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IMPLEMENTATION OF PURE PURSUIT ALGORITHM BASED CONTROLLER FOR A MOBILE PLATFORM

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Most of the conventional PID based controllers are prone to consume more computational time for controlling the mobile robot motions. This paper discusses a geometric based control strategy to control the motion of a mobile platform designed for carrying an upper body humanoid robot. Pure pursuit geometric algorithm is employed for controlling the mobile platform. The algorithm calculates the current position of the mobile platform as well as waypoints in the given path. The look ahead distance is finalized based on the average displacement error and average angle error values. The time taken for tuning waypoints is very less which in turn decreases the computational complexity of the algorithm. A simulation is also carried out to prove the advantages of proposed geometric algorithm for controlling the mobile platform motion.

1. Introduction

Mobile robots are employed in manufacturing and service sectors due to its wide variety of applications. The development of a stable controller for controlling the motion of mobile robot through planned waypoints consuming less computational time is also an important part of mobile robot navigation. There are different types of PID and Non PID based controllers. A non PID controller, known as pure pursuit path controller is introduced [1]. The effects of changing the look ahead distance is explained. A brief review of different pure pursuit path following control algorithms is discussed [2]. Dynamic model of a vehicle is used along with pure pursuit control strategy to map the curvature of calculated path in [3]. An analytical method is also used for determining the lookahead distance. Pure pursuit Path tracking control algorithm considering the corner curvatures are demonstrated in [4]. The proposed algorithm is also compared with traditional method for proving the advantages. A pure pursuit algorithm with optimized look ahead distance is described [5]. Pure pursuit algorithm for reducing the tracking error of UAV is demonstrated [6]. An application of pure pursuit controller for high-speed applications is illustrated [7]. Methods for tuning the look ahead distance are given in [8] – [12]. An optimization technique of pure pursuit algorithm by adding PI controller and low pass filter is illustrated [13]. The low pass filter smoothens the steering angles for the optimized path. The path following of a non-holonomic mobile robot fitted with a 2D laser scanner is carried out [14].

In this paper, pure pursuit algorithm is employed for controlling the mobile platform motion. The algorithm determines the waypoints and traverses the mobile platform through the determined waypoints. The look ahead distance is optimized based on average displacement error and average angle error values for generating the smooth path with less computational time. The proposed pure pursuit algorithm is easier to implement, and velocity tuning also requires less effort.

The pure pursuit algorithm is explained in section 2. Section 3 presents the results and discussions along with the simulations of the proposed algorithm. Conclusion and future scopes are given in section 4.

2. Pure pursuit control

Pure pursuit algorithm is a type of robust and reliable control algorithm which consumes less computational time for path planning applications. The mobile platform moves from start location to goal location through a curvature calculated by pure pursuit algorithm. The mobile platform is assumed to be following a point located some distance ahead of the robot. This particular distance is termed as look ahead distance. The look ahead distance depends upon the twists, curves, and conditions of the path. The mobile platform is following a sequence of 2D waypoints. The waypoints are assumed to be in mobile platform frame of reference. The platform is also assumed to be able to localize itself.

2.1. *Geometric interpretation of pure pursuit algorithm*

The main task is to select a waypoint from a series of waypoints. Pure pursuit control algorithm [1] calculates the curvature of movement of a mobile robot from start location to end location. The mobile robot is assumed to be following a point located at a distance prescribed as lookahead distance. The current location and goal location is connected to form an arc. The arc is not unique and the arc whose center is in the y axis is selected. The chord length of the constructed arc is the lookahead distance. The concept of lookahead distance is given in figure 1. Consider the lookahead distance L units in the path. The point P1 is connected to the origin using a curve.

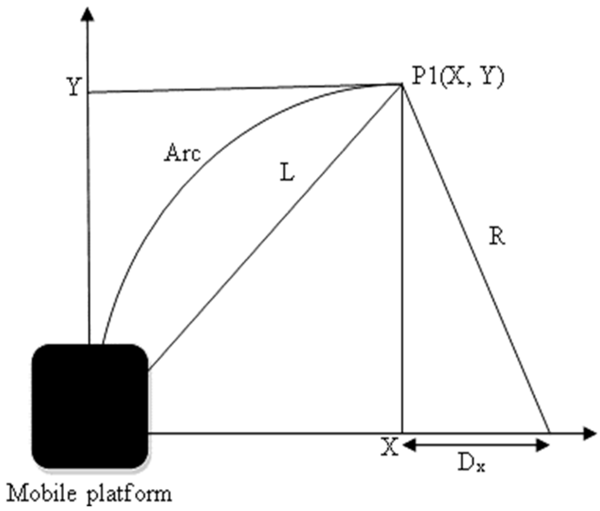

Figure 1. The concept of Pure pursuit algorithm

The pure pursuit algorithm is given in flowchart as shown in figure 2.

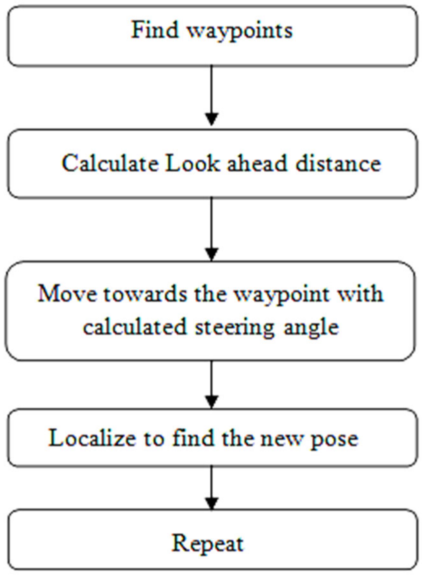

Figure 2. Flowchart of Pure pursuit algorithm

Small L contradicts the dynamic limits and Large L causes problem with obstacles. Tuning of L parameter changes the overall behavior of pure pursuit. The waypoints are taking into account the velocity and acceleration values at various waypoints during the process. However, pure pursuit algorithm is not considering the dynamic properties. Equation (1) gives the circle with radius L with respect to the origin and the circumference of the circle represents the locus of the path of mobile platform to travel from origin to point P1. Equation (2) gives the radius of arc R, goal location X and offset distance D_x.

$$X^2 + Y^2 = L^2 \quad (1)$$

$$X + D_x = R \quad (2)$$

The current location of the mobile base is calculated based on global reference frame. The goal location is assumed to be within look ahead distance. The goal point location is to be transformed to vehicles local coordinate system. The curvature is calculated based on mobile base coordinate system only. The wheel platform follows the curvature and the corresponding velocities of right and left wheels, V_r and V_l are calculated by the controller based on equations (3) and (4)

$$V_r = \omega\left(r + \frac{1}{2}\right) \quad (3)$$

$$V_l = \omega\left(r - \frac{1}{2}\right) \quad (4)$$

Where r is the radius of the wheel and ω is the corresponding angular velocity of the wheel. The velocity of mobile platform V is calculated using equation (5)

$$V = \frac{(V_r + V_l)}{2} \quad (5)$$

The lookahead distance is changed for determining the accurate arcs. Smaller lookahead distance results in more oscillations and curves. However, Larger lookahead distance even though results in less oscillations and only converges to the path little slowly. Hence, finding an optimal lookahead distance is very important and ranges between 0 to 2R.

3. Results and Discussions

Pure pursuit algorithm determines the waypoints for traversing the mobile platform. The path is generated using a hybrid algorithm. Lazy PRM technique [15] and LPA star algorithm [16] are used for generating the path. Lazy PRM technique generates nodes in the configuration space. LPA star algorithm creates the path through these nodes. The optimized final path is obtained by connecting the nodes present in the configuration space. The mobile robot follows a series of waypoints from start node to goal node determined using pure pursuit algorithm. The control block diagram is shown in figure 3(a). The individual blocks are given in figure 3(b) to 3(d)

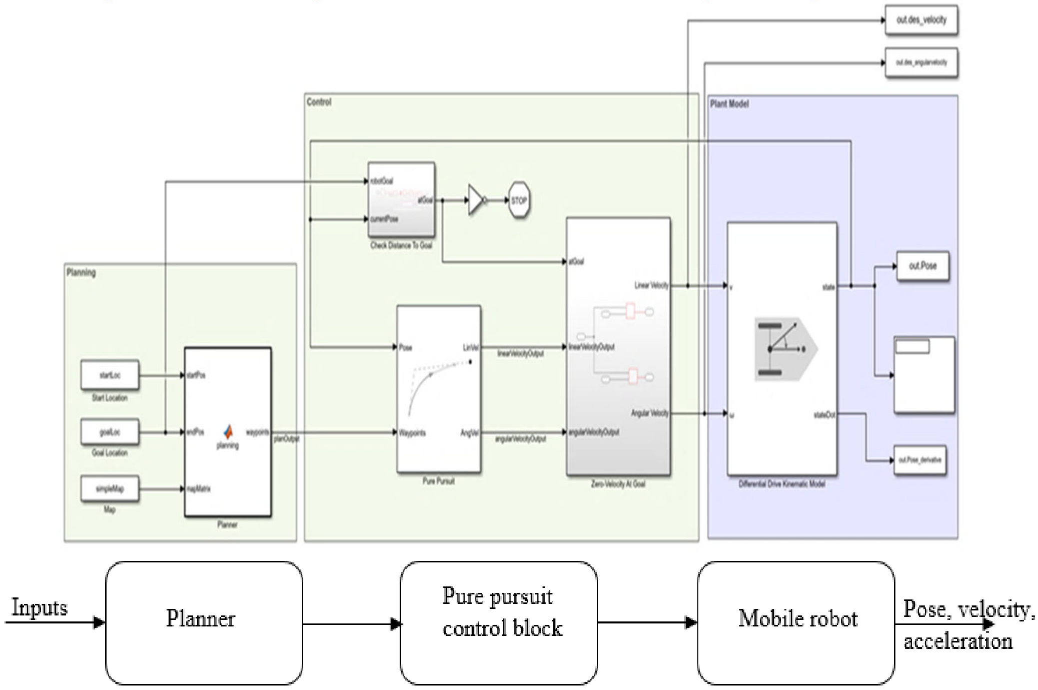

Figure 3(a) Pure pursuit control block diagram

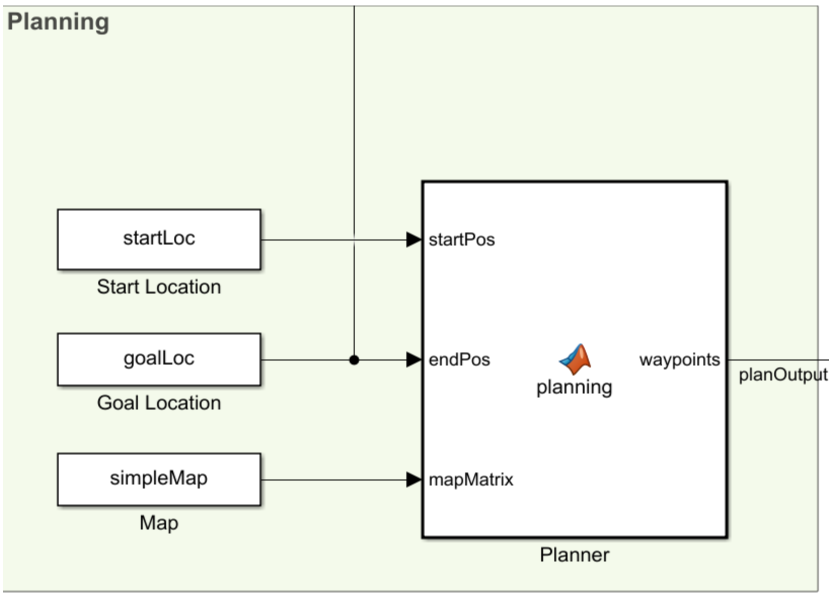

Figure 3 (b) Planner block

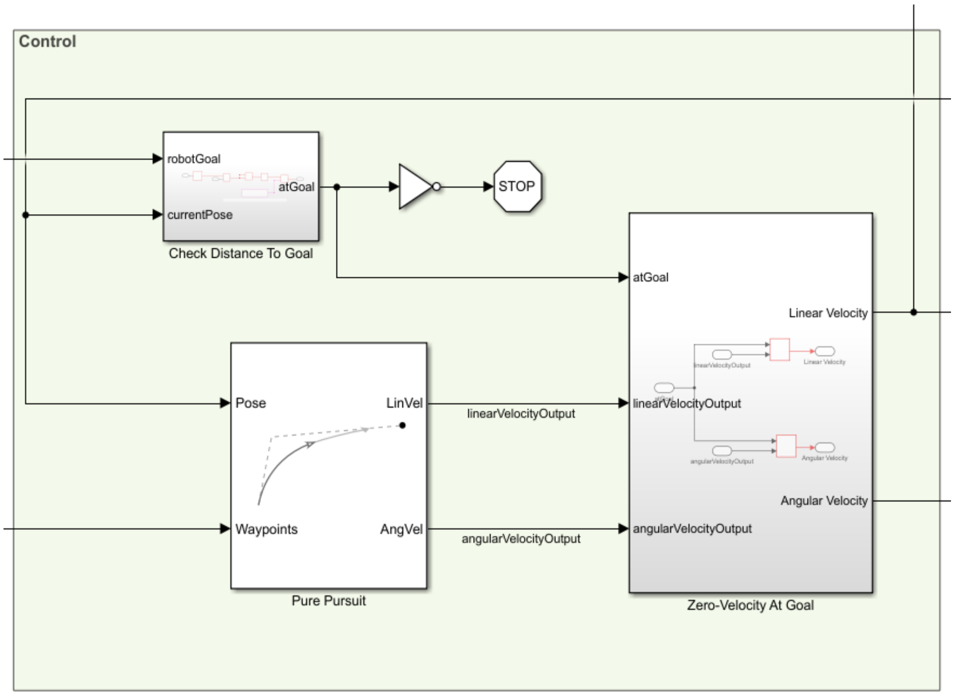

Figure 3 (c) Pure pursuit block

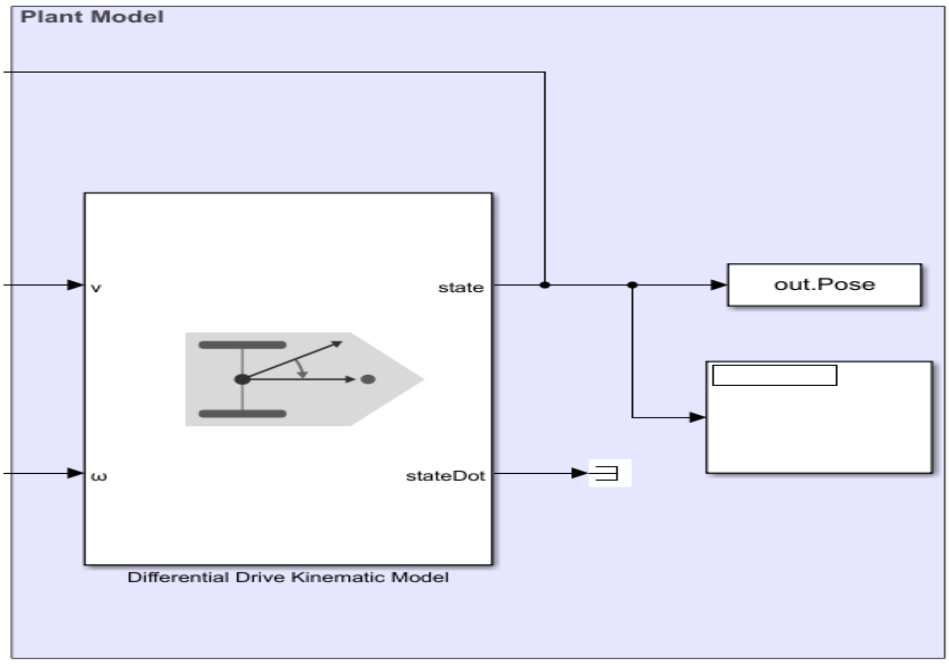

Figure 3 (d) Plant model

The control blocks of pure pursuit algorithm-based controller are divided into three main divisions. The first division consists of input parameters and planner. Start location, end location and map are introduced into the planner. Planner consist of hybrid algorithm to determine the waypoints. The output from planner is fed into the second division. The second division consists of pure pursuit controller algorithm block. The pure pursuit algorithm controls the motion of mobile robot through the generated waypoints. Desired values for angular velocity and linear velocities can be fed in to the controller. The whole parameters are transferred into differential drive block in third division. The outputs are obtained from third block. The input parameters for the control blocks are given in table 1.

Table 1. Parameters used for pure pursuit controller

Sl. No.	Parameters	value	unit
1	Maximum velocity of robot	0.2	m/s
2	Maximum angular velocity	1	Rad/s
3	Lookahead distance	0.5	m

The maximum linear velocity and angular velocity are selected based on the average speed required for completing the task. Look ahead distance is fixed as 0.5 m by considering the limits of selecting the parameter as explained in section 2.1. Smaller look ahead distance results in oscillations while large look ahead distance results in more time for convergence to the specified path. The simulated path and controlled path using pure pursuit control algorithm are compared in figure 4.

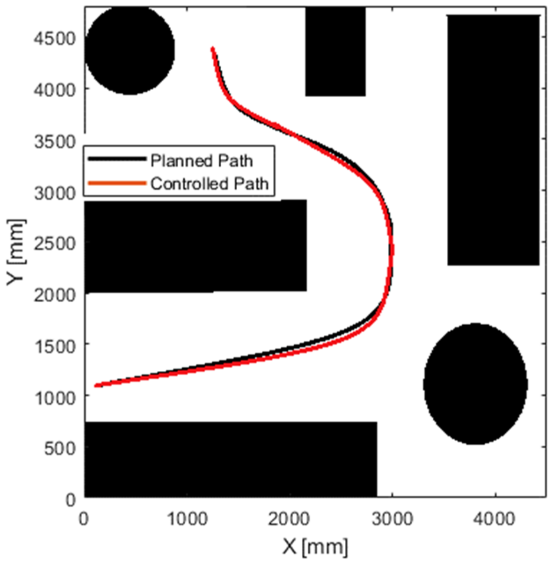

Figure 4. Comparison of simulated and controlled path

The controlled path using pure pursuit algorithm is found to be smooth and the waypoints are determined using the hybrid algorithm. The look ahead distance is varied up to 1m and the corresponding average angle error and average displacement error are calculated for tuning the look ahead distance. The corresponding values are found to be low for a look ahead distance of .5m as shown in figure 5. The average angle error and average displacement error are calculated as .14 m and .215 radians for the look ahead distance of .5m.

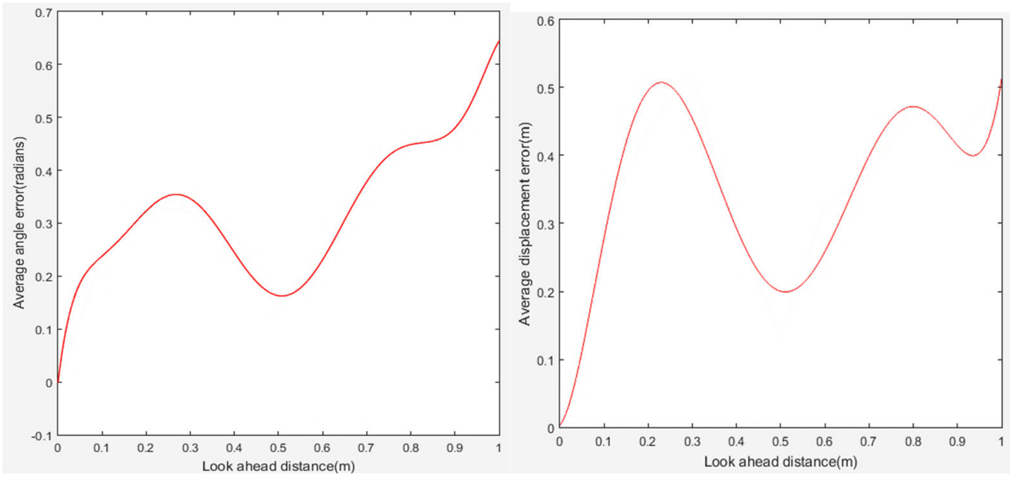

Figure 5. Average angle error and Average displacement error

The output velocity and accelerations of mobile robot are given in figure 6.

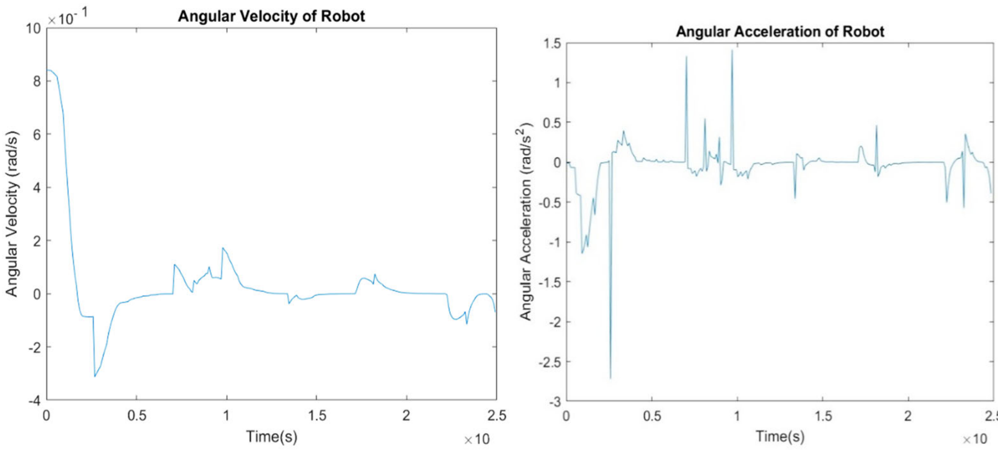

Figure 6. Output angular velocity and angular acceleration of robot

4. Conclusion and future scope

A non PID control technique known as pure pursuit algorithm is implemented for controlling the motion of the mobile platform through the generated path. The main advantages of implementing pure pursuit algorithm are the easiness of tuning waypoints and computational efficiency as compared to conventional PID control schemes. The absence of derivative components in the algorithm plays an important role in decreasing the computational load. The look ahead distance is also a crucial parameter for controlling the motion of the mobile platform. The average angle and displacement errors based method are effective in calculating the suitable look ahead distance. In this work, the look ahead distance L resulted in smoother trajectory. Pure pursuit controller can be combined with robust and adaptive type controllers to increase the controlling options in future works.

References

1. Conlter, R. C. (1992). Implementation of the Pure Pursuit Path'hcking Algorithm.

2. Samuel, Moveh, Mohamed Hussein, and Maziah Binti Mohamad. "A review of some pure-pursuit based path tracking techniques for control of autonomous vehicle." *International Journal of Computer Applications* 135.1 (2016): 35-38.
3. Campbell, S. F. (2007). *Steering control of an autonomous ground vehicle with application to the DARPA urban challenge* (Doctoral dissertation, Massachusetts Institute of Technology).
4. Hellstrom, T., & Ringdahl, O. (2006). Follow the Past: a path-tracking algorithm for autonomous vehicles. *International journal of vehicle autonomous systems*, *4*(2-4), 216-224.
5. Wang, R., Li, Y., Fan, J., Wang, T., & Chen, X. (2020). A novel pure pursuit algorithm for autonomous vehicles based on salp swarm algorithm and velocity controller. *IEEE Access*, *8*, 166525-166540.
6. Yamasaki, Takeshi, Hiroyuki Takano, and Yoriaki Baba. *Robust path-following for UAV using pure pursuit guidance*. IntechOpen, 2009.
7. M. Elbanhawi, M. Simic, and R. Jazar, ``Receding horizon lateral vehicle control for pure pursuit path tracking," J. Vib. Control, vol. 24, no. 3, pp. 619642, Feb. 2018, doi: 10.1177/1077546316646906.
8. H. Ohta, N. Akai, E. Takeuchi, S. Kato, and M. Edahiro, ``Pure pursuit revisited: Field testing of autonomous vehicles in urban areas," in Proc. IEEE 4th Int. Conf. Cyber-Phys. Syst., Netw., Appl. (CPSNA), Nagoya, Japan, Oct. 2016, pp. 712.
9. M.-W. Park, S.-W. Lee, and W.-Y. Han, ``Development of lateral control system for autonomous vehicle based on adaptive pure pursuit algorithm," in Proc. 14th Int. Conf. Control, Automat. Syst. (ICCAS), Seoul, South Korea, Oct. 2014, pp. 14431447.
10. L. Yu, X. Yan, Z. Kuang, B. Chen, and Y. Zhao, ``Driverless bus path tracking based on fuzzy pure pursuit control with a front axle reference," Appl. Sci., vol. 10, no. 1, p. 230, Dec. 2019, doi: 10.3390/app10010230.
11. C. G. Serna, A. Lombard, Y. Ruichek, and A. Abbas-Turki, ``GPS-based curve estimation for an adaptive pure pursuit algorithm," in Proc. MICAI, Cancun, Mexico, 2017, pp. 497511.
12. W.-J. Wang, T.-M. Hsu, and T.-S. Wu, ``The improved pure pursuit algorithm for autonomous driving advanced system," in Proc. IEEE 10th Int. Workshop Comput. Intell. Appl. (IWCIA), Hiroshima, Japan, Nov. 2017, pp. 3338.
13. Chen, Yuanpeng, et al. "Optimization of pure pursuit controller based on pid controller and low-pass filter." *2018 21st International Conference on Intelligent Transportation Systems (ITSC)*. IEEE, 2018.
14.Morales, Jesús, et al. "Pure-pursuit reactive path tracking for nonholonomic mobile robots with a 2D laser scanner." *EURASIP Journal on Advances in Signal Processing* 2009 (2009): 1-10.
15. Bohlin, R., & Kavraki, L. E. (2000, April). Path planning using lazy PRM. In Proceedings 2000 ICRA. Millennium Conference. IEEE International Conference on Robotics and Automation. Symposia Proceedings (Cat. No. 00CH37065) (Vol. 1, pp. 521-528). IEEE.
16. Koenig, S., & Likhachev, M. (2002). D^* lite. Aaai/iaai, 15.