Gentle Robot Approach with Individual Action Perception Fields

Apichaya Mongkolphinyopas[1], Ryo Saegusa[2, *]

1. Chulalongkorn University
2. Kanagawa Institute of Technology

*corresponding author: ryo.saegusa@syblab.org

Keywords: Robot approach, Human action and perception, Potential field, Path generation

1. Introduction

The aging population has become a serious issue worldwide, including in Japan. The support of increasing elderly individuals in the future will require a greater number of hospital and care facility staff. However, the current situation shows a decline in the number of these staff members. To solve this problem, a robot called Lucia was created, Lucia can perform various tasks such as patrolling, taking vital measurements, and engaging in communication with patients. The approach of robots must not make patients feel uncomfortable, and this relates to the concept of personal space. Personal space is a natural psychological boundary where individuals feel the need to maintain distance from unfamiliar people within approximately 1.2 meters, and being approached within this range can cause discomfort. And each individual has their own personal space boundaries and field of vision, so the goal is to approach them in a way that suits their unique needs. For instance, the distance might differ for someone sitting down or standing up, and individuals with visual impairments or hemiplegia may have limited vision on one side. The aim is to customize the approach based on each person's specific requirements.

2. Method

The desired direction for the robot is achieved using the potential field method. This method involves defining the potential that the robot experiences as it moves towards the target location, and based on this potential, the robot generates an appropriate trajectory[(1)]. The areas to be avoided are represented as "mountains" in the potential function, while the areas to be approached are represented as "valleys," creating a potential field. The equation (1) and (2) denote the way to create mountains and valleys, respectively. When combining both equations, we get equation (3). By substituting values, we can visualize in 3D graph as shown in Fig 1. Then, using equation (3), we find the gradient to generate a path for the robot.

$$f_p(x,y) = \exp\left\{-\frac{1}{2}(x-x_t, y-y_t)\begin{pmatrix}\sigma_{xx,p} & \sigma_{xy,p}\\ \sigma_{yx,p} & \sigma_{yy,p}\end{pmatrix}^{-1}\begin{pmatrix}x-x_t\\ y-y_t\end{pmatrix}\right\}, \quad (1)$$

$$f_n(x,y) = -exp\left\{-\frac{1}{2}(x-x_t, y-y_t)\begin{pmatrix}\sigma_{xx,n} & \sigma_{xy,n}\\ \sigma_{yx,n} & \sigma_{yy,n}\end{pmatrix}^{-1}\begin{pmatrix}x-x_t\\ y-y_t\end{pmatrix}\right\}, \quad (2)$$

$$f(x,y) = f_n(x,y) + f_p(x,y), \quad (3)$$

where (x, y) indicates Lucia's position, (x_t, y_t) indicates target's position, and $\begin{pmatrix}\sigma_{xx} & \sigma_{xy}\\ \sigma_{yx} & \sigma_{yy}\end{pmatrix}$ indicates the matrix for deformation.

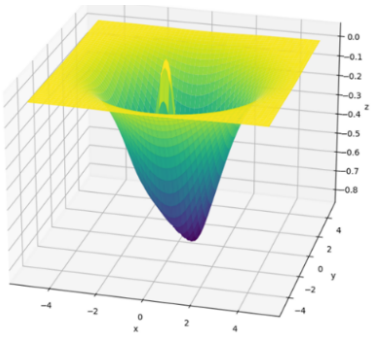


Fig 1. 3D view generated by the equation (3).

Fig. 1. shows a 3D view generated by the equation (3), where $(x_t y_t)$ was set as $(0,0)$, the matrices of the parameters of the positive and negative potential fields were set as $\begin{pmatrix}\sigma_{xx,p} & \sigma_{xy,p}\\ \sigma_{yx,p} & \sigma_{yy,p}\end{pmatrix} = \begin{pmatrix}\sqrt{0.5} & 0\\ 0 & \sqrt{0.5}\end{pmatrix}$, and $\begin{pmatrix}\sigma_{xx,n} & \sigma_{xy,n}\\ \sigma_{yx,n} & \sigma_{yy,n}\end{pmatrix} = \begin{pmatrix}\sqrt{5} & 0\\ 0 & \sqrt{5}\end{pmatrix}$, respectively.

3. Result

From the gradient and the path of the robot, when starting at three different points: (-0.2, -0.4), (-3, 4), and (3, -3), we obtain the results as shown in Fig. 2 with black, green, and brown colors, respectively. By changing the center point of the mountain, we can find suitable paths for individuals, like the example shown in Fig. 3, representing the path of a person with limited vision on the right side. The starting points are different and set at (-0.2, -0.4), (-3, 4), and (3, -3), resulting in the paths shown in Fig. 3, represented by black, blue, and brown colors, respectively.

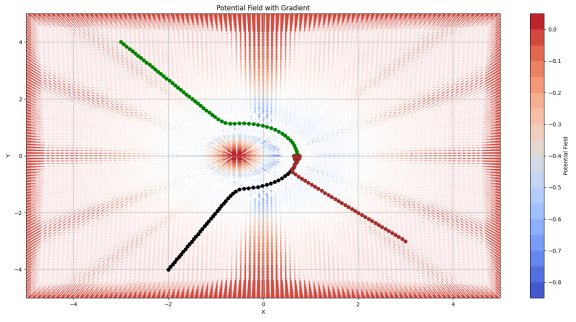


Fig. 2. Path generation for healthy person.

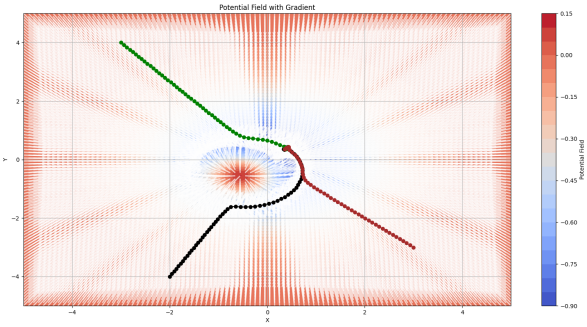


Fig. 3. Path generation for unilateral blindness.

4. Discussion

When we set the starting point of the robot as a point just behind the target, the robot could not reach the target. The robot stopped at a certain point, which meant that the robot was stuck in a local minimum. In order to solve these cases, we introduced small randomness into the gradient of the potential field, and this allowed the robot approach the front of the target smoothly from behind as desired.

5. Conclusion

In this study, the concept of gentle robot approach was proposed, and path generation was demonstrated based on the individual potential fields. The generated paths allow the robot to approach the specified target from the outside of the personal space into the visible angle and range of users. In future works, we will try to design individual potential fields with data obtained from users in the field.

Reference

(1) Yashiro, Yusuke, et al., "Development of obstacle avoidance control for robotic products using potential method," Mitsubishi Heavy Industries Technical Review 51(1), 34-39, 2014.

Biography



Apichaya Mongkolphinyopas is a student at Chulalongkorn University Her research interest includes mechanical enginee-ring.



Ryo Saegusa is an associate professor at Kanagawa Institute of Technology. His research interest includes symbiotic interaction between human and machines towards coevolution