Collision Detection Of A Moving Polygon In The Presence Of Polygonal Obstacles In The Plane

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Abstract

We consider the following collision detection problem in the plane: An object rotates around one of its points with a constant angular velocity and translates towards a set of obstacles with constant velocity. Determine if any collision will occur. The rotation requirement to an object may occur in many cases. One example is that a camera mounted on a robot may need to rotate horizontally with a constant angular velocity for scanning the surrounding environment or for searching a target. This 3-D case might be simplified to a 2-D case if the shapes of the object and the obstacles do not change with respect to the vertical axis.

While a non-rotating object moving along a straight line does not hit any obstacle, a rotating object may hit some obstacle. The collision of the object and the obstacles is determined by the initial positions of the object and the obstacles, and the velocities of rotation and translation of the object. Thus, the crucial point is to find the relationship between the collision and these parameters at the beginning of a straight line path. A brute-force method for solving this problem is to calculate the skeleton of the loci of the moving object and to determine if any obstacle intersects the skeleton. This method clearly is time consuming.

Our approach is to find a constant number of points of the loci and to show these points carry adequate information for the collision detection. We shall decompose the case into several simple cases and solve the desired case by first solving these simple cases. We first consider a line segment l rotates at one of its endpoints with constant velocity ω and translates towards an obstacle point p with constant velocity v_o. We shall show that this problem has non-trivial answer. However, by finding the velocity of the crossover point of l and a line L' (which is parallel to the direction of v_o and passing through p), and by determining the extreme points of the locus of the crossover point, we can determine the collision of l and p in O(1) time. We then consider the moving object to be a triangle. We shall show that the collision (if any) can be detected in O(1) time. When the object is a simple polygon with n vertices, the collision (if any) can be detected in O(n) time. We also show that both convexity and uni-modality of a polygon do not help in this case. We further consider the object is a triangle and the obstacle is a line segment. We shall show that the collision of them (if any) can be detected in O(1) based on the extreme points of the loci of the moving triangle along a certain direction. We finally consider the object to be a polygon with n vertices and the obstacles to be polygonal objects (polygons, line segments, or points) with m vertices. we shall propose an algorithm to detect the collision of the object and the obstacles in O(mn) time, which is optimal in worst case.