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A new Algorithm for Reverse Car Parking Problem

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Abstract: - This paper presents a new automatic control system for the determination of a set of necessary maneuvers for reverse parking of a car. The studies of the mathematical model of the problem is not enough for realizing a control system so this paper proposed the determination of parking trajectory through genetic algorithms. This paper presents the mathematical model, the characteristics of the genetic algorithms and the relative software that has been used. Moreover we also describe and explain by help of experiments the validity of our solution.

Key words:- car parking; genetic algorithms; control system; automation.

1 Introduction

The automatic control system technology applied to automobiles is a tendency that in the last years has given many physical benefits to motorists (reduction of road accidents) and psychological benefits (reduction of stress). Satellite systems like ABS, AIRBAG and navigators are now installed in the most common cars. The problem of parking is still object of study and development, and is finalized to reduce the number accidents. This document demonstrates that by using the paradigm of the genetic algorithms, it is possible to determine the trajectory of an automobile in the case of prefixed parking. The development of hardware technologies, the use of these techniques is not extremely high, it is therefore possible to plan a system that is effectively capable of development.

The problem of Smart Parking has already been faced and resolved by various researchers. The proposed solutions preview a common base which is the mathematical-cinematic model of the automobile system; the control system has then been developed according to the theories and the technologies of fuzzy logic[1][3] the neural nets[4][8] and the neurofuzzy nets[6][7], obtaining appreciable results. Our work, introduced in this document, has the dynamic model as a mathematical base which is also present the literature system, and in the development of the control system, the use of genetic algorithms. Our control system, given in imput the position and the orientation of the automobile, reinstates in output the set of steering angles and the maneuver speed necessary for parking.

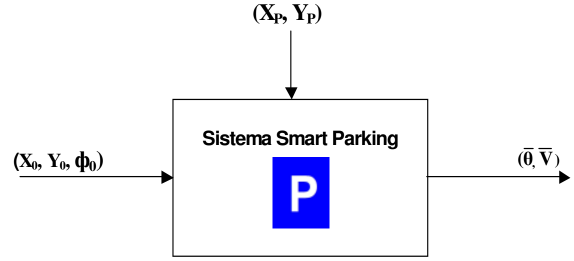

Fig. 1

2 Mathematical Model Of The Problem

We consider the dynamic model of an automobile [2] [5] the one shown in figure 2.

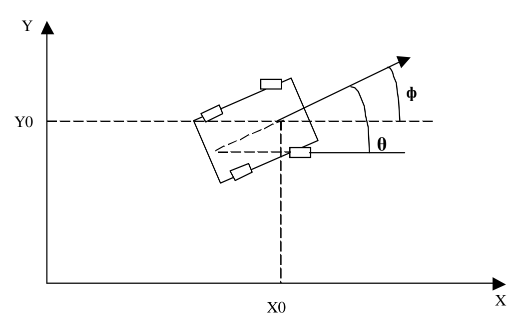

Fig. 2

In this research the automobile is considered as a punctiform object.

The mathematical model with its due approximations is:

$$x_{k+1} = x_k + v\cos(\phi_k + \vartheta_k)$$
$$y_{k+1} = y_k - v\sin(\phi_k + \vartheta_k)$$
$$\phi_{k+1} = \phi_k - \frac{v}{L}\sin(\vartheta_k)$$

Where:

- x_k and y_k, are the co-ordinates of the barycentre of the car
- ϕ_k, is the orientation of the front of the car.
- ϑ_k, steering angle
- $v > 0$, speed
- *L*, is the distance between the axis of the front wheels and the back ones.

The initial orientation of the car can vary from 0° to 180°, while the normal in parking is worth 90°, according to the reference shown in figure 3.

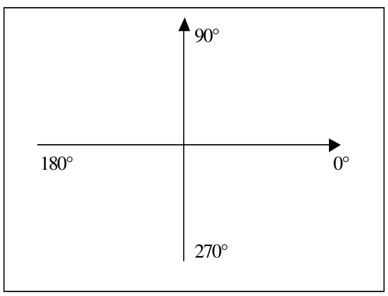

Fig. 3

The steering angles can vary from -30° to + 30°. The parking trajectory is made up by no more than 25 steering angles, the car is to be considered parked when the barycentre of this coincides with the barycentre of the space destined to the parking.

3 Problem Analysis

During our research we have analysed three phases that characterise reverse parking:

- the centralisation phase, in which we less move the automobile within the limits of the abscissa of parking, at less than an error
- the alignment phase, in which we move the car in order to align with the normal of parking
- the positioning phase, in which we move (steering angle=0°) the automobile within the parking place.

Having considered the automobile as a uniform point, it is possible to distinguish two independent cases during initial orientation:

- Initial position of the car on the left hand side of the parking place
- Initial position of the car on the right hand side of the parking place.

In the first case it is necessary to determine a trajectory that moves the car with an orientation between 90° and 180°, in a virtual parking place positioned on the right hand side and near the real parking space (see fig. 4).
In the second case it is necessary to determine a trajectory that moves the car in a virtual parking place and near the real parking space with an orientation between 0° and 90°, in order to facilitate the alignment phase.

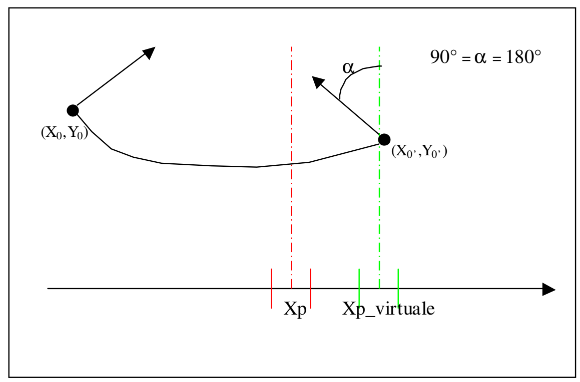

Fig. 4

4 Genetic Algorithms: Solution

During the centralisation phase the search of a trajectory happens by the means of the use of the genetic algorithm AG_1, which finds a set of steering angles and centralisation speed (*v_acc*), which satisfy the condition of centralisation. From this new position of the car (X_0', Y_0',θ_0 '), the genetic algorithm Ag_2 finds a set of steering angles and alignment speed *v_all* that satisfy the condition of alignment.
The last step consists in determining by means of a procedure (once known the position of the car, the parking place and the number of steps possible), the positioning speed *v_psz*, which allows us to complete the phases of parking. The trajectory covered by the car with its three different speeds turns out to be the union of three trajectories obtained during the three phases.

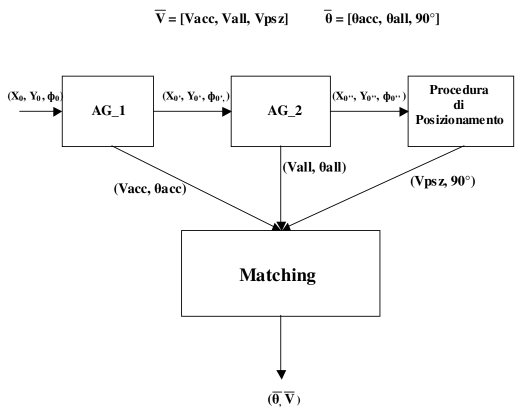

Fig. 5

4.1 Centralisation Phase.

During this phase, the genetic algorithm receives the information about the initial position in input (X_0, Y_0) and reinstates in output the set of steering angles and speed *v_acc* in order to reach the conditions of centralisation. These conditions are necessary for the genetic convergence of the algorithm of alignment.

The condition of centralization is characterized by three ties in relation to the dimension of the geometrical space of our problem:

- Abscissa condition $Xp-\varepsilon \le X \le Xp+\varepsilon$
- Ordinate condition $Y > Y_{min}$
- Orientation condition
  - $90° < \phi_k \le 180°$ (if we start on the left hand side)
  - $0° \le \phi_k \le 90°$ (if we start on the right hand side)

These conditions characterise the fitness function of AG_1. Let's see the characteristics of the genetic algorithms that have been used.

Chromosome: every chromosome of the population is constituted of 11 genes of which 10 for the steering angles and 1 for the speed *v_acc*.

Genes: the genes regarding the steering angles are numbers between [- 30, +30]. The gene regarding the *v_acc* is an entire number between[20, 50]. The condition that allows the variation of the speed depends on our projectile choices.

Fitness Function: Th fitness function, knowing the position of the car, takes into consideration the condition of the abscissa, the ordinate and orientation.

$$\text{Fitness} = \textit{parte intera}\,\frac{30}{K_x + K_y + K_{all}}$$

where:

- $Kx \in [1, 10]$ is the estimate of the distance to the abscissa of the parking area(1→ distance, 10 → near);
- $Ky \in [1, 10]$ is the estimate of the distance to the ordinate of the parking area (1→ distance, 10 → near);
- $Kall \in [1, 10]$,is the estimate of the distance to the normal of the parking area. (1→ distance, 10→ near);

To speed up the convergence of AG_1, to every new generated chromosome, we calculate the fitness function for a number of steps less than 10 (number of maximum steps). If we should obtain a higher result than the prefixed limit, we arrest AG_1and so give the results.

Algorithms of selection: selection for torneo and etilismo [10].

Algorithms of reproduction: crossover single point, mutation [9].

Exit condition: control on the fitness function and of the maximum number of evolutionary cycles carried out.

4.2 Alignment Phase

Phase of genetic algorithm alignment takes place after the phase of centralization, it receives in input the information abuot the position of the automobile (X_0', Y_0', θ_0') and reinstates in output the set of steering angles necassaery to reach the conditions of centralisation:

- Abscissa condition $Xp-\varepsilon \le X \le Xp+\varepsilon$
- Ordinate condition $Y > Y_{min}$
- Orientation condition $90-\eta \le \phi_k \le 90+\eta$

These conditions characterise the fitness function of AG_2. Let's see the characteristics of the genetic algorithms that have been used.

Chromosome: every chromosome of the population is constituted of 11 genes of which 10 for the steering angles and 1 for the speed *v_all*.

Genes: the genes regarding the steering angles are numbers between [-30, +30]. The gene regarding the *v_all* is an entire number between [-30, +30]. The genes relative to the *v_ all* is an entire number that is comprised in determinated intervals following the outline:

- $60° < \phi < 120°$ *v_all* $\in [1, 20]$
- $30° < \phi < 60°$ o $120° < \phi < 150°$ *v_all* $\in [10, 40]$

- otherwise $v\_all \in [10, 50]$

Fitness Function: the fitness function, takes into consideration the conditions of the abscissa, the ordinate and the orientation.

$$\text{Fitness} = \textit{parte intera} \; \frac{30}{K_x + K_y + K_{all}}$$

where:

- Kx ∈ [1, 10] is the estimate of the distance to the abscissa of parking.
(1→ distance, 10 → near);
- Ky ∈ [1, 10] is the estimate of distance to the ordinate of parking.
(1→ distance, 10 → near);
- Kall ∈ [1, 10] , is the estimate of the distance to the normal of parking
(1→ distance, 10→ near);

To speed up the convergence of AG_2, to every new generated chromosome, we calculate the fitness function for a number of steps less than 10 (number of maximum steps). If we should obtain a higher result than the prefixed limit, we arrest AG_2 and so give the results.
Algorithms of selection: selection for torneo and etilismo.
Algorithms of reproduction: crossover single point, mutation.
Exit condition: control on the fitness function and of the maximum number of evolutionary cycles carried out.

4.3 Positioning Phase

The positioning phase takes place after the centralisation and alignment phase, and receives in input information about the position of the car (X_0'', Y_0'', θ_0'') with the following characteristics:

- $Xp - \varepsilon < X_{0''} < Xp + \varepsilon$
- $Y_{0''} > Ymin$
- $90° - \eta < \theta_{0''} < 90° + \eta$

At this point we are in line with our parking area and we can now effectuate our reverse parking at steering angle = 0°.
Therefore knowing (X_0'', Y_0'', θ_0'') and (Xp, Y_P),we can calculate the distance from our parking area; having acquired this data and having fixed the steps (steps=5) we can determine the speed *v_psz* with which we can complete the traejctory and our parking operation.

5 Experimental Results

Our results are based on:

- Dimention of the car parking area X ∈ [0,320], Y ∈ [0,500]
- Barycentre position of the parking area X_p=160, Y_p=5
- Initial orientation of the car Φ ∈ [0,180]

1[a] experimental try:

Initial abscissa of the car = 70,00	Initial ordinate of the car =140,00	Initial orientation of the car = 50,00°
Initial population = 2000	Max number of cicles = 300	Fitness prefixed limit = 6
Not Convergence		

2[a] experimental try:

Initial abscissa of the car = 200,00	Initial ordinate of the car =110,00	Initial orientation of the car = 30,00°
Initial population = 2000	Max number of cicles = 300	Fitness prefixed limit = 6
Not convergence		

3[a] experimental try:

Initial abscissa of the car = 250,00	Initial ordinate of the car =180,00	Initial orientation of the car = 45,00°
Initial population = 3000	Max number of cicles = 300	Fitness prefixed limit = 6
Fitness=10		

4[a] experimental try:

Initial abscissa of the car = 70,00	Initial ordinate of the car =170,00	Initial orientation of the car = 50,00°
Initial population = 2000	Max number of cicles = 300	Fitness prefixed limit = 6
Fitness=10		

5[a] experimental try:

Initial abscissa of the car = 70,00	Initial ordinate of the car =170,00	Initial orientation of the car = 150,00°
Initial population = 2000	Max number of cicles = 300	Fitness prefixed limit = 6
Fitness=7		

6ª experimental try:

Initial abscissa of the car = 250,00	Initial ordinate of the car =180,00	Initial orientation of the car = 45,00°
Initial population = 1000	Max number of cicles = 300	Fitness prefixed limit = 6
Fitness=7		

7ª experimental try:

Initial abscissa of the car = 150,00	Initial ordinate of the car =350,00	Initial orientation of the car = 80,00°
Initial population = 2000	Max number of cicles = 300	Fitness prefixed limit = 6
Fitness=6		

8ª experimental try:

Initial abscissa of the car = 150,00	Initial ordinate of the car =350,00	Initial orientation of the car = 80,00°
Initial population = 2000	Max number of cicles = 300	Fitness prefixed limit = 6
Fitness=7		

Nuova Posizione del baricentro del parcheggio X_p=200, Y_p=5

9ª experimental try:

Initial abscissa of the car = 150,00	Initial ordinate of the car =350,00	Orientamento iniziale auto = 80,00°
Initial population = 2000	Max number of cicles = 300	Fitness prefixed limit = 6
Fitness=6		

Nuova Posizione del baricentro del parcheggio X_p=200, Y_p=50

10ª experimental try:

Initial abscissa of the car = 150,00	Initial ordinate of the car =350,00	Initial orientation of the car = 80,00°
Initial population = 2000	Max number of cicles = 300	Fitness prefixed limit = 6
Fitness=7		

6 Conclusions

Our experience has demonstrated that the use of genetic algorithms has given good results in resolving the problem of reverse parking. We have noticed that fixing to 10 the maximum number of steps for every genetic algorithm and considering the variable speed in the intervals that we have chosen, the convergence of both algorithms has been verified for an initial value higher than y_0=150. This limit can be reduced by varying the number of maximum steps and the intervals of the genetic algorithms speed variation.
Our solution is to be considered valid even when we vary our car parking position, within the geometrical space of our problem.

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