

# Parking Spot Tracking using Interval Methods

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## Introduction

Helping drivers to park their car in parking spots is a functionality already sometimes available in modern cars, in different forms (often referred as *parking assist*). However, since the current solutions might not always be fully satisfying nor reliable, initiatives such as the UTAC Challenge are being organized to improve the state of the art in this field. In this presentation, we propose to explore how interval methods could be used to help track parking spots from cameras embedded directly in the car.

## Main results

Indeed, it seems that few existing works try to mix the use of interval methods and classical video processing (see e.g. [Jaulin and Bazeille, 2009], [Kenmogne et al., 2017]).

While parking assist system often use proprietary algorithms, many research works propose various methods, see e.g. [Ma et al., 2021] for a review. Here is the principle of the spot tracking considered here:

- We just want to choose a spot not far away and track it. The question of spot occupancy, obstacle avoidance and control maneuver will not be studied here.

- Multiple cameras are installed directly on the car, to get a view of what is surrounding it. Note that the position on the car of the cameras is often constrained by several factors, so it is expected that the desired spot might not be always fully visible, hence the need to use tracking methods able to determine which visible spot is the desired one.
- A homography transform is done using typical methods to gather the images from all cameras and generate a bird's eye view as if a virtual down-looking camera was several meters above the car. All the processing will be done on the images from this bird's eye view.
- No learning techniques will be used in this study.
- We will assume here that spots are made of 2 parallel white lines, crossed by a 3rd perpendicular line. Those lines might not be continuous. Typical color/lighting selection and thresholding methods (including e.g. transformation from BGR to HLS color spaces, computation of a lighting indicator to adjust the threshold in conjunction with Otsu thresholding, dilatation and erosion, etc.) as well as the use of line detectors such as the Hough transform are applied to get a list of white segments assumed to contain lines from spots. Some extra filtering is also done to merge segments that are too close in terms of position and angle. This filtering could be done with interval arithmetic and set operations, and Hough transform-like algorithms using interval methods has been proposed in [Jaulin and Bazeille, 2009].
- Spot detection for each frame. Here, perpendicular or angle spots with open entrances will be assumed. Some characteristics need to be found to determine whether segments are those from a parking spot. An idea can be to first detect parallel segments (still with some distance and angular tolerance) and then, check if there exists a third segment in the image which is crossing them almost perpendicularly. Then, the direction of the spot (to determine where

is its entrance, where there should be no line) can be obtained by choosing the longest parallel segment length from the third line (note that we might have 2 opposite spots sharing the same perpendicular line, but one of them will be probably out of our field of view most of the time). The spot center will be defined from the barycenter of intersection points, at half of the typical spot length in the spot direction. Finally, the inclination of the spot needs also to be computed to determine if it is a perpendicular or angle spot. Also, the dimensions of the segments forming the spot and inclination angles need to be within typical values.

- In an image at time  $t$ , there might be multiple spots identified. We need to determine if some of the spots visible at time  $t + dt$  are already known spots. Car state equations can predict the spot movement from the car point of view:

$$\begin{cases} \dot{x} &= v \cos \delta \cos \theta \\ \dot{y} &= v \cos \delta \sin \theta \\ \dot{\theta} &= \frac{v \sin \delta}{L} \end{cases} \quad (1)$$

with  $x, y, \theta$  the position of the rear axle center and orientation of the car, and where  $\delta = u_1$  (angle of the front wheels w.r.t. to car chassis) and  $v = u_2$  (speed of the car) are assumed to be known thanks to accurate sensors, and  $L$  is the distance between the front and rear axles. An approach similar to [Le Bars et al., 2012] can be used to predict the tube  $[\mathbf{x}](\cdot) : \mathbb{R} \rightarrow \mathbb{I}\mathbb{R}^n$  as an interval of trajectories containing the trajectory  $\mathbf{x}(\cdot) : \mathbb{R} \rightarrow \mathbb{R}^n$  of the spot state in the image. At the image at time  $t \in \mathbb{R}$ , the vector  $\mathbf{x}(t) \in \mathbb{R}^n$  would be the evaluation of the trajectory  $\mathbf{x}(\cdot)$  at  $t$ , and the best compatible spot inside this box should be considered as the currently tracked spot, and therefore could be used to contract the tube to help for next time steps. Additionally, tracked spots might be sometimes partially visible and therefore not directly identified as a spot due to the logic described in the previous point. Techniques inspired from [Tillet et al., 2022] could be used to match partial lines with a tracked spot.

The CODAC library (see [Rohou et al., 2022]) can simplify the solving of problems that can be modeled with intervals. Interval methods could be used in parallel as a safeguard of existing, possibly more optimized methods but theoretically difficult to guarantee.

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