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The Rambler

Coverage Path Planning Algorithms in Mobile Robotic Systems

Introduction

Mobile robots (MRs), which move through the environment to perform a specific task in that environment, are becoming more abundant on the market. MRs depend heavily on reliable navigation of the environment to work properly. This paper specifically reviews the Coverage Path Planning (CPP) algorithms that allow MRs to create and travel along a path that will cover the entire operating area. [1]

Technology Currently on the Market

CPP is mainly used in MRs that perform tasks which require them to move over the entire operating area. Maybe the most common occurrence of CPP on the market is in the robotic vacuum cleaner. To complete their task, robotic vacuum cleaners must cover the entire area that is to be cleaned. Two such vacuums that are prominent are the iRobot Roomba and the Samsung Powerbot. [2][3] The Roomba from iRobot not only covers the entire operating area when it is vacuuming, but it also maps out the area at the same time and allows the user to select which rooms should be vacuumed. [3] The Roomba can cost anywhere from $300 to $950. [3] The Samsung Powerbot is another robotic vacuum cleaner, and it claims to have a more efficient and organized CPP algorithm than other robotic vacuum cleaners on the market. [2] The Samsung Powerbot can cost anywhere from $300 to $800. [2]

CNH industrial revealed at the 2016 Farm Progress Show that it is developing a line of autonomous tractors that will be able to traverse entire fields by themselves. [4] To achieve this, CNH industrial uses software running CPP algorithms to plan the most efficient route through a GPS mapping of the field. [4] As this technology is still in development, there currently isn't any pricing on autonomous tractors.

Detailed Operation of Coverage Path Planning

CPP algorithms allow the MR to travel the shortest overall distance, cover the entire area and minimize revisiting portions of the area. [1] Because of these characteristics, the performance of CPP algorithms can be determined based on the time it takes to generate the path versus the length of the path generated by the algorithm; this is a common trade off in CPP algorithm design. [6]

CPP algorithms can be classified based on whether the path generated is guaranteed to produce complete coverage and whether it is based on prior knowledge of the area. [5] If a path generated by the algorithm does not guarantee full coverage of the area, but instead guarantees acceptable coverage, it is called a heuristic algorithm. In contrast, a complete algorithm generates a path that guarantees coverage of the entire area. [5] If an algorithm uses a previously mapped area to generate a path, it is called off-line, while an on-line algorithm uses real-time sensing to generate the path as it goes. [5]

The Roomba employs a heuristic type algorithm called the randomized approach. In a random algorithm, the MR moves about randomly and avoids obstacles along the way. If the MR moves around randomly for a long enough time, it will cover most of the area and produce an acceptable result. [5]

In general, most complete CPP algorithms work like this: To begin, the path is broken down into smaller sections called cells. [5] These cells are of a predictable size and shape, allowing the MR to move through the cell efficiently. If the entire area is broken down into cells and each cell is traversed in the same way, then the entire area will eventually be covered. [5] Whether the decomposition into cells occurs before or during traversal of the environment determines if the algorithm is off-line or on-line respectively.

Most CPP algorithms work using traditional geometric shapes to form cells, but this isn't always true. [1] The algorithm described in [1] proposes that cells be created using an intrinsic coordinate system rather than the typical Euclidian coordinate system; the MR can then use this coordinate system to generate more efficient paths. [1] Another algorithm proposed in [6] does not use cells, instead producing parallel lines across the area called main lines. These main lines are near enough to each other that they guarantee complete coverage of the area when traversed; the paths created with [6] are almost always shorter than those created with other algorithms though they often take more time to generate. [6]

Hardware Required for Coverage Path Planning

The amount of hardware needed to aid the CPP algorithm varies based on the specific algorithm used. MRs using random or off-line algorithms may only need simple sensors to avoid obstacles and a microcontroller to execute the desired movement, since these algorithms do not need to generate detailed maps of the environment. Algorithms that work on-line may need more complex sensors that allow the MR to get a more accurate sense of the environment and more robust computational tools to execute the algorithm in real-time. According to [1] sensor selection and algorithm selection are related, and both should be based on the type of environment being covered. The correct choice of algorithm will yield the most efficient path which will in turn consume the least amount of power when executed. [1]

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