Artificial Intelligence and Terrain Handling of a Hexapod Robot

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***Abstract*—The focus of the master's thesis project "Artificial Intelligence and Terrain Handling of a Hexapod Robot" has been getting a six-legged robot to autonomously navigate around a room with obstacles. To make this possible a time-of-flight camera has been implemented in order to map the environment. Two force sensing resistors were also mounted on the front legs to sense if the legs are in contact with the ground. The information from the sensors together with a path planning algorithm and new leg trajectory calculations have resulted in new abilities for the robot.**

During the project comparisons between different hardware, tools and algorithms have been made in order to choose the ones fitting the requirements best. Tests have also been made, both on the robot and in simulations, to investigate how well the models work.

The results are path planning algorithms and a terrain handling feature that work very well in simulations and satisfyingly in the real world. One of the main bottlenecks during the project has been the lack of computational power of the hardware. With a stronger processor, the algorithms would work more efficiently and could be developed further to increase the precision of the environment map and the path planning algorithms.

I. Introduction

The growing trend of developing and using automated, unmanned vehicles could be very useful for making the work in dangerous and non-human friendly environments safer and more efficient. A robot could, for example, be used in the ruins after a big earthquake to find survivors and possible paths for emergency workers. This is one application that has inspired the work and the goals of the thesis on which this summarizing article is based [2].

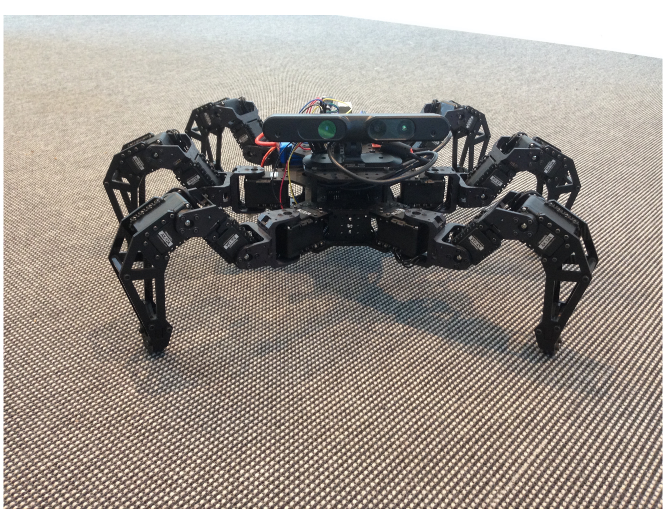

Fig. 1. Hexapod with RGB-D camera and onboard navigation.

The project is based on a previous master thesis for Combine Control Systems in Lund where locomotion and movement patterns were developed for a six legged robot, also named hexapod [1]. Since the hexapod is stable, has many legs and is relatively small it could work very well together with sensors and a path planning algorithm for applications in non-human friendly environments. An autonomous terrain handling hexapod is also a great possibility for Combine Control Systems to demonstrate their work and a way to present their competence and business idea at a technical fair. The hexapod is presented in Figure 1.

II. Sensors

The first step of being able to move autonomously in the world and traverse terrain is to use sensors to acquire information about the environment. A depth-camera, ASUS Xtion Pro, was mounted on the hexapod in order to capture the surrounding environment. The depth camera provides a matrix much like a regular camera, but with the depth instead of RGB values. Another method of sensing the environment was by attaching force sensors to the feet of the hexapod. These allowed for the hexapod to feel when each leg was in contact with the ground.

III. Mapping

In order for the robot to be able to walk around and navigate autonomously the surrounding environment has to be taken into account by building a map. A 2D map is built by using the information from the depth-camera and transforming it into a point cloud where each point represents the position in space where the camera has seen an obstacle. All of these points are projected onto a plane which is to become the map. The map is a grid where the projected points are added as obstacles in the cell to which they have been projected. An illustration is presented in Figure 2.

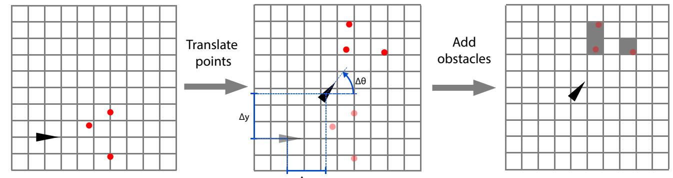

Fig. 2. Adding an obstacle to the map

IV. Planning

When a map has been built the locations of all visible obstacles are known and the robot is to move from its current position to a preferred one. In order to do so a path has to be planned from the current position to a goal. A graph structure is built by viewing free cells in the grid as nodes and connecting the adjacent free cells with edges. The path is found by performing search in the graph. Search is done by expanding the nodes, starting with the current node, in the graph into a tree structure until the goal is found. An illustration is presented in Figure 3 where a map graph structure is transformed into a search tree.

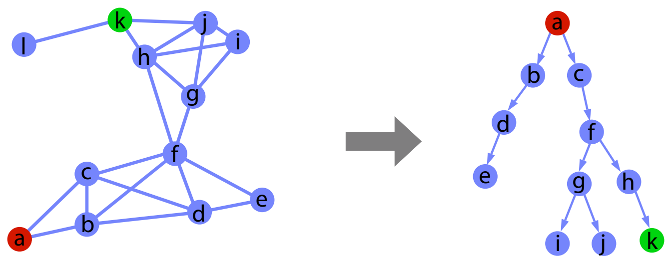

Fig. 3. Expanding a graph into a search tree

There are many ways of choosing how to expand the graph. The algorithm used for expanding the graph in this thesis is called D* Lite. It is an algorithm that uses information about the world to make efficient choices regarding which nodes to expand. It only allows re-planning in areas which have been changed, which makes it ideal for real-time dynamic planning. A planned path in a map is presented in Figure 4.

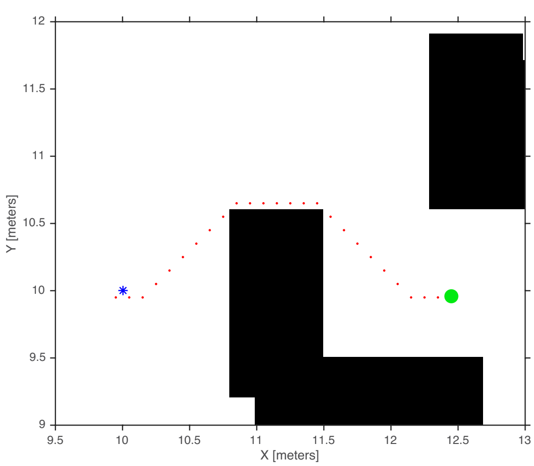

Fig. 4. Planned path in map

V. Path-Following

When a path has been planned the next step is to actually follow the path with the robot. Two control signals were available for use, one controlling forward velocity and the other rotational velocity. Since the path is a set of points which are to be followed, decisions have to be made regarding which point to aim for at what time. The robot will rotate until it is aimed at the closest point and then walk forward until that point has been reached within a threshold. The following point will then be set as current goal until the final goal has been reached. See Figure 5 for a small illustration of what errors are driving the path-following algorithm. ϵ_d is the distance from the hexapod to the following goal point and ϵ_θ is the angle error.

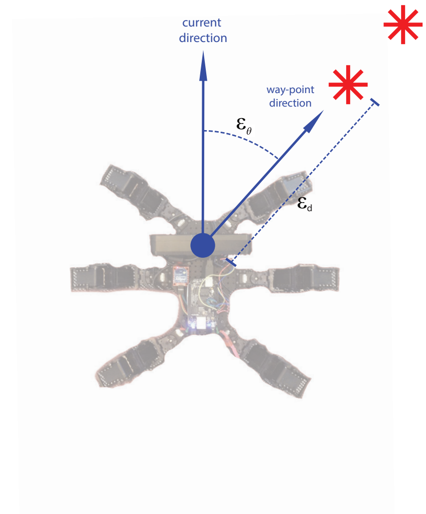

Fig. 5. Path-following directions and errors

VI. Results

The resulting hexapod could fully autonomously walk from one position to another avoiding obstacles dynamically. However, the computational power needed for smooth operation was more than what was provided. The final version of the hexapod walked for one second and then stopped for half a second to perform planning and mapping. The force sensors which were mounted on the feet were used to check if the legs were in contact with the ground. This allowed the hexapod to maintain different feet positions depending on the terrain. If the front feet were extended too far below the expected terrain level the hexapod would shy back since it might have reached an edge.

VII. Discussion

The final hexapod ended up working fairly well. However the uncertainty of the real world always poses a challenge and the robustness of planning algorithms really depend on the environment. With a flat floor of the correct floor type and generous obstacle margins, planning worked great. However, much more development is required in order for the hexapod to work well in all environments.

References

[1] D. Thilderkvist and S. Svensson, *Motion Control of Hexapod Robot Using Model-Based Design*, Department of Automatic Control, Lund University, Sweden, 2015, ISRN LUTFD2/TFRT–5971–SE.

[2] M. Malmros and A. Eriksson, *Artificial Intelligence and Terrain Handling of a Hexapod Robot*, Department of Automatic Control, Lund University, Lund, Sweden, 2016, ISRN LUTFD2/TFRT–6010–SE, Avaliable at http://www.control.lth.se/Publications.html.