Optical Flow Based Local Navigation

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The Problem: The goal of our research project is to develop methods that will be used by mobile agents for robust autonomous navigation. And the major type of input to our algorithms is visual input. In our research, we are using ideas and techniques from two major branches of artificial intelligence research; computer vision and navigation.

For the vision part, we are using monocular vision systems to provide sequences of images of the environment, and we are trying to extract some features from these sequences that we use for motion decisions. One such feature is the optical flow fields. Optical flow of a sequence of images is "the apparent motion of the brightness pattern" [3]. It is a vector field that shows the direction and magnitude of the intensity changes from one image to the next one in the sequence [1]. An example optical flow field is shown in Figure 1. Optical flow fields can be used to extract useful information like the layout of the surfaces seen in the images, and the motion of the observation point [2].

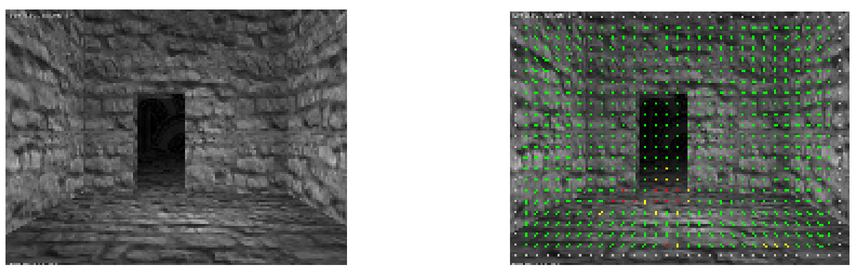

Figure 1: The picture on the left shows a scene from a simulated environment, where the agent has just moved one step forward from its initial starting position. The picture on the right shows the computed optical flow field that results from the motion of the agent, superimposed on the first picture.

For the navigation part, we are primarily concerned with local navigation, i.e. navigation in small-scale spaces such as rooms, offices, hallways, etc. Our research group also has other members working on global navigation by using our local navigation algorithms to abstract away most of the low level details. We are studying some interesting and successful navigation algorithms, trying to understand their strengths and weaknesses, and modifying them to use on our research robot. A sample simulation run of our robot using modified potential field method of navigation is shown in Figure 2.

Motivation: Among the popular sensors in robotics research, such as laser range finders, sonar sensors, infrared sensors, etc., vision seems to be the most interesting one. It is also a very computationally challenging one given the complexity of most of the algorithms developed by vision researchers. Therefore, we are interested in understanding how human-beings can easily and quickly use vision for navigation.

Also, there are many successful navigation algorithms for various types of mobile agents and for various situations. We would like to try modifying them or developing new methods that can be more generally applicable.

Approach: We have studied two local navigation methods; the potential field method [4], and a new dynamical steering method that is designed by two scientists in Brown University, William H. Warren and Brett Fajen, after many experiments on human subjects to model the way humans navigate through obstacles. With some modifications, both methods are working properly in our simulations and also on our research robot, provided that the x-y coordinates of target and obstacle locations are known. We use vision to extract these necessary coordinates from

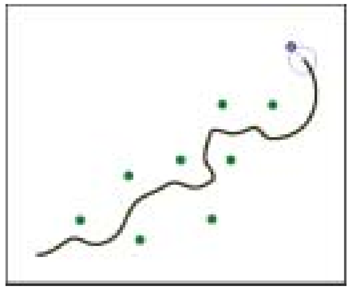

Figure 2: In this simulated run, the robot starts from the lower left corner and moves to the target located at the upper right corner while avoiding the obstacles on the way. We also get the exact same behavior from our robot on real runs provided that we have the x-y coordinates of the target and the obstacles as in the simulation.

the image sequences as follows: We first compute the optical flow fields by performing a patch matching operation [6, 7] to find the corresponding edges [5] in two successive images. And then, by using some geometric relations, it is possible to convert each vector in a flow field to a metric range value. We then apply another geometric transformation to the range values corresponding to the locations of interest to us, and obtain the necessary x-y coordinates to feed into the navigation algorithms that control the robot.

Impact: Visual sensing can be used for both indoor and outdoor applications and in various environments. Even when the amount of ambient light is not sufficient for a regular camera system to function properly, there are night vision systems that can easily be used to provide high quality visual input to a navigation system. Therefore, implementation of a robust visual navigation system may lead to some very useful applications like autonomous helpers for blind people, unmanned vehicles to accomplish a variety of things under various conditions that may possibly be dangerous for human beings, etc.

A powerful navigation system will also help many robotics researchers to abstract away the low-level details and concentrate on other high-level tasks that will eventually require autonomous motion.

Future Work: The smallest unit of length available to us when using the patch matching algorithm to find the optical flow vectors is limited by the size of the pixels in the images. Due to this discrete nature of our calculations, the x-y coordinates that we compute are also discretized and do not reflect the correct values most of the time. This results in difficulties and inconsistencies in locating the obstacles by using the vision system. We are trying to find some solutions to these kind of problems that will enable us to clearly identify obstacle locations.

Research Support: This research is supported by the DARPA Mobile Autonomous Robot Software (MARS) program under contract DABT 63-99-1-0012.

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