Stop doing it!
Approaching Strategy for a Robot to Admonish Pedestrians

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***Abstract*—We modeled a robot's approaching behavior for giving admonishment. We started by analyzing human behaviors. We conducted a data collection in which a guard approached others in two ways: 1) for admonishment, and 2) for a friendly purpose. We analyzed the difference between the admonishing approach and the friendly approach. The approaching trajectories in the two approaching types are similar; nevertheless, there are two subtle differences. First, the admonishing approach is slightly faster (1.3 m/sec) than the friendly approach (1.1 m/sec). Second, at the end of the approach, there is a 'shortcut' in the trajectory. We implemented this model of the admonishing approach into a robot. Finally, we conducted a field experiment to verify the effectiveness of the model. A robot is used to admonish people who were using a smartphone while walking. The result shows that significantly more people yield to admonishment from a robot using the proposed method than from a robot using the friendly approach method.**

Keywords—approaching behavior, admonishment

I. Introduction

"Would you stop smoking here?", we sometimes admonish others not to do some behavior. In such a scene where one admonishes another, they typically know the behavior is not appropriate, like littering and running amok, yet the person who is admonished feels uncomfortable. Sometimes, they will ignore the admonishment and not comply. This seems like a difficult task for us, human beings. How difficult is it for a robot?

A world where robots admonish people is coming to be a reality. Social robots have begun to serve in various roles in our society. Here, we consider the admonishment task, which is part of some social roles. For instance, guard robots have begun to patrol markets [1]. Although the robot does not have the capability to give admonishment, a human guard is able to do so when needed. Likewise, for robots that serve in roles such as clerk, receptionist, teacher, police, and guard, giving admonishment is part of the role (Sec. II-A).

Nevertheless, to our knowledge, no robot has yet been used for giving admonishment. Why? There are many possible reasons: for example, people do not wish to be controlled by AI and robots. But, more fundamentally, we have noticed that this task is difficult for a robot. Fig. 1 is a scene from our preliminary study, in which a robot tried to approach a person who smokes while walking. It moved toward him and spoke an admonishing utterance near him; however, he took a glance at the robot and continued walking, still smoking. He might have noticed that he was addressed by the robot; yet, he ignored the robot as if no one said anything.

Fig. 1. A robot gave admonishment, but it was ignored

Our study tackles the problem of the capability to give admonishment to pedestrians. We started our research by observing behaviors of professionals, i.e. a shopping-mall guard. We had a research question about professionals' approaching behavior for admonishment. That is,

RQ1: Does the way a professional approaches someone for admonishment differ from when they approach for a friendly purpose?

In fact, our analysis (Sec. III) revealed such a difference. Thus, we modeled their admonishment behavior (Sec. IV), and then implemented the developed model on a human-like robot with omni-directional locomotion capability (Sec. V). Finally, we conducted a field experiment to identify the effectiveness of the model (Sec. VI). That is, our field study was conducted to answer the following research question:

RQ2: Can a robot provide more effective admonishment if it follows a model derived from a human professional?

II. Related Works

A. *Social Robots that might possibly give admonishment*

Various possible roles for social robots have been studied, such as a museum guide [2], a shopping-assistant [3], a receptionist [4], a teacher in a class room [5], and a garbage-collection [6]. Some robots proactively initiate services by themselves. For instance, A city-exploration robot asks passers-by to stop and input information [7]. An advertisement-providing robot approaches pedestrians who seems interested in advertisements [8]. These robots perform some of the tasks of relevant human workers (guides, shopkeepers, receptionists, teachers, cleaners). While such robots usually only provide a single service so far, the human workers can also provide admonishment when needed. For instance, a receptionist would usually offer information, but when some nearby visitors start to smoke in a prohibited area, it is likely that he/she admonish them. Likewise, with the future growth of AI, robotics, HRI, and other relevant technologies, it is plausible that these robots will be more capable and serve for multiple tasks, including admonishing tasks.

B. Approaching behavior and proxemics

When a robot and a person meet, one should approach the other. One aspect people have studied is proxemics [9]. In HRI, researchers have found that people often position themselves in relation to a robot in a similar way as they do to a person [10, 11]. There are studies about how a robot can perform comfortable, socially-appropriate behaviors. For instance, Michalowski et al. modeled spatial zones around a robot to choose when / to whom it would talk [12]. Mumm et al. revealed the importance for a robot to adjust social distance depending on social context [13]. Sisbot et al. developed a technique to consider social constraints on navigation planning [14]. Hayashi et al. developed a roaming behavior modeled from a guard, which enables a robot to provide a friendly impression [15].

More specific to a robot's approaching behavior, there are some requirements that have been discovered. For instance, Dautenhahn et al. investigated from which direction people prefer a robot to approach them [16]. They found that people prefer a robot to approach from right or left, but not from the front. Satake et al. investigated an effective way of approaching, and developed a planning algorithm that enables a robot to approach a customer from the front rather than from the back [8]. Kato et al. analyzed how people politely approach each other, and developed a robot that choose whether to approach or be approached [17]. However, all of these approaching methods were considered in a 'friendly' context; thus, approaching for admonishment is a new challenge.

C. Requesting and persuasion

People help a robot when requested. Yamamoto et al. revealed the case where a person complies to a request from a robot [18]. Huttenrauch et al. revealed that people are more willing to help a robot if they are less busy [19]. Bainbridge et al. discovered the importance of physical presence, i.e. that more people heeded the request of a physically co-located robot than a remote robot [20]. Siegel et al. studied how to make a robot more persuasive, and revealed that the gender of the robot affects how much money people will donate [21]. Whether techniques for requesting and persuasion can be used for admonishment is an open question. It may be possible, but typically in the requesting and persuasion research, people are willing to comply with robots. In contrast, in the case of admonishment, people are more likely to be unwilling to comply with a robot, especially if they already know that their do behavior is undesirable (e.g. smoking at prohibited place). Moreover, our study focuses on approaching behavior, which none of above requesting and persuasion studies have addressed.

D. Alarm, warning, and admonishment

There are studies in human science about the influence and effect of alarm, warning, and admonishment, often in a context of risk communication, e.g. for public health [22, 23]. For instance, the effect of the appeal to fear in public messages has been investigated, though its effectiveness was under suspicion [24]. Yet, warning messages were found to be important in some contexts, like tobacco use [25]. Alarm design has been considered in HCI research [26]. Researchers have studied the use of an avatar robot for risk-communication [27]. Some studies focus more specifically on the setting of face-to-face social communication. For example, it has been reported that even infant seems to understand whom should be admonished [28]. Though, few studies report about an effective way to give alarm, warning, or admonishment. Our work is original in the respect that it addresses what is a good behavior for a social robot to give alarm, warning, and admonishment.

III. How does a Guard Admonish Pedestrians?

As discussed in the Sec. I, we aim to answer the RQ1, i.e. whether a professional would approach someone differently for admonishment and for a friendly purpose. We employed a person who has worked as a guard. Then, we analyzed his approaching behaviors in two settings: when he gives admonishment, and when he approaches for a friendly purpose. For this analysis, we select the strategy to analyze behaviors of a single expert to find the effective design elements for admonishing approach rather than building a model of guards that can be generalizable to all the guards.

A. Data Collection

1) Environments and settings

We conducted the data collection in a hallway space of a shopping mall, where a human-tracking system was installed [29]. The tracking system allows us to obtain the positions of all pedestrians in the area at 20 Hz frequency, with an accuracy of approximately 30 cm. Video cameras were also installed to record the behavior of pedestrians.

2) Participants

We hired a guard (33 years old, male) who had 9.5 years of experience working as a guard. In public spaces in Japan guards that offer friendly services (e.g. offer support to the disabled and elderly, provide directions, and help lost children) and admonishment (e.g. ask people not to enter to prohibited area, ask people not to do prohibited behaviors like smoking in prohibited areas) are quite common.

To collect a reasonable amount of data to be used for analysis, we decided to observe the guard's behavior toward participants hired to act as pedestrians (had we targeted naïve visitors, the number conducting admonish-able behaviors could have been too few). Thus, we hired 12 pedestrian participants (2 males and 10 females, average age: 36.8 years).

3) Procedure

We instructed the guard to interact with the pedestrians by either helping (e.g. provide directions for a person who seemed lost) or admonishment (e.g. for dangerous and troublesome behavior). We instructed the pedestrians to be either one of the following:

- *Inappropriate visitor*: pretended to smoke while walking, knowing that it is prohibited there.
- *Visitor who needs help*: pretended to be lost and searching for some destination.

The pedestrian walked across the observation area one by one. For the simplicity, they started from the same location and moved toward the same destination. The guard waited at a fixed point; when he noticed a pedestrian, he approached the pedestrian to give either admonishment or help. Each pedestrian conducted each behavior twice in a random order.

(a) (b) (c) (d)

Fig.3. An example of admonishing approach

In the real situation, the guard does not have any knowledge about visitors. To simulate this, we didn't explain the guard about the type of visitor's behavior, and the order of the visitor (and his behavior). To prevent the guard always approaches to a visitor, the visitors sometimes just walked in the environment, where the guard was not necessary to approach him.

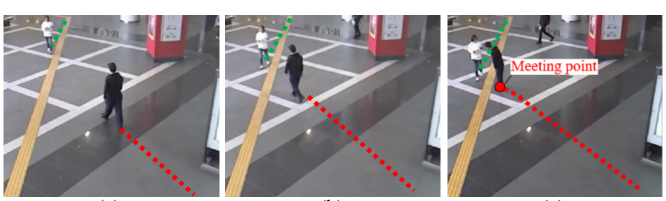
We recorded the scene, the guard's utterance, and their trajectories. His utterance was recorded with a wireless microphone and used to analyze the timing of when he spoke to the pedestrian.

B. Observation and analysis

We found that, in fact, the guard altered his approaching behavior depending on whether he gave help or admonishment. We named the guard's approaching behavior for admonishing the inappropriate pedestrians *admonishing approach*, and the one for the pedestrians who needed help *friendly approach*. We asked the guard about the difference of his behaviors, but he was not aware that he behaved differently. Probably, he unconsciously learned this way of approaching to be more successful for admonishment. From here, we further investigate the behavioral differences.

Fig. 2 illustrates one of the typical examples of the friendly approach. The guard moved straight to the point where he can meet the target pedestrian. We refer this point as the *meeting point*. Then, when he was nearby the pedestrian, he talked to him. In this case, the pedestrian accepted the offer from the guard, so they stopped walking and started to talk.

Fig. 3 illustrates one of the typical examples of the admonishing approach. The guard initially moved straight to the meeting point, exactly like the one seen in the friendly approach (Fig. 3.a-b); however, at the last moment, while he started to utter, he changed his motion course and quickly appeared in front of the pedestrian (Fig. 3.c). We refer to this point as the *turning point*. Since the pedestrian ignored him and did not stop walking, the guard stayed in the pedestrian's view by walking in front of him and continued to give admonishment (Fig. 3.d).



(a) (b) (c)

Fig. 2. An example of the friendly approach

To confirm the above observations and to provide more detailed parameters to define each of the admonishing and friendly approaches, we conducted a series of analyses ((a)-(d)) below. For these analyses, we analyzed all the approaching behaviors observed in the data set. In total, 24 admonishing approaches and 24 friendly approaches were analyzed.

a) Where is the meeting point?

Does the guard try to meet at a (distance-wise) middle point between them? If so, the guard needs to adjust his speed depending on the pedestrian (i.e. the guard walks fast when the pedestrian walks fast). If not, the meeting point changes based on the speed of the pedestrian. If the guard usually walks at a constant speed, they will meet at a time-wise middle point between them. Which idea is more likely? To answer this question, we analyzed the locations of the meeting points.

Fig. 4 shows two cases of the friendly approach. For a fast pedestrian (1.36 m/sec), they met at a point relatively close to the guard's origin (Fig. 4.a). For a slow pedestrian (0.73 m/sec), they met at a point relatively close to the pedestrian's origin (Fig. 4.b). The guard walks at 1.14 m/sec for the fast pedestrian, and 1.21 m/sec for the slow pedestrian; it seems that the guard uses a similar speed for both pedestrians. Thus, we concluded that the guard meets the pedestrian at a time-wise middle point between them in the friendly approach.

(a) Pedestrian with fast speed (b) Pedestrian with slow speed

Fig. 4. Analysis of meeting points in friendly approaches

Fig. 5 shows two cases for admonishing approach. For a fast pedestrian (1.68 m/sec), they met at the point relatively close to the guard (Fig. 5.a). For the slow pedestrian (1.04 m/sec), they met at the point relatively close to the pedestrian (Fig. 5.b). The guard walks at 1.31 m/sec for the fast pedestrian, and at 1.15 m/sec for the slow pedestrian. The guard might slightly increase his speed, but the meeting points varied a lot. Thus, we modeled that the guard meets the pedestrian at the time-wise meeting point for the admonishing approach too.

(a) Pedestrian with fast speed (b) Pedestrian with slow speed

Fig. 5. Analysis of meeting points in admonishing approaches

b) How fast did the guard walk?

We compared the average speed of the admonishing and friendly approaches (Fig. 6). We found that the guard walks faster in the admonishing approach (1.31 m/sec, s.d. 0.14 m/sec) than for friendly approach (1.13 m/sec, s.d. 0.10 m/sec). We applied t-test, which reveals the significant difference between two types of approach (t=4.751, p<.001).

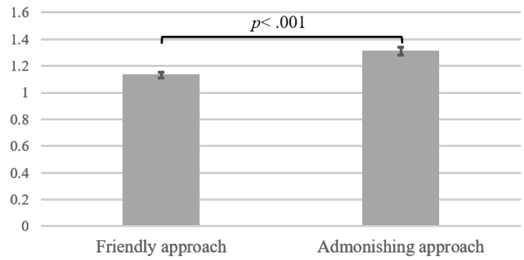


Fig. 6. The average speed of the guard

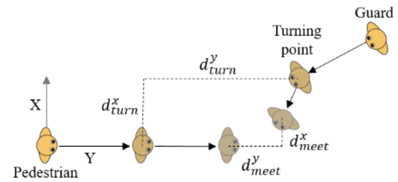
c) In admonishing approach, where is the turning point?

First, we confirmed that the admonishing approach typically has a *turning point*. For this, we analyzed the change in the guard's direction of motion. We set a criterion for the *turning point* as to be when the guard changes his direction of motion more than 30 degrees within 3m from the meeting point.

We found *turning points* in 17 cases out of 24 admonishing approaches. (In 5 of the 7 cases where turning points were not found, the guard was not able to turn in such a way due to interference with other pedestrians). On the other hand, we found no turning points in the friendly approaches. Thus, we concluded turning points only exist in the admonishing approach.

Why is there a turning point in the admonishing approach? Is it the guard who initiates the course change? Or, does the pedestrian initiate (e.g. to avoid the approach of the guard) such that the guard must change course to intercept? To confirm this, we analyzed the behavior of the pedestrians. We analyzed the speed and direction of each pedestrian before and after the guard changed his direction (i.e. at the *turning point*). We found that there is only a small difference (speed difference: avg. 0.07 m/sec, direction difference: avg. 0.96 degree), and no statistically significant difference in either the speed (t=-1.868, p=0.07) nor in the direction (t=-1.12, p = 0.2781). Thus, we concluded that it is mainly the guard, not the pedestrian, who initiates the course change. Our interpretation is that perhaps the guard anticipates that the pedestrian will not stop to listen, so he changes his direction to easily move in parallel to the pedestrian (Fig. 3.d).

We further analyzed the data to determine where the turning point occurs. We define an admonishing approach with four parameters as shown in Fig. 7: vertical and horizontal distance at the turning point (d^x_{turn} and d^y_{turn}), and at the meeting point (d^x_{meet} and d^y_{meet}). To extract these parameters, we averaged over the 17 cases of admonishing approach that had *turning points*. The meeting point toward the front of the pedestrian, but it does not block the motion of the pedestrian. The turning point is about a half meter ahead of the meeting point.



Parameter	Value
d^x_{turn}	1.24 m
d^y_{turn}	2.41 m
d^x_{meet}	0.74 m
d^y_{meet}	0.71m

Fig. 7. Parameters of admonishing approach

d) Timing of utterance

The guard seems to start his utterance before he arrives at his meeting point. To confirm this, we analyzed *utterance distance*: the distance to the pedestrian where the guard started his utterance. For admonishing approach, the utterance distance is 2.69 m (s.d. 0.43 m). It shows that the guard starts his utterance at the turning point (distance from the guard to the pedestrian at the turning point: 2.71 m). For the friendly approach, the utterance distance is 2.47m (s.d. 0.31 m), which is greater than the distance at the meeting point (1.03 m). We applied t-test and found no significant difference between two types of approach (t=1.134, p= 0.26).

IV. Model of Admonishing Approach

A. Model of Admonishing Approach

Based on the analysis of the approaching behavior of the guard, we modeled the admonishing approach as follows:

a) *Meet at the time-wise meeting point (not distance-wise):* For either friendly or admonishing approaches, the guard does not adapt his own speed, but keeps a constant speed (which we refer as *preferred speed*). Thus, the guard meets with the target pedestrian at the time-wise meeting point between them.

b) *Slightly fast speed*: The guard walks slightly faster in the admonishing approach (1.3m/sec) than in the friendly approach (1.1m/sec).

c) *Shortcut*: At the *turning point*, the guard quickly changes his direction, as if taking a shortcut, to suddenly appear in front of the pedestrian. After that, the guard stays in front of the pedestrian while maintaining the meeting distance ($d_{meeting}$) until his admonishment is over.

d) *Start utterance before arrival*: The guard starts his utterance before arriving at the *meeting point*.

B. Design Requirements

We considered the design requirements for the robot's software and hardware to implement the above model. Of course, it requires standard functions that most mobile robots have, such as localization and people-tracking capabilities. Moreover, the robot also needs the following functions that typical mobile robots do not necessarily have:

- *Omni-directional mobility*: the above 'shortcut' motion is not possible with a standard mobile base with bi-directional wheels (e.g. a robot in Fig. 1). At the turning point it needs to quickly change direction; after the meeting point, it needs to orient its body toward the person while moving parallel to the person. Thus, it should be able to move in a direction independently of its body orientation.

- *Fast maximum velocity*: many robots move at a speed similar to a pedestrian's normal speed, approximately 1.2 m/sec or less. However, the robot needs to approach the pedestrian at 1.3 m/sec. (Emperically, we found that sometimes the robot has to move as fast as 1.5 m/sec to meet the pedestrian in time.)

V. Implementation

A. Robot Hardware

We used the upper body of Robovie-R3 (Fig. 10), which is characterized by its human-like physical appearance with a height of 110 cm. We used QFS-02-ver1 developed by Qfeeltech for its mobile base. It has omni-directional wheels that allow it to move in any direction at a maximum speed of 1.5 m/sec. Its maximum angular velocity is 30 degrees/sec. The robot is equipped with a LIDAR (Velodyne HDL-32E) at 143 cm height, which is used for localization and people-tracking.

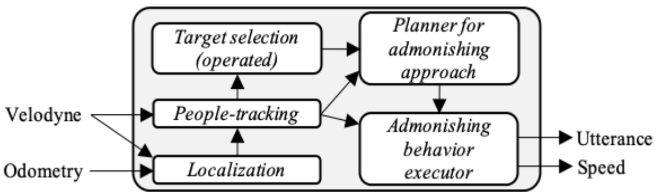


Fig. 8. System architecture

B. Architecture

Fig. 8 illustrates the system architecture. The robot mainly uses two sensors, Velodyne and odometry, for *localization* and *people-tracking*. One of the main modules is the *planner for admonishing approach*, which computes the trajectory for approaching a given target pedestrian, provided by the *target selection* module. Finally, the plan is executed by the *admonishing behavior executor*, which controls the velocity of the robot, and outputs an utterance using the robot's speaker. These modules are implemented on the ROS framework, and periodically executed at 0.1 sec intervals.

C. Planner for Adomonishing Approach

The planner searches for the best approach plan that brings the robot to the *meeting point* of a target pedestrian, with the assumption that it moves at the *preferred speed*. It generates a set of candidate plans and then selects the plan with maximum utility.

The planner generates a list of candidate plans with the following three steps, altering the planned meeting time t_{meet} from t_{meet} = 0 to 10 sec at 0.01 second intervals:

Step 1) Compute the pedestrian's position at the meeting time:

The future position of the pedestrian at the given meeting time t_{meet} is computed. For simplicity, we based this prediction on the participant's current velocity ($\boldsymbol{v}_p$). That is,

$$\boldsymbol{P}_p(t_{meet}) = \boldsymbol{P}_p(t_{now}) + \boldsymbol{v}_p(t_{meet} - t_{now})$$

where $\boldsymbol{P}_p(t)$ is the future position of the pedestrian at time t and t_{now} is the current time.

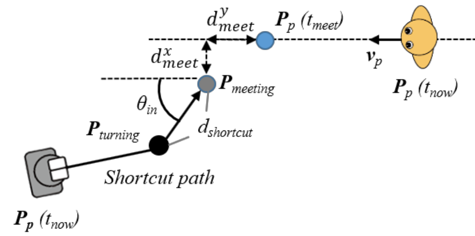


Fig. 9. Planning the shortcut path at t_{meet}

Step 2) Decide the approach path:

For a given t_{meet}, we computed the *turning point* and *meeting point*, which defines the approach path, including the shortcut path (Fig. 9). The meeting point is computed from $\boldsymbol{P}_p(t_{meet})$ with the parameters d^x_{meet} and d^y_{meet} whose values were set in our model (Sec. IV-A-a). Then, given the meeting point, we computed the turning point as the point that satisfies 1) incoming angle to the meeting point to be θ_{in}, and 2) the distance of shortcut to be $d_{shortcut}$. We adjusted these parameters empirically to d^x_{meet} =0.7 m, d^y_{meet} =1.1 m, θ_{in}=84.3 degree, $d_{shortcut}$=1.0 m, in order to give a similar impression as the guard. (Because, the robot is shorter but wider than the human guard, the human's parameters needed some adjustment.)

Step 3) Compute utility:

The utilities of the paths computed above were computed based on how much time passed between the robot reaching its target location and meeting the pedestrian. I.e. paths with short gaps between arrival and meeting have higher utilities. For this computation, we used the difference between the arrival time of the target pedestrian and the robot. Thus, we defined the utility $U(t_{meet})$ for a given t_{meet} as follows:

$$U(t_{meet}) = -|t_{arrival} - t_{meet}|$$

where $t_{arrival}$ represents the arrival time of the robot that follows the computed path with the preferred speed. We assume that the robot has an omni-directional mobile base. Thus, arrival time can be simply computed by dividing travel distance by the speed as follows:

$$t_{arrival} = (d(\boldsymbol{P}_{meeting}, \boldsymbol{P}_{turning}) + d(\boldsymbol{P}_{turning}, \boldsymbol{P}_r(t_{now})))/v_{pref}$$

where d($\boldsymbol{P}_1, \boldsymbol{P}_2$) is the distance between point $\boldsymbol{P}_1$ and $\boldsymbol{P}_2$, $\boldsymbol{P}_{meeting}$ and $\boldsymbol{P}_{turning}$ are the meeting point and the turning point, $\boldsymbol{P}_r(t_{now})$ is the position of the robot at the current time, and v_{pref} is the preferred speed of the robot (which is 1.3 m/sec for admonishing approach, as modeled in Sec. IV-A-b).

D. Adomonishing Behavior Executor

The behavior executor controls navigation and robot speech based on the plan prepared by the planner (Sec. V-C). It has three states as follows:

State 1) Move to the turning point:

This is the initial state. When the executor receives a plan, it computes the actual velocity the robot should take in order to reach the meeting point by the time t_{meet}. Thus, actual speed can be higher or lower than the v_{pref}. When the robot arrives at the turning point, it transits to the next state. Otherwise, as far as the system stays in this state, the planner periodically re-plans the approach. The robot starts the admonishment utterance when the distance with the target pedestrian is less than the threshold. We used the threshold (4 m) so that the robot starts to speak before its shortcut motion.

State 2) Shortcut (move to the meeting point):

After the robot passes the turning point ($\boldsymbol{P}_{turning}$), it changes direction. Now, it moves toward the meeting point ($\boldsymbol{P}_{meeting}$). This motion is called the 'shortcut'. In this state, the planner stops re-planning. It transits to the next state when 1) the current time reaches t_{meet}, and 2) the distance with the target pedestrian is less than $d_{meeting}$, or the robot reaches the meeting point.

State 3) Following:

Until the robot finishes the admonishment utterance, it moves in parallel to the pedestrian while staying to their front right/left while keeping the distance $d_{meeting}$. It moves at the same speed as the pedestrian.

E. Other Modules

1) Localization

For the input from LiDAR and odometry, we applied a particle-filter-based method. For each particle, we conducted map-matching using an end point model for computing the concordance. The module periodically corrects the robot's location every 0.1 sec. For the localization module, we prepared a 3-dimensional map in advance. We navigated the robot around the environment to collect scans from its 3D range finder and odometry, and IMU information. After the data collection, we created a map using a 3D Toolkit SLAM library to match consecutive scans and perform global relaxation [30].

2) People-tracking

We implemented a people-tracking algorithm for the point cloud from LiDAR. It consists of three process steps: background subtraction, people detection, and people-tracking. Background subtraction is done immediately after the localization, compares the map and the raw point cloud, and removes the entities recorded in the map. After this, the remaining point cloud shows the movable entities. At the people detection step, it applies clustering and detects entities that are the size of a person. Finally, in the people-tracking step, it applies a particle filter to the detection result, so that even with occlusions, e.g. people passing by, it can continuously track the locations of people. In our setting, the system tracked people who were within 20 m of the robot every 0.1 sec.

3) Target Selection

We used a Wizard-of-Oz approach for this specific module. That is, there is an operator who watches the pedestrians in the environments, and notifies the system who is the target pedestrian that needs admonishment. We believe that in the future it will be possible to automatically detect targets based on their posture using machine learning; though, given the focus of this study, we considered it best to let a human accurately make the decision.

VI. Field Trial

We conducted a field trial at the shopping mall to evaluate the effect of the developed model.

A. Hypothesis and Prediction

So far in HRI, researchers have only developed friendly methods of approaching (Sec. II-B). However, we found that the guard altered the way he approached (Sec. III). He took an admonishing approach to pedestrians with inappropriate behavior but a friendly approach to pedestrians who needed help (Fig. 2). The difference between these behaviors can be rather subtle. So, does it matter? Professionals likely alter their behavior because it affects their task performance. As our RQ2 (Sec. I), we speculated whether the method of approach would also matter for robots. Based on the above speculation, we made the following prediction:

Prediction 1: A robot that takes an admonishing approach will more frequently stop more inappropriate pedestrian behavior than a robot that takes a friendly approach.

B. Study Context

The dangers of the using of smart phones is well known, e.g. risk of collision and falling. It is more problematic in areas crowded with many pedestrians. In Japan, this is considered to be a societal problem, and hence discouraged in many public places. There are announcements and signboards that inform people not to use smart phones while walking, though there are no legal penalties.

Thus, we chose to target pedestrians using smart phones while walking. We conducted the field trial in the same shopping-mall hallway in which the data collection was conducted (Sec. III). This shopping mall also announces not to use smart phones while walking. Nevertheless, we occasionally observe pedestrians who use their smart phones while walking.

C. Method

1) Participants

The participants were visitors of the shopping mall who used their smart phones while walking. We placed our robot in the hallway of the mall shown in Fig. 10. A human operator hidden from the target area (the area with red line in Fig. 10) detected a pedestrians who were using a smart phone while walking among other pedestrians. The selected pedestrians were considered to be the 'participants' of the experiment.

Fig. 10. The environment of field trial (left) and the robot (right)

2) Condition

Two conditions were compared:

Admonishing-approach condition: The robot uses admonishing approach model with the implementation explained in the Sec. V: It aims to approach the participant and follow them until it finishes the admonishment. There is a shortcut after the turning point, and v_{pref} is 1.3 m/sec.

Friendly-approach condition: The robot uses friendly approach model: It aims to approach the participants and follow them until it finishes the admonishment. The same implementation in Sec. V was used except that no shortcut or turning point is computed (Sec. V-C step 2) and v_{pref} is 1.1 m/sec as observed in Sec. IV-A-b. Fig. 11 illustrates the difference in target trajectories between two conditions.

3) Procedure

The study was conducted from 1pm to 6pm over ten weekdays. We prepared a pair of time slots each day. For each pair, two conditions were assigned with the order counter-balanced. The robot gave admonishment to the human participants. It approached them using one of the approaching methods explained in the condition section. Then, when it got close to the target participant, it admonished them by saying, "Excuse me. Using a smartphone while walking is dangerous. Please stop using it." After the participant leaves from the robot, an experimenter approached them and asked for an interview. We asked why they complied (or did not comply) with the robot. Note, we canceled the robot's task when the pedestrian stopped using his smartphone before the admonishment, and when the robot was unable to approach due to external reasons (e.g. other pedestrian blocking the robot's path). The experimental protocol was approved by our IRB.

4) Measurement

We coded each participant's behavior, i.e. whether they complied with admonishment from the robot. Thus, the following measurement was evaluated:

Success ratio: The percent of participants who stopped using the smartphones while walking after the admonishment.

Participants' behavior immediately after the admonishment was evaluated. The admonishment was coded as a failure if the participant only stopped looking at the smartphone once (e.g. to listen to the robot) but then continued to use it after the admonishment. The coding was done by two independent persons who do not know the experimental hypothesis; their coding results reasonably match, yielding Cohen kappa coefficient of 0.746. We use the result from one of the coder.

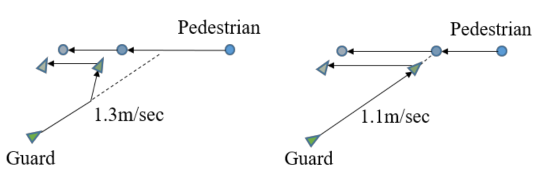


Fig. 11. Admonishing approach (left) and friendly approach (right)

D. Result

1) Observations

In the friendly approach condition, there were 11 participants selected as the target during the experiment. Among them, there were 9 failures and 2 success. Fig. 12 shows a typical failure in the friendly approach condition. The robot moved toward the target pedestrian (Fig. 12.a), and started the admonishment utterance. The participant glanced at the robot (Fig. 12.b), but did not stop walking nor using the smartphone, and finally left while still using the smartphone while walking (Fig. 12.c). Likewise, the robot was ignored when it failed. In successful cases, people stopped to listen when it approached.

(a) (b) (c)

Fig. 12. Failure in friendly approach

There were 8 successful admonishments out of 13 trials in the admonishing approach condition. Fig. 13 shows a typical success. The robot moved toward the target pedestrian, started the utterance, and turned at the turning point (Fig. 13.a). Then, the participant noticed the robot and looked at it. The robot stayed in front of the participant while talking and the participant looked at the robot again (Fig. 13.b). Finally, he stopped using the smartphone and left (Fig. 13.c). Likewise, participants listened to the robot and stopped using their smartphones when the robot was successful. In contrast, when it failed, the robot was ignored as in the friendly approach example.

(a) (b) (c)

Fig. 13. Success in admonishing approach

In a couple of cases, we found a situation where a short-cut path works effectively (Fig. 14. In such a case, a visitor noticed the robot and its utterance just when the robot changes its course (Fig. 14.a). But, he continued to use his smart phone and slightly change his course to avoid the robot (Fig. 14.b). Then the robot changed its motion to enter in front of his course from side (Fig. 14.c). The visitor noticed that the robot entered in front of his course as he expected, and finally gave up to use his smart phone (Fig. 14.d). In this example, the visitor seems to perceive that the robot looked try to block the visitor's course after the visitor did not follow the robot's utterance of admonishment.

2) Verification of hypothesis

Fig. 15 shows the success ratio in each condition. We applied Fisher's exact test. (Since the number of observation is rather small, Fisher's exact test is recommended rather than chi-square test.) It revealed a significant difference between the conditions (p=.047). Thus, our prediction was supported. The success ratio in the admonishing approach condition is significantly higher than in the friendly approach condition.

Fig. 14. Success case of short-cut path in admonishing approach

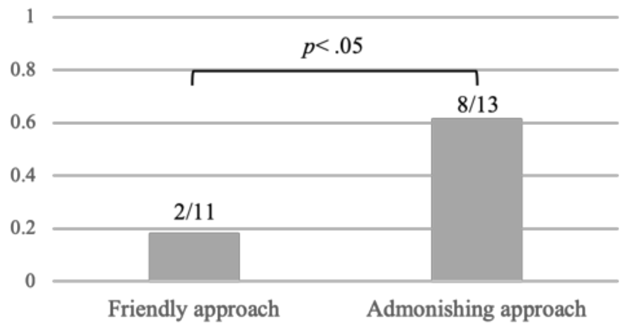


Fig. 15. The result of field trial

3) Interview result

There were 8 participants who accepted our interview (7 in admonishing approach condition (6 success, 1 failure), and 1 in friendly approach condition for whom it failed). We asked the reason why they stopped using the smartphone while walking. All 7 participants in the admonishing approach condition reported that they were impressed or surprised by how the robot approached them. For instance, one of them mentioned that "I noticed the robot approaching me, and I was impressed with it, so I stopped (using the smartphone)." In addition, 3 of them mentioned that they were convinced of the danger.

We asked the participants who did not comply with the robot why they did not comply. The person in the admonishing approach condition said that he thought it was not a problem, so he did not stop using the phone. Though, note that he stopped using it when the experimenter approached him. This suggests a potential difference between the effect of a person and a robot. One participant, in the friendly approach condition, said that he was unable to understand what the robot said.

VII. Discussion

A. Summary and Findings

We started by observing the behaviors of a human guard and found two types of approaching behaviors: *admonishing approach* and *friendly approach*. We modeled the admonishing approach as a behavior that has a shortcut in its approaching trajectory with slightly faster speed than the friendly approach. The difference between the admonishing approach and the friendly approach can be rather subtle; yet, our field experiment revealed that the robot with the admonishing approach resulted in significantly more success than the robot with the friendly approach. It seems that the 'shortcut', which makes the robot suddenly appear in front of the target pedestrian at the last moment of the approach, is important.

Is a robot better at admonishment than a person? We did not rigorously compare, so it is an open question. We asked a guard who works in the shopping mall about his experience. He reported that about 80% of people complied with his admonishment. So, if this number is accurate, the robot is still below human capability, which is convincing to us. The approaching behavior is now rather human-like, yet when it speaks everyone knows that it is a robot who does not necessarily have the same social power as human guard.

B. Do people welcome admonishing robots?

It is arguable if it is good to have such a robot that provides admonishment to human beings. Some people could be upset about such a future, particularly if they are people who would be admonished by the robots. It is possible (though, it needs further study), that people would be more comfortable if they are admonished by a person rather than by a robot.

On the other hand, in many countries, an aging society is a serious societal problem. Hence, lack of workers is a real problem. The task of giving admonishment is not a comfortable task. If a worker admonishes a stranger, the admonished person might get upset and be aggressive to the worker. This means that people may not wish to perform such a task. Thus, seeing the situation from service providers' perspective, it can be a useful solution with a robot for such undesired, dangerous work.

C. Generalizability and Limitation

Our admonishing approach model was designed for a human-like robot in a shopping mall context in Japan. Thus, we need careful consideration if we apply our model to other forms of robots. The model was developed by observing a single person, so other professionals might behave slightly differently (but, at least it is confirmed to be more effective than normal approaching behavior). We believe that our model well captures the important characteristics of an admonishing approach, but it is possible to find new parameters for better performance. The model was developed at the situation of forward-facing. We expect that our model could be used in any similar public space, as far as there is enough space to move with a main flow of pedestrian where we can use forward-facing interaction; in case of narrow areas, the behavior may be different. Furthermore, it may be necessary to adjust the parameters for different cultures.

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