# Artemis: An Autonomous Mobile Robot for Search and Rescue Operations

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***Abstract*—Artemis is an approach to mapping unknown environments by following a person instead of autonomously wandering through the environment to map it. The benefits of this approach is to find a safe path through the environment, as determined by the guide, where the robot will not get damaged and that the created map can be shared with other people to know the safe paths. The person is identified and followed via augmented reality tags that are tracked by a camera on the robot.**

***Index Terms*—Autonomous, Robot, TurtleBot, AR Tags, Mapping, SLAM, Search and Rescue**

## I. Introduction

Every year, natural and man-made disasters happen and rescue teams are sent in to find and evacuate civilians to safe areas. Currently, there is a lot of research into ways to incorporate robots into the rescue efforts. This paper introduces our robot, Artemis, which will be the first step in getting robots into these dangerous environments.

The goal of Artemis is to follow rescue workers into the field and map out the safe path the worker finds. That map can then be used by other rescue aid robots or other human rescue workers to navigate the disaster zone. So this project will focus on the following behavior and the mapping of the safe path through the disaster area.

## II. Related Work

In this section, we will address some of the important work that has been done in areas relevant to our project. Since our project primarily involves mapping, as well as identification and following behaviors, we will describe relevant work in both these fields as follows:

### A. Mapping

Mapping is defined as the problem of acquiring spatial models of physical environments through a mobile robot [1]. Mapping is an extremely important tool for robotic applications since robots often rely heavily on these maps to perform autonomy tasks such as navigation. These maps are useful not only for the robot to perform future tasks, but also for humans to understand a new and unknown environment. Large environments are very difficult to map and often require incremental mapping, and these maps might require frequent updates that further add to their complexity [2]. A particularly useful domain of research in mapping is Simultaneous Localization and Mapping (SLAM). SLAM allows the robot to not only map the environment, but to determine its location within the map as it is being created [3].

In this project, mapping will play a central role – our aim is to provide a highly accurate and reliable map to end users, for example search and rescue teams, that they can use to determine ”safe” routes in a possibly unsafe area. Previous research in the use of autonomous robots for search and rescue has highlighted some unique challenges in mapping these kinds of environments, particularly: environment size, material heterogeneity, possible lack of structures or significant landmarks, and non-planarity [4]. Due to the difficulty of emulating these types of complicated domain-specific features within our given environment (Link Lab), we will ignore these issues in our project implementation. However, our implementation will provide an informative proof-of-concept that can and should be extended to incorporate solutions to these outlined problems.

### B. Identification and Following Behaviors

In the previous subsection, we detailed the challenges involved in mapping. We need a human involved in the mapping process in our case, so they can guide the robot to only move in safe paths through the environment to avoid damage. This presents a two-fold challenge: first we must be able to identify the target at all times, since we want to make sure we only follow the same target, and second we must follow the target at a close distance in a consistent way.

Some interesting work has been done in these areas – for example, Hirai et al. [5] developed a strategy for the robot to follow a human by visually tracking his/her back and shoulder. Another such approach attempts to use skin color detection to distinguish a human head and follow the human if it is in the center of the image [6]. However, these types of approaches often involve the use of computationally expensive computer vision algorithms and consume large amounts of power to train models and perform computation. This can be a detrimental drawback for robotic applications such as ours, since mobile robots generally have limited compute power and restricted energy capacity. Therefore, alternative techniques must be considered to optimize for our problem space.

A particularly interesting approach is the use of April Tags [7]. April Tags, similar to QR Codes, are a viable alternative since they provide an inexpensive yet robust way to have interact with robots. Also, they can be recognized with great precision and thus can be used as a reliable target for the robot to follow. For our purposes, we will use AR Tags [8], which are conceptually the same as these April Tags, but have a more convenient library for using them in ROS (which we will discuss below in the Approach section). Essentially, this reduces the identification and following problem to simply scanning the environment using the camera to search for a particular code, and once found, go towards its location.

## III. Problem Formulation

The problem addressed in this paper is to follow a specific individual and map out the path the person takes. This path is designated the ”safe path” and allows the robot to map the uncertain and possibly dangerous environment in a way that prevents possibility of injury to the robot. This is in contrast to the exploration approach, where the robot would map the environment autonomously, and while doing so, risk going into unsafe areas and get damaged because it lacks a human or animal to guide its exploration. The person is followed using special tags attached on him, and the map created is passed on to search and rescue teams that can use it to detail plans for rescuing and evacuating those affected.

## IV. Approach

The approach that we used to solve this problem is separated into three different parts. The first part being the mapping out the environment. The second is identification of a specific person, and he third being the following of said person. Also the entire implementation was done with the ROS (Robot Operating System) [9] on the turtlebot [10] platform.

### A. Mapping

The mapping for this project is accomplished by the ROS package ”gmapping” created by OpenSlam organization [11]. This package creates a particle map out of the environment by utilizing the kinect-like sensor’s distance scan. Gmapping’s algorithm is loosely based on a particle filter. The particles used in the filter come from the distances that the kinect like sensor produces. The particles are correlated by time and position relative to the robot.

### B. Identification

Identification of a specific individual can be done via many different methods. The method that is implemented here is augmented reality (AR) tags attached to the individual. This was chosen in particular over other methods so that the identification tags can be swapped between people quickly, and also have the ability to follow other entities as well, including animals or other robots.

The specific implementation of augmented reality tag (AR tag) tracking this project used was a package created by Andrew Dahdouh [8]. This tracking tool will take the raw image data from the kinect-like sensor on the turtlebot platform and find any AR Tags within its viewing range and publish to a topic.

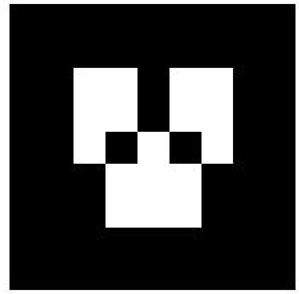

Fig. 1. Example AR Tag.

The information that will be given is the AR tags seen and their relative positions from the camera. There are multiple different AR tags to identify people and other things with; this allows us to use a specific tag per individual that is to be followed.

### C. Following

The following behavior is implemented as a modified go-to-goal algorithm. The goals for the go-to-goal algorithm are created from the relative positions of the specific AR tag that the robot is following. The goal is specifically made to be one meter away from the tag and is updated every time the AR tag identification tool publishes new data. The method by which the go to goal behavior is implemented by using a PID (proportion integral derivative) controller on controlling the speed of the robot. The angle to goal is set by a proportional controller.

## V. Results

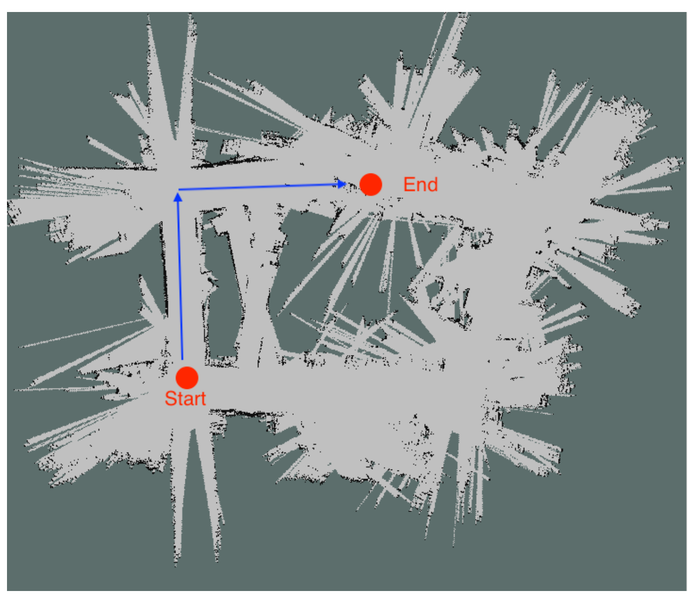


Fig. 2. Complete demonstration area map. Starting and ending points for the individual are shown as well as the path in blue.

The demonstration of Artemis was done in the University of Virginia's Link Lab located in Olsson Hall. The procedure for the demonstration was picking a subset of the entire lab to map out manually with the turtlebot using teleoperation while running the gmapping algorithm.

The map shown in figure 2 is the section of the Link Lab that was going to be our demonstration area. After that map was created, Artemis was run and followed the AR tag illustrated in figure 1. The path that the individual took is illustrated by the blue arrows and the red circles are the starting and ending points. The map that was generated by Artemis during following in figure 3 below.

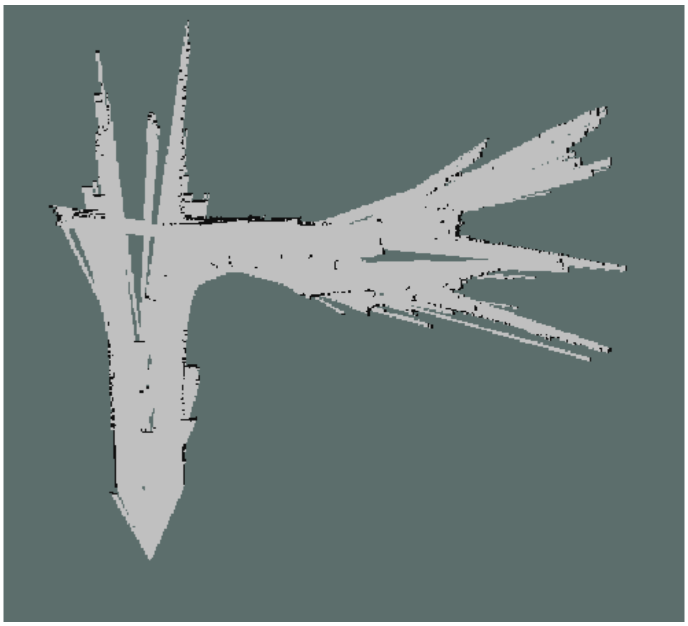

Fig. 3. Path of individual map.

From looking at the results, it is clear that Artemis did its job to follow the person with the tag and mapped out the "safe" path through Link Lab.

## VI. Conclusion

The results of our experiment highlight the interesting features of our project and provide a sufficient proof-of-concept for our application. We observed that the robot was able to follow the guide (via the AR tag) through a safe path on our overall map. In practical extensions to this project, we may want to use a search-and-rescue dog specifically trained for that purpose, so as to not put any humans at risk in more dangerous areas. We could also have it follow drones or other aerial robots (tele-operated by humans at the base station) to further mitigate risk. Another extension to this project can involve the use of these follower robots in military operations. Often times, military operations are conducted in unknown and unsafe areas, so it would be useful to have a robot follow a guide around and map the area for reconnaissance.

Ultimately, this proof-of-concept shows that our robot has the potential to help rescue teams do their jobs more efficiently. For fires, like the one in California last month, for hurricane-affected areas, or for any other natural-disaster stricken area, we have demonstrated that deploying such a robot to create maps for rescue teams is a viable solution, and we hope that it can prevent tragedy and aid relief.

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