considering the known obstacles in the room. The inflation radius is set to be the radius of the robot footprint (0.3 m). During the entire path, the robot is considered to be collision-free, as the center of the robot locates in the free space.

Figure 4(c) provides the Socialmap of the room established based on Equations (1) and (2) from Section 2. Here, the parameters are shown in Table 1, where φ_1 , φ_2 and φ_3 represent A, B, and C, respectively. By applying a higher maximum influence value and a lower decreasing parameter, the care recipient φ_1 has been configured to have stronger influence than φ_2 and φ_3 . Compared with the costmap in Figure 4(b), the Socialmap does not get influenced by the shape of the objects, and influences from different objects can blend well.

TABLE 1. Parameters for the Socialmap

Parameters	Values
$\emptyset_0\{\varphi_1\}$	1.0
$\lambda\{\varphi_1\}$	1.0
$\emptyset_0\{\varphi_2\}$	0.6
$\lambda\{\varphi_2\}$	7.0
$\emptyset_0\{\varphi_3\}$	0.6
$\lambda\{\varphi_3\}$	5.0

More specifically, the influence values obtained by the robot as it navigates through the path are shown in Figure 5 (showing the values for 11 positions). It is worth noting that there is a process of increasing and then decreasing the influence values. If 0.4 is used as the threshold value at this point, then in Period 2 the robot will be alerted that the current environment is “dangerous”. At the same time, Period 2 is exactly when the robot crosses A and B, which should be considered “dangerous”.

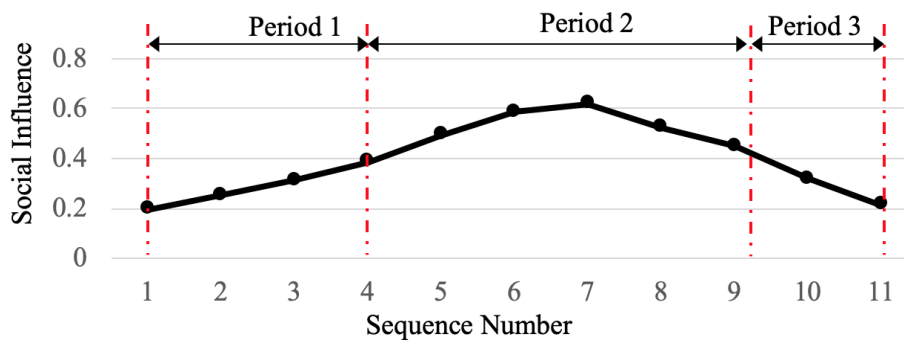


FIGURE 5. Social influence during the simulation

In summary, as introduced in Section 2.3, the robot performs obstacle avoidance and path planning based on the costmap; additionally, by using the Socialmap proposed in this work, the robot is able to adjust its behavior pattern appropriately through social information such as the “danger level” of its surroundings.

3.2. Discussion. As presented, a smooth, continuous, and reasonable evaluation of social influence can be obtained with the proposed Socialmap. Objects with different considerations can be modeled, and the influence from multiple objects can be added up so that scenarios such as walking between two people (which requires extra caution) can be

described accordingly. Based on such kind of map, context-aware robotic applications including safe control can be conducted.

4. Conclusion. In this work, we present a type of Socialmap for the safe control of care robots. With the help of Socialmap, robots will be able to evaluate the influence caused by the existence of other objects in a more detailed and reasonable way; as a result, suitable motion patterns can be triggered to active care services that can be safer and better accepted by the care recipients.

Additionally, we are currently working on experiments with real personal care robots. And the usage of a Socialmap is not limited to the field of safety control; we will explore the possibilities of various directions in future work.

Acknowledgment. This work is supported by JSPS KAKENHI Grant Number No. 15H-03951, the Canon Foundation, and the Casio Science Promotion Foundation.

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