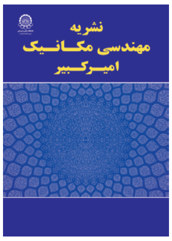

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A Novel Algorithm for Automatic Parallel Parking a Car Based On Continuous-Curvature Clothoid Path Planning

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ABSTRACT: Nowadays making car intelligent consists wide range of their subsystems control. Intelligent Parallel parking without human interposition can be mentioned as an automobile industrial achievement in recent years. It had been tried in this paper with a new algorithm based on specification of continuous curvature clothoid to design a suitable path for parallel parking. Car movement in this smooth path is safe, continuous and with constant velocity. By this algorithm, the system can park the car with single maneuver in a space with 1.6 times of car length. One of the advantages of our new algorithm is control method of car movement to the parking slot. In this method we change the question of controlling car movement in desired path, to question of control the velocity of the car to desired value. So we could reach more precision in car movement from start to goal position. As steering and linear car velocities are constant, car will move in stable speed and smooth path while driving to the parking slot, so our algorithm has more driving comfort in comparison with other path planning algorithms. The results of implementation in real situations shows high accuracy and popper performance compared with other algorithms.

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1- Introduction

Today many different smart systems are existed for human comfort and peace autonomous parking assistant systems is named to the systems which in them automobile will be able to find parking place by itself and moved to parking place with complete safety and place correctly at parking slot. Basement process of parking will classify in three general levels: 1. Find the parking place, 2.designing path movements and 3.control of car movement on planed path until the goal position.

In recent years researchers had proposed suitable path and controllable methods for car movement to the parking slot by using trigonometric functions [1], fifth degree polynomial [2, 3] and Geometric methods [4-8]. Geometric methods are important for researchers because of few calculations indeed and it's usable for real time calculations. The only problem of these methods is discontinuous movement. In this situation car have to stop between the roots for change steering wheels angle [9]. So by proposing a suitable algorithm for making it continues and correcting these method, it would make continuous and safe path for movement.

2- Kinematic Model and Path Planning

The considered kinematic model [8] to describe the vehicle dynamics is represented in Eq.(1).

$$\dot{q} = \begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\psi} \\ \dot{k} \end{bmatrix} = \begin{bmatrix} \cos(\psi) \\ \sin(\psi) \\ k \\ 0 \end{bmatrix} v + \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} \sigma \qquad (1)$$

Where X and Y are the horizontal and vertical positions of the vehicle in x-y frame, ψ is the orientation angle respect to the horizontal axis, k is curvature of the path, and v is the velocity of the vehicle. σ is the rate of the curvature, which is dependent on the steering wheel angle rate.

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3- Clothoid Path Planning

In this paper clothoid curvature is considered to design continuous curvature for parallel parking. In clothoid curvatures, radius parameter is linearly dependent to the length of the clothoid path [10]. The curvature and the length of the clothoid are shown as k and s respectively. With considering of constant coefficient α. Equation $k = \alpha \cdot s$ shows k and s are linearly dependent [10]. The size of clothoid curve depends on using different α values.

The car which moves by velocity v and change its steering angle rate σ, gradually can move on a clothoid path with coefficient α. The smooth path for parallel parking is designed by choosing suitable value for v and σ. The final path is created by continuous clothoid curvature. The curvature of the path starts with a negative value k_{start} and ends with a positive value k_{end}. The coordinates of each points of the path is calculated by clothoid equations that presented in [8]. By using these equations the coordinates, orientation and curvature of the path will obtain. Elapse time for parking and the past distance by the vehicle is calculated by Eqs.(2) and (3).

$$\varphi_{end} = \dot{\varphi} \cdot t + \varphi_{start} \rightarrow t = \frac{\varphi_{end} - \varphi_{start}}{\dot{\varphi}} \; \& \; L = vt \qquad (2,3)$$

Fig.1 shows the path planning flowchart which had been used in new proposed algorithm for parallel parking.

4- Parallel Parking New Algorithm

The planned path is designed by constant steering and linear

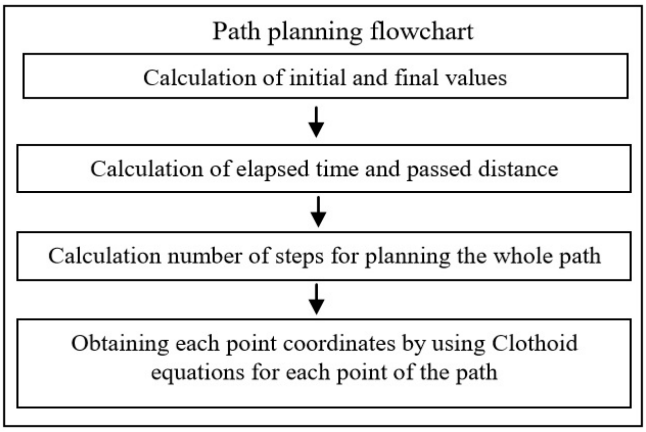

Fig.1. Path planning flowchart

velocity. By considering of different steering velocities various passes are generated where they have the same ending points and also their start points are in different lateral distance as it shown in Fig.2 (a). A curve was fitted on the start points to cover all of possible starting points for parallel parking. This fitted cure is used to calculate two important parameters; the first one is coordinates of p3 relative to lateral distance and second is to find an appropriate α value. Fig.2 (b) shows the parallel parking steps by using the new algorithm.

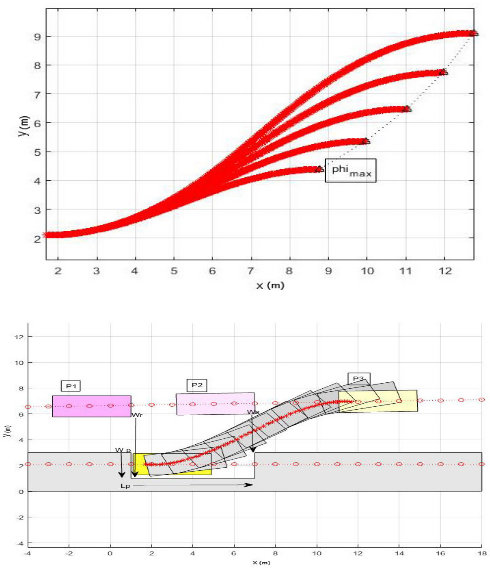

Fig.2. (a- left) Paths with different lateral distance. (b- right) Parallel parking steps

The proposed algorithm contains three principle sections 1-parking slot detection, 2-Path planning 3-motion control. For detecting of parking slot an ultrasound range finder and vehicle odometer are used to find p1 and p2. In step 2, p3 is calculated as a function of lateral distance and path is designed by using the fitted curve which is shown in Fig.3. In step 3 by using consider value for α , identical lateral and steering velocity is obtained to move the vehicle on planned path to final point.

5- Simulation and Results

Peugeot 206 factory specification is used for presented algorithm simulation. Calculation is done by using reverse linear velocity 10 km/h and steering velocity of σ_{max} and $\sigma_{max}/2$. As observed in Fig.4, the car needs an area 1.6 times bigger than its lengths.

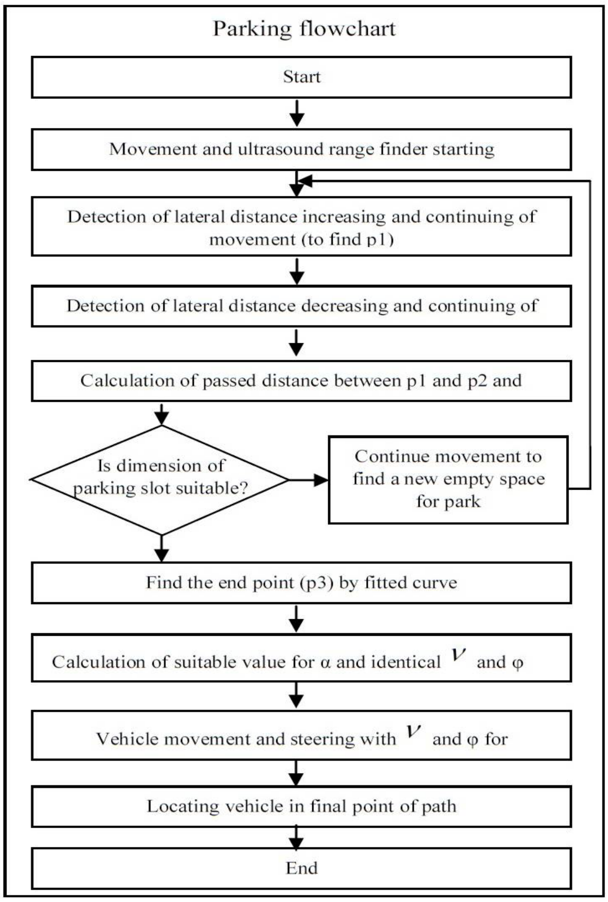

Fig.3. Parking flowchart with new algorithm

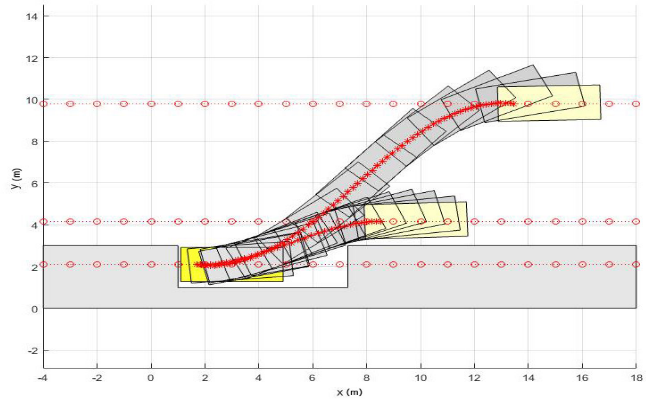

Fig.4. Parking manure with σ_{max} and $\sigma_{max}/2$

In Fig.5 (a) blue line is designed path by using clothoid curve and black dotted line in car movement is calculated path by using Adams-Bashforth numeral integrating.

In Fig.5 (b) error value is presented between each step of clothoid designed path and calculated path with cinematic equations. Maximum value of Error rate in comprehension with car scale is venial.

6- Conclusion

In This paper a new algorithm for parallel parking manure is presented. In this method the car would be able to park in an area 1.6 times bigger than the car size and also this way does not depend on the initial lateral distance. In this way,

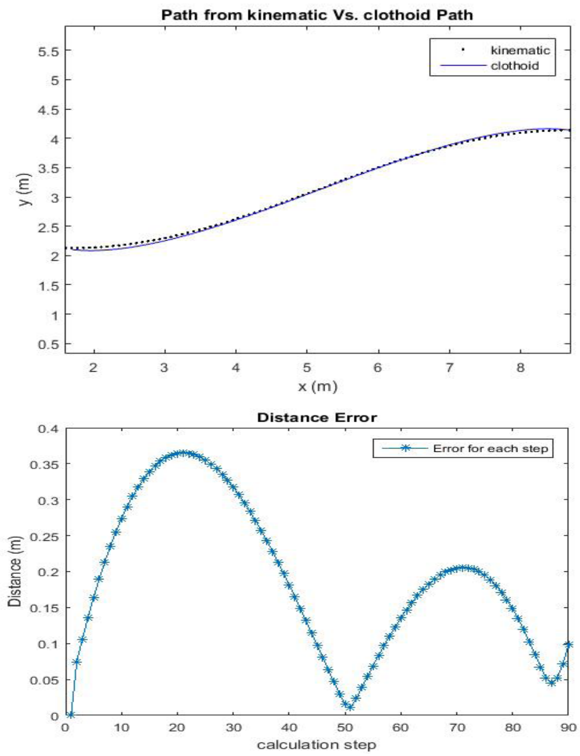

Fig .5. (a-left) Clothoid and cinematic paths. (b-right) Error value for each calculating step

automobile can park without using position and orientation measurement tools and large amount of calculation methods while is prepared safe conditions for car movement.

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