COMMENTS ON AUTOMATED ROUTE PLANNING IN UNKNOWN NATURAL TERRAIN

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ABSTRACT

This brief paper provides one person's perspective on route planning problems for autonomous mobile robots operating in unknown natural terrains. These problems include representation of geometric and nongeometric conditions, reasoning in dynamic situations, obstacle sensing problems and incomplete world knowledge. Several researchers' attacks on these problems are reviewed.

INTRODUCTION

Autonomous mobile robots operating in unstructured or unknown environments with sensors which provide an incomplete view of those environments require complex planning systems to determine the appropriate route from the initial location to the destination. Several mobile robots have been constructed which had such planning systems[1-5] and at least two such efforts are ongoing[6,7]. All of these efforts plan routes only in two dimensions. All of these robots are equipped to function in environments unknown to various degrees. Only two of these efforts attempt to find routes through natural terrain[3,7].

Route planning is the process of deciding what path a robot should take to get from point A to point B within such prescribed constraints as minimum fuel use, minimum transit time and maximum use of cover. Route planning requires models of both the robot vehicle and the environment. The vehicle model must describe such independent properties as geometry (e.g., length, width, height and shape), mass, terrain loading, maximum surmountable obstacle height and minimum turn radius. The vehicle model must also describe such environment/action dependent properties as maximum speed, maximum turn rate, maximum transverse and lateral accelerations, buoyancy and fuel consumption rate. The environment model includes both surface and volume descriptions of the surroundings. The surface description includes models of terrain slope, shear strength, support strength and roughness properties. The volume description includes models of obstacle geometric properties, distribution in space, deformability and density. The vehicle model must have both structural and causal descriptions. A structural model of an environment is sufficient if the environment is static. However. when interactions between components of the vehicle and the environment are important to the planning process then both structural and causal descriptions of the environment are necessary.

ROUTE PLANNING ISSUES

The various route planning issues discussed here are organized in terms of the problems of representation, obstacle sensing and incomplete world knowledge.

Representation Problems

Much of the terrain can be modelled geometrically. Various representations have been developed for geometric models. Most robot route planners take a 3D sensor representation of the terrain and transform that data to a 2D representation used for the route planning[1-7]. This technique works quite well in indoor environments where geometric obstacles can be sufficiently represented by cylinders or polyhedra with principal axes normal to the ground plane. However, complex natural terrains can rarely be modeled so simply. 3D representations are presently used only in route planning for legged vehicles[8,9] and planning manipulator motions[10,11]. However, no robot vehicles have actually been tested which use 3D representations of terrain for planning.

When it is necessary to optimize the robot's route using such criteria as fuel consumption or minimum time it becomes necessary to model nongeometric terrain conditions and their effect upon such vehicle performance factors as maximum speed, fuel consumption and turn rate. Nongeometric terrain properties include shear strength, support strength, roughness and volume density. Nongeometric obstacle properties include deformability (e.g., trees vs. bushes) and density. Several authors have approached models of different objects[1-6, 12-14] but only one effort is known which models the conditions of natural environments which influence vehicle mobility for route planning[15].

Natural environments are notoriously dynamic and little work has been done in modeling dynamic environments. The dynamic elements of an environment can be divided into two classes, active objects and varying terrain conditions. Active objects are elements of the environment that can move as well as change their nongeometric properties. The issues associated with modeling objects which move, change the positions of other objects and interact actively with the robot have been barely discussed[12]. Varying terrain conditions include shear strength and support strength changes caused by such factors as precipitation. Modelling these conditions have not been approached at all although existing reasoning mechanisms are certainly able to incorporate some of these effects if they could be effectively modeled. However, existing planning mechanisms have limited temporal reasoning abilities.

Obstacle Sensing Problems

Two problems arise when trying to sense any environment, poor sensors and poor objects. Real sensors are noisy, inaccurate and, generally, provide an incomplete picture of the surroundings at any one time. Some work has been done in planning with unreliable sensors[13] but this work is very preliminary. Much more such work is necessary to adequately deal with the problem of poor sensors. Real environments impose certain limitations on otherwise good sensors. Real obstacles are grouped together and are often only partially available to sensor scrutiny. In addition, atmospheric electromagnetic propagation conditions are drastically affected by weather and terrain reflecting properties create extremely complex multipath situations. Many of the ambiguities generated by these adverse situations must be resolved to provide a sufficiently accurate picture of the surroundings from which to create a practical route plan. Model based sensor interpretation can solve some of the difficulties associated with both types of sensor problems. However, much work remains to integrate complex sensor interpetation schemes with route planners operating in natural terrain.

Incomplete World Knowledge

Perfect world knowledge consists of complete and accurate information of the properties of every object in the environment over the entire mission time. A mobile robot with perfect prior world knowledge can plan and traverse a route without any other information. Unfortunately, perfect prior world knowledge is rarely available for natural terrains. In many cases, imperfect prior world knowledge is available in the form of approximate maps and models of object behavior. In these cases, the mobile robot must have sensors to determine the true world conditions. Often only incomplete and inaccurate sensor information is available as discussed above. These situations can be overcome by using filtering and models of object behavior to enrich the world knowledge. Two groups have developed algorithms for route finding in natural terrains using existing map databases [7,15]. A mobile robot traversing completely unknown terrain is the worst possible case for it has the least prior world knowledge. In this instance, the robot would have only models of object behavior but no specific knowledge of object locations or exact properties. Several mobile robot efforts have approached this problem area for simple indoor environments[1,2,4,6]. Only one such effort approached an unknown outdoor environment[3] and that effort demonstrated their robot only in terrain with simple relief and limited extent.

Autonomous transit over unknown terrain is partly actual transit and partly route finding activity. The terrain type and robot viewpoint determines what proportion of the total transit time is spent finding the route through unknown territory. Terrain of low relief, such as typical desert terrain, is easier to evaluate from any single point on the surface. Routes in such terrain can often be identified during the actual transit activity thus requiring no separate path finding activity. Terrain of high relief is more difficult to assess from any single point. In such terrain, a robot must spend more time than with simple terrain just gathering information about the terrain through which to plan the route. The route finding activity involves transits to observation points which often do not directly contribute to the transit to the destination. These different terrains place significant different demands upon the planning process. No actual experience has been gained in designing and operating automatic planners in complex natural terrains.

CONCLUSIONS

Much past work has been done in the area of route planning for an autonomous mobile robot and several actual mobile robots have been constructed and tested. However, very little work has been done which addresses the problem encountered in planning in complex natural terrains. Important limitations include but are probably not limited to representation of nongeometric terrain properties and dynamic situations. Some preliminary work has been done in planning for dynamic situations but much work remains, especially in the areas of representing knowledge and reasoning in dynamic situations. While model based sensor interpretation helps overcome obstacle sensing problems much of this work needs to be integrated with route planners for use in natural terrain. The effect of incomplete prior world knowledge on the planning process also needs further exploration.

In the opinion of this author, these problems need resolution before successful route planners for unknown natural environments can be demonstrated. However, many of the intermediate steps between the present state of the art and the desired capability have already been taken in such efforts as those described in references [7] and [15].

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