Inter-Rays uncertainty and Fixed Size assumption for objects tracking using a Laser Scanner

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Abstract: This paper presents a geometric representation based method for objects tracking using laser sensory data. The representation model, based on an Oriented Bounding Box (OBB), is achieved by using a two-stage procedure. The first one concurs a LRF data based convex hull technique of object's contour extraction. The second stage consists of contour analysis by a geometric method, called Rotating Calipers. In order to obtain good estimation for the geometric parameters of the object, two concepts are proposed. The first one, called Inter-Rays uncertainty, is introduced to consider the fact that the raw data points representing the extremities of the extracted OBB do not coincide with the real object's extremities. The second concept, called Fixed Size assumption, is integrated to take into account that the size of the object dos not change during the tracking process. The tracking is ensured by the Extended Kalman Filter with Discrete White Noise Acceleration model. Experimental results are presented to show the robustness of the proposed method.

Keywords: Tracking, Object representation, Laser range sensor, Intelligent vehicle, Signal processing

1. INTRODUCTION

Representation of dynamic objects is crucial for tracking and trajectory planning. In the literature concerning tracking, points with elliptical uncertainty are used for representing objects position (see Bar-Shalom and Fortman (1988), Blanc et al. (2004)). This representation is good enough for obstacle detection, collision warning or driving assistance systems in well structured environments like highway (see Blanc et al. (2004), Hofmann et al. (2003)). In the urban areas, there are less constraints on the objects movements. Thus, for the task of autonomous navigation in demanding urban areas, these representation methods are not sufficient. Oriented Bounding Box (OBB) (see Toussaint (1983), Ericson (2004), Nguyen et al. (2005)) provides a good approximation of the size, shape and orientation angle of dynamic objects, with a good data compression ratio.

In this paper, an OBB model, with an Inter-Rays (IR) uncertainty paradigm and a Fixed Size (FS) assumption, is proposed to represent dynamic objects. The IR uncertainty and FS assumption are introduced to increase the reliability of tracking in terms of object's size and centre position. The IR uncertainty is developed to handle the fact that the raw data points representing the extremities of the extracted OBB do not coincide with the real object's extremities. The idea of the FS assumption is to consider that objects' size does not change during the tracking. The tracking process is based on the Extended Kalman Filter (EKF) with Discrete White Noise Acceleration Model (DWNA) (see Bar-Shalom and Fortman (1988)) and ego odometry.

The paper is organized as follows. Section II presents the OBB representation model. The IR uncertainty paradigm is described in section III. Section IV develops the FS assumption. The tracking process is explained in section V. Before concluding, experimental results are presented in section VI.

2. OBB BASED REPRESENTATION

Urban environments are characterised by limited spaces available for navigation and there are little objects movement constraints. In these conditions, geometrical representation of dynamic objects is necessary. Oriented bounding box (OBB) is a way of representing objects geometry with sufficient approximation for the means of navigation. Most of the dynamic objects in urban environment are convex and as such can be effectively represented by OBB. The minority of the objects are concave, and in some cases, their concavity is not navigable, and thus, OBB is suitable. The mentioned objects can be called compact ones (see Figure 1). As a contrast, there are also complex objects whose concavity cannot be neglected as a navigable area. These can be represented as a combination of several OBB.

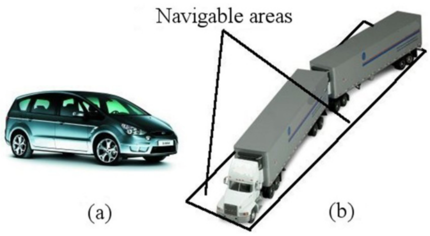

Fig. 1. (a) Compact object (b) complex object.

The proposed method of the OBB construction consists of two main steps. The first step is to find a convex contour of the tracked objects. In the second step, a method of Rotating Calipers (see Toussaint (1983)) is used to construct an OBB, which is the best aligned to the object's contour.

In the first stage of the OBB construction method, semi-convex-hull is created for the visible part of the object. The methodology is based on sequencing characteristic of the raw scan points. To explain the method let us use two examples (see Figure 2). The example shows a convex-hull, which is described by the points D, C, B and A. It is assumed that the point O represents the origin of the sensor's coordinate system. When a new point N is considered, two cases can be distinguished. In the first one (see Figure 2 (a)), the point N can be added to the existing convex-hull by connecting it with the point A, without violating the convexity constraint. The second case takes place (see Figure 2 (b)), when by adding the point N, the convexity constraint is broken. In this case, connecting the points N and A produces a concavity represented by NAB.

To recognise the two mentioned cases, the proposed algorithm computes and compares lengths of the two line segments OP and OA, where P is the intersection of the lines NB and OA. If the length OP is greater than OA, the point N is added to the convex-hull and the next iteration of the algorithm takes place. When the length OP is less or equal to OA, the point A is removed and the concavity test is repeated for the remaining points constructing the convex-hull (in the example: B, C, D). The repetition of the test is stopped when the convexity appears.

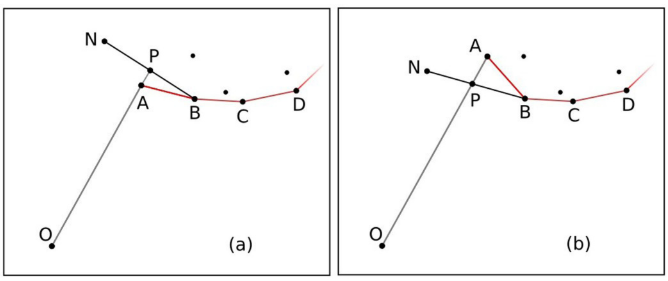

Fig. 2. Convex-hull construction.

The created convex-hull is used to create a minimum-area OBB. In the algorithm, it is assumed that the contour of visible and invisible parts of the object are symmetrical with respect to the point, which is the middle of the segment defined by the two extremities of the constructed contour (see Figure 3). The rotating calipers (RC) algorithm (see Toussaint (1983)) begins by bounding the contour through it's extreme points using four lines determining a rectangle. Because of the symmetry assumption, the algorithm uses only two perpendicular lines. In each step of the algorithm, at least one of these lines coincides with one of the edges of the contour. The lines are simultaneously rotated in one direction, about their supporting points ($P2$ and $P4$ in Figure 3) during each iteration of the algorithm. The rotation angle has a value which permits for one of the lines to coincide with the next edge of the contour (in Figure 3 the lines are rotated by the angle α). For each lines' position, an area of an OBB, created by four lines ($L1$, $L2$ and their symmetrical lines) is computed. This is performed by computing the area of the rectangle defined by the line segments $MM1$ and $MM1$, where M is the middle of the line segment defined by the points $P1$ and $P5$, $M1$ and $M2$ are respectively the intersections of the lines $L1$ and $L2$ with theirs perpendicular lines passing by the point M. The process is repeated until the lines have been rotated by the right angle from the beginning of the algorithm. The smallest area over all iterations indicates the orientation angle of the minimum-area OBB.

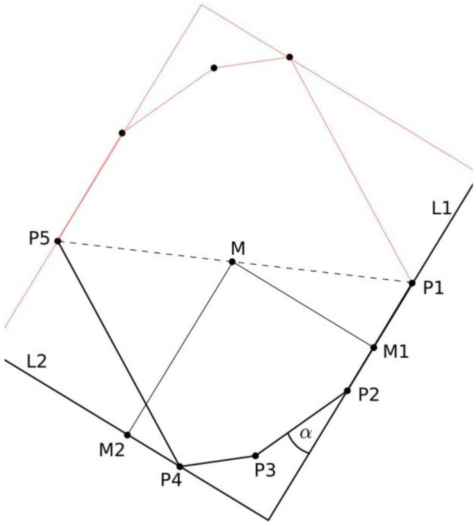

Fig. 3. Rotating calipers.

The OBB based representation is described by two vectors z (1) and σ_z^2 (2). The first one represents the OBB geometry and includes the centre coordinations cx, cy, the orientation angle θ and the size dx, dy. The second vector represents uncertainties on the components of the vector z.

$$z = [cx, cy, \theta, dx, dy]^T \tag{1}$$

$$\sigma_z^2 = [\sigma_{cx}^2, \sigma_{cy}^2, \sigma_\theta^2, \sigma_{dx}^2, \sigma_{dy}^2]^T \tag{2}$$

3. INTER RAYS

An important aspect of OBB extraction is the fact that the raw data points representing the extremities of the extracted OBB do not coincide with the real object's extremities (see Figure 4).

In the Figure 4, $minX$, $minY$, $maxX$, $maxY$ are respectively the minimum x coordinate, the minimum y coordinate, the maximum x coordinate and the maximum y coordinate of the extracted OBB. The line Lr (respectively

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