

AN EFFICIENT COLLISION WARNING ALGORITHM FOR ROBOT ARMS

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ABSTRACT

A hashing technique is used as an arm collision warning algorithm for two armed robots which can be expected to be a factor 10^3 more efficient in memory resources than a direct geometrical calculation. Computational savings are also achieved.

I. INTRODUCTION

A. Motivation

The warning of imminent collision, one with another, by two arms of a robot is a practical problem with considerable economic interest. We present here a warning algorithm which is efficient in memory resources and in computational requirements. Assumed in all the following is the existence of an algorithm which proposes a new arm position which is at no point further away from the old position than the resolution capabilities of the warning algorithms to follow. We introduce the efficient algorithm by first considering an intuitive but inefficient algorithm.

II. THE DIRECT APPROACH

A. Direct Geometry

To avoid collisions no part of two objects should occupy the same space at the same time. With the volume of an object (a robot arm) represented by the union of volumes of a finite covering of spheres, cubes, prisms, et cetera, and with the Euclidian space, E, within reach of the arms represented by contiguous cells (conveniently cubes) then we have the following trivial but workable algorithm:

1. Direct Algorithm

a. For every element of a finite covering of one arm, mark every cell in E which is touched by the covering element.

b. At the proposed position of the other arm, for every element of the arms covering, check whether any portion of it lies within a cell of E previously marked by the other arm. If so for any

element of the covering then collision is predicted for the proposed arm position.

B. Memory cells

If, E, the working volume of the two arms is of the order 10^7 cm³ and if about a one centimeter warning distance is required then algorithm A requires 10^7 memory cells.

III. A BETTER WAY

A. The Indirect Method

We note that the volume of the arms themselves is likely to be of the order 10cm x 10 cm x 100 cm, or a factor of 10^3 less than the volume of E. This immediately suggests the use of a hashing function to compress the ratio of volumes with consequent reduction in memory requirements. Thus we are lead to the following philosophy: To avoid collisions no part of two objects should occupy the same part of hashed space unless a direct geometrical check has been made to determine that only a statistical collision exists. If the coordinates of each cell of E are hash mapped to H(E) then we have the following algorithm:

1. The Hashed Algorithm

a. For every element of a finite covering of arm A, deposit in every bucket of H(E) the label of each element of finite covering which maps to that bucket.

b. At the proposed position of the arm B, for every element of its finite covering, check the corresponding bucket of H(E); if no one of the arm A coverings denoted by the possibly nil set of labels is physically coincident as checked by direct geometric calculations then no collision exists.

B. Advantages

With a $1/k$ loading of the hashed space then only one in k statistical collisions leads to the computational burden of direct geometrical calculation. But the direct geometrical calculation is made efficient since only a small subset of the relevant coverings are considered.

Thus the retrieval properties of hashing minimize the square law explosion in covering combinations on each arm which must be considered. This same technique can be used to efficiently check for collisions of arms with other obstacles in E provided the volume of the obstacles is much less than the volume of E.

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