Obstacle Avoidance and Guidance Algorithm for Mobile Robot with Shared Control

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ABSTRACT: This paper describes the development of obstacle avoidance and guidance algorithm with shared control for a human assistive mobile robot. In this concept, we envisioned that the directional control of the mobile robot is executed as minimally as possible via the use of a vision-based eye-tracking algorithm while its obstacle avoidance behaviour is executed autonomously. Such a concept is particularly useful in the healthcare robotics scenario, where for example, a disabled person would use an eye-tracker to control the movement of a mobile teleconference robot or a robotic wheelchair. For proper execution, the switching of states between the *go-to-goal* behaviour (from the eye-tracking system) and the *obstacle-avoidance* behaviour must be executed as smoothly as possible. In order to achieve this, the behaviour of the mobile robot is modelled using a hybrid automata concept and a states-blending strategy together with a Proportional-Integral-Derivative (PID) based goal tracking was proposed. A MATLAB simulation shows the strategy's effectiveness in which good goal tracking was achieved using the proposed technique. A further comparison with a naïve hard-switching strategy between states further validated the smoothness of the proposed approach.

Keywords: *mobile robot, shared control, hybrid automata*

1. Introduction

Recently, the application of mobile robots in improving the well-being of the disabled has been an active area of research by many. Coupled with the technological advancement brought by the 4th industrial revolution, mobile robot technology in healthcare has become more prevalent and ubiquitous than ever. One noble application of such technology particularly is towards improving the healthcare and well-being of patients with severe mobility conditions or people with a high degree of disability (i.e quadriplegic patients, those with a severe neuromuscular disorder, strokes patients or other similar types of diseases and conditions which hinders the mobility and independence of the patient).

In such conditions, while the patient's mobility is severely limited, most patients still retain upper-neck motor functions such as tongue movement, ocular (eye) control or even control over facial muscle. This allows for the development of human assistive technology that allows patients with the aforementioned conditions to convey commands via their motor functions that are still intact to machines that translate them into meaningful actions[1].

Motivated by the scenario above, this paper presents the modelling of the robotic behaviour based on the concept of hybrid automaton [2]. Here, directional control of the mobile robot (the goal) is generated by the eye-tracking algorithm that tracks the user's gaze. The robotic system aims to switch between the *go-to-goal* state and the autonomous *obstacle-avoidance* state with minimal user interaction. In order to achieve this, we proposed a state blending strategy together with PID controller that tracks the resultant directional vector generated. While there are many research that focuses on the directional control of a healthcare-focused mobile robot, to date, no studies have considered the switching strategy between the autonomous and user-controlled behaviour that we are aware of.

2. Methodology

Modelling of the mobile robot behaviour using hybrid automaton consists of identifying states of robots [3]. Here a state machine is employed for describing its behaviour such as shown in Figure 1. A state machine is a strategy that can be used to simplify the supervisor controller to execute any of the controllers based on the situation occured. The use of 'if else' in Matlab coding is a must in order to reach the goal location when there is an 'obstacle or wall' or 'obstacle and wall'.

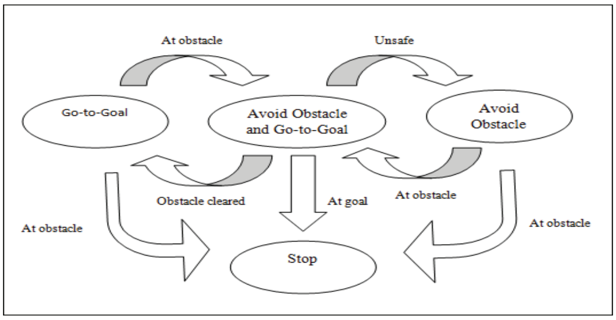

Figure 1: The implementation of a state machine in the Supervisor controller

2.1 Go-to-Goal Controller

The implementation of Go-to-Goal controller will steer the robot to the goal location. The gain adjustment of proportional, Kp, Intergral, Ki and Derivatives, Kd controller is crutial in order to steer the robot with less overshoot and good settling time. The input error that needs to be minimized is the error of angle from Go-to-Goal and also the angle of heading of the robot.

2.2 Avoid Obstacle Controler

The avoid obstacle controller is required to ensure that the robot does not collide with any obstacles. The distance between the robot and the obstacle will be determined by the output from the IR sensors. It is necessary to calculate the spot in the globe to which these distances relate. This controller approach is employed in order for the robot to successfully avoid obstacles. The Infrared Red to Point Transformation is depicted in

2.3 Avoid Obstacle + Go-to-Goal Controller

There are basically two types of arbitration use in the controller

a) Blending - located in Go to Goal + Avoid Obstacle controller
b) Switching - located in Supervisor Controller

Blending is a technique use to blend between Go-to-goal and Avoid Obstacle Controller. The execution of both Go-to-Goal and Avoid Obstacle is done simultaneously by controller. This execution is implemented in the Avoid Obstacle and Go-to-Goal controller. Given that $\dot{x}$ is the resultant states of the blending operation, the equation of the operation is then:

$$\dot{x} = \alpha u_{ao} + (1 - \alpha)\, u_{agtg} \quad (1)$$

Here α is the states blending coefficient and u_{ao} and u_{agtg} is the avoid obstacle and go-to-goal states respectively.

3. Results and discussion

3.1 Eye reference input and direction of robot.

As mentioned previously, direct directional control to goal is provided via a vision-based eye-tracking algorithm. For this purpose, we employed the algorithm described in [4]. A feedback PID controller, as described in section 2.1 was employed for accurate tracking. Here, the PID controller gain K_P, K_I and K_D were set to 5.156, 0.20 and 0.25, respectively, following a simple experiment to determine these values.

3.2 Arbitration between naïve hard-switching and state-blending

The blending strategy provides a faster convergence from the two strategies time to reach the desired goal compared to switch strategies as shown in Figure 2. But the disadvantages of using blending controller is that only two controller can be blend at one time. Table 1 shows the actual time taken between the two strategies.

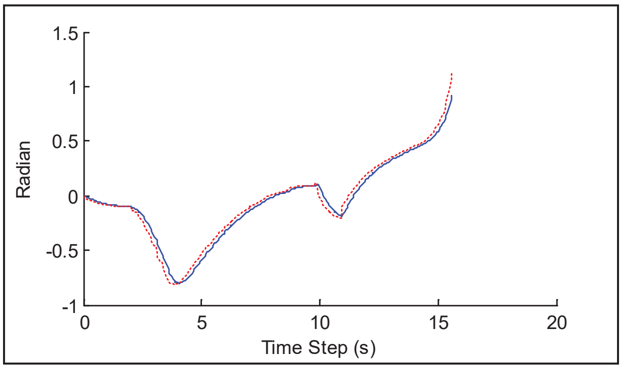

Figure 2: Graph of Robot and reference angle in radian versus time step in seconds using blending strategy

Table 1:

Strategy	Time taken to reach goal in seconds	Distance taken to reach goal in unit
Switching	14.050	22
Blending	15.050	24

4. Conclusion

As for the conclusion, the development of obstacle avoidance algorithm with shared control is based on the algorithm that is from the combination of Go-to-Goal controller, Avoid Obstacle controller, Avoid Obstacle and Go-to-Goal controller.Lastly the analysis is based on the two abbritation strategy that are switching and blending of the controller. The proposed state-blending together with PID tracking provides a smoother goal tracking compared to naïve hard-switching strategy.

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