

MEng PROJ515

Autonomous Mobile Manipulator

Executive Summary

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This summary provides details of our report on GINA (Grasping Interacting Navigation and Manipulation) for autonomous locating, fetching, navigation and manipulation of objects.

The team responsible for the development of GINA have an excellent track record. Having already produced several highly regarded robotic systems prior to the construction of GINA, the team has experience with integrating state-of-the-art technology in their solutions.

## Purpose

Robots are already an integral part of modern industry. Careful implementation of controlled and structured environments have permitted robots to perform highly specific and repetitive tasks, transforming the manufacturing industry.

Preliminary research has identified a lack of safe and affordable robots in the commercial sector.

Until now, indoor mobile robotics has meant one of two things. At one end of the spectrum are home robots. These machines perform simple tasks (such as hoovering) in completely unstructured environments. On the other end of the spectrum are factory and warehouse robots. These operate in highly controlled and dangerous environments, often to the extent that humans are not permitted to approach the robot's working area.

There is a huge, untapped middle ground for robotic solutions in the semi-structured environments of commercial enterprises. Businesses such as museums, hotels, banks and shopping malls must adhere to strict regulations such as the 1995 disability discrimination act, which states that all publicly accessible buildings must be handicap accessible. By constraining GINA's dimensions to those of an electric wheelchair, our robot is able to navigate publicly accessible buildings unassisted.

## Safety

To ensure user safety and product longevity, GINA was constructed with a variable stiffness robot arm. This cutting edge technology allows GINA to move through a crowded room without any risk of damage to itself or people. Variable stiffness technology allows GINA to change the rigidity of every joint in its arm. High stiffness is used for small, precise movements and low stiffness is used for faster motions. When moving, the arm is set to low stiffness mode in order to absorb the force of any accidental impacts or collisions. The introduction of variable stiffness technology increased the mean time before failure from 1,000 hours to over 10,000 hours of continuous operation, reducing the lifetime maintenance cost for both the user and the manufacturer.

## Adaptability

ROS (Robot Operating System) is used extensively throughout the robot's architecture. One benefit of ROS is an abstracted hardware interface which allows untrained users to upgrade or replace hardware. For example, when the next generation of laser scanners are released, a user will be able to unplug GINA's current laser scanner and replace it with a new one without the user having to write or modify any code. This specific example would increase the maximum speed the robot can achieve when navigating autonomously, but the plug and play capability of the robot extends to almost all of the robot's hardware elements.

## Applications

GINA has numerous applications, from shop assistant to sports coach or personal care assistant. The robot can be used to fetch items in the home of a mobility impaired person, or keep track of the possessions of an Alzheimer's patient. GINA could also be used as a supermarket assistant, where it can restock shelves overnight without supervision.

A by-product of the way in which GINA navigates is the generation of dimensionally accurate 2D maps. These maps are automatically created by the robot in both manual and automatic control modes and can be pushed to a remote computer, making GINA suitable for the exploration and mapping of potentially hazardous environments.

The robot's mechanical drive system is inspired by all-terrain electric wheelchairs, enabling outdoor operation. In a personal care situation, GINA can follow a user to a supermarket and aid in the carrying of shopping or personal possessions.

In addition to being a functional end-user product, GINA is also a highly capable research and teaching platform. Modifications to GINA are encouraged, and additional technical support is available to customers who wish to modify their robot.

## Sensors

GINA uses a 2D laser scanner to generate a map of its surroundings and detect obstacles as it moves. Ultrasonic sensors provide additional information on hazards that would be missed by the laser scanner, such as glass cabinets or the robot approaching the top of a staircase. Velocity measurement devices on all driven wheels allow a user to set a maximum speed limit. Six high resolution, low latency joint position sensors coupled with twelve high precision servos result in emotive, fluid execution of arm movements. An infrared range-finder in the palm of the gripper helps guide the arm during the final stages of the grasping process.

Pressure sensors embedded in a new, innovative gripper allow GINA to sense the shape of an object by touch, preventing damage to the gripper and the object to be manipulated. The robot has no difficulty in picking up a range of items such as smartphones, television remotes, a tennis racket or even an egg.

Multiple camera systems are involved in the fetching process. A camera mounted on the robot's head identifies and stores the location of objects the robot has seen as it moves through a room. If a user requests an object for GINA to fetch, the head camera is used to position another camera, situated in the base of the gripper, in such a way that it faces the object to be grasped. Once positioned, the gripper camera takes over for precise control of the arm during the rest of the grasping cycle.

## Features

The four-fingered gripper automatically reconfigures itself when approaching an object to give the best chance of a successful grasp. The hand camera observes the shape of an object to be manipulated and sends instructions to motors at the base of each finger. These motors are not used for grasping, but instead reposition the fingers around the base of the gripper to match the shape of the object, ensuring optimal contact and an equal distribution of force over the object to be manipulated.

In addition to GINA's autonomous capabilities, the robot can also be controlled via a remote computer. Should GINA find itself unable to complete a task, a user can take control and help the robot achieve its current goal.

### Highly Competitive Price

The cost of the prototype for GINA was £6000. This is one third the cost of the next cheapest commercially available solution, and 2.5% the cost of the market leader. Mass production can further reduce the cost per unit to £4000. GINA can be sold at a retail price of £15,000, which when factored in with other production costs leads to a profit of £6000 per unit sold.

### Test success

Two particularly successful elements of GINA are the gripper and the navigational system. In one test scenario, a success rate of 97% was achieved when the gripper was tasked with picking up a variety of objects with a size range of 4cm to 15cm. When these tests were repeated with the objects arranged in intentionally awkward orientations, the success rate fell to 70%. However, under normal operating conditions GINA will observe the shape of an object and position itself accordingly, making these awkward orientations unlikely to arise in real world situations.

GINA is able to navigate to within 7cm of an object. By reducing the distance the arm has to travel during grasping, the time taken to complete a fetching cycle was reduced by 40%. The robot can achieve speeds of 0.7m/s when navigating autonomously, which increases to 1.2m/s when manually controlled.

### Support

Our dedicated support team of highly skilled engineers will provide any setup or demonstration as requested by the customer. This service includes two days tuition on how to use GINA. A full range of spare parts are available on request.

In addition to support from us, our customers can take full advantage of the extensive and rapidly expanding ROS community of researchers, developers and hobbyists.

This robot has been developed in collaboration with Plymouth University. The developers worked hand in hand with leading experts in the fields of variable stiffness robotics, software for autonomous systems, and computer vision. This wealth of expertise has influenced all aspects of GINA's design, leading to a truly universal solution for personal assistance robots.

GINA is an open platform which can meet a wide variety of needs. Affordable, robust, safe and adaptable, customers will find that GINA can increase productivity and financial efficiency in almost all working environments.