

Design and Implementation of a Multi-sensor Mobile Platform

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I. ABSTRACT

In the last several years, mobile manipulators have been increasingly utilized and developed from a theoretical viewpoint as well as for practical applications in space, underwater, construction, and service environments. Our mobile manipulator RISCbot, is comprised of a manipulator arm mounted on a motorized mobile base wheelchair. The work presented in this chapter explores the use of multi-sensor for combining measurements from ultrasonic and infrared sensors for mobile manipulator navigation and obstacle avoidance. Furthermore, we deal with the problem of controlling of a mobile manipulator via sensor fusion in order to reduce the uncertainty in localization and obstacle avoidance. Sensor fusion is used by combining and integrating data gathered from sensory information provided by ultrasonic and infrared sensors to enhance the quality of information provided to RISCbot.

II. INTRODUCTION

A mobile manipulator is a manipulator mounted on a mobile platform with no support from the ground. A mobile manipulator offers a dual advantage of mobility offered by the platform and dexterity offered by the manipulator. For instance, the mobile platform extends the workspace of the manipulator. We are developing and constructing a mobile manipulation platform called RISCbot. The prototype of the RISCbot is shown in figure 1.

Sensor fusion has been an active area of research in the field of computer vision and mobile robotics. Sensor fusion can be defined as a method for conveniently combining and integrating data derived from sensory information provided by various and disparate sensors, in order to obtain the best estimate for a dynamic system's states and produce a more reliable description of the environment than any sensor individually. Sensor fusion algorithms are useful in low-cost mobile robot applications, where acceptable performance and reliability is desired, given a limited set of inexpensive sensors such as ultrasonic and infrared sensors. Depending on the modalities of the sensors, sensor fusion can be categorized into two classes (as described in [1]), sensor fusion using complementary sensors and sensor fusion using competing sensors. Complementary sensors consist of sensors with different modalities, such as a combination of a laser sensor and a digital camera. In contrast to complementary sensors,

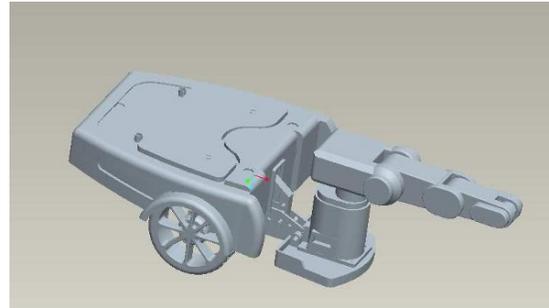


Fig. 1. A prototype of the RISCbot.

competing sensors are composed of sensors suit which have the same modality, such as two digital cameras which provide photographic images of the same building from two different viewpoints.

Sensor fusion has some critical problems such as the synchronization of sensors. Different sensors have different resolutions and frame rates so the sensors need to be synchronized before their results can be merged by fusing the data from multiple sensors and presenting the result in a way that enables autonomous robot to perceive the current situation quickly. Sensor fusion is commonly used to reduce uncertainty in localization, obstacle avoidance, and map building. In this paper, we discuss sensor fusion for navigation and obstacle avoidance, describe our mobile manipulation platform, and present our results.

III. DESIGN SPECIFICATIONS

A. Data Acquisition

In our project, we used a data acquisition module called *Data Translation DT9814* which is a low cost USB data acquisition module that offers 24 analog input channels, 2 analog outputs channels, and one 32-bit counter timer to accommodate most applications. Furthermore, it provides a resolution of 12 bits for both the analog input and analog output subsystems, and input throughput up to 50 kHz. The analog signal range is from -10 Volt to 10 Volt. This module also provides the following features: (as described in [14])

- One 32-bit counter/timer channel.
- Internal and external A/D clock sources.

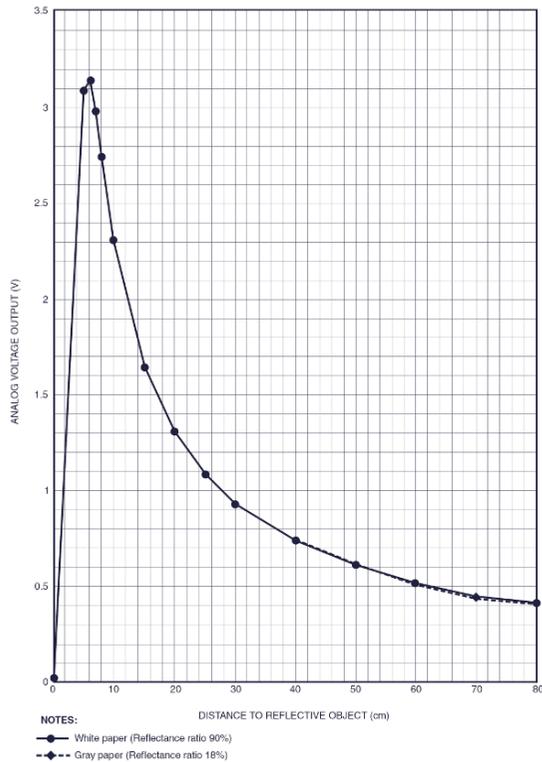


Fig. 3. Analog output vs. distance to reflective object (As described in [7]).

sensor - Sharp GP20A21YK. As described in [7], this sensor has an analog output that varies from 3.1V at 10 cm to 0.4V at 80 cm as shown in figure 3. The analog sensor simply returns a voltage level in relation to the measured distance. As shown in figure 3, it is clear that the sensor does not return a value linear or proportional to the actual distance because the intensity of the infrared signal is inversely proportional to the square of the distance. Therefore, the infrared signal falls rapidly as the distance increases.

C. Jazzy 1122 Wheelchair

As described in [3], the jazzy wheelchair has two main assemblies: the seat and the power base as described in figure 4. Typically, the seating assembly includes the armrests, seatback, and controller. The power base assembly includes two drive wheels, two anti-tip wheels, two rear caster wheels, and a body shroud. In our project, we remove the armrests and seatback as shown in figure 5.

The specifications of the Jazzy 1122 wheelchair are described in table 1. The jazzy 1122 wheelchair also provides the following features: (as described in [3])

- 1) Active-Trac Suspension: The wheelchair is equipped with Active-Trac Suspension (ATS) to be able to traverse different types of terrain and obstacles while maintaining

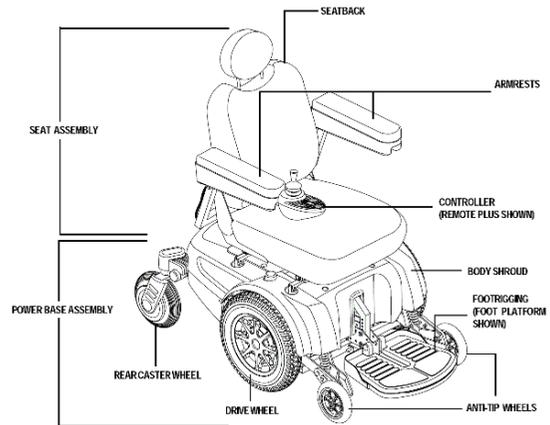


Fig. 4. The Jazzy 1122 (As described in [3]).



Fig. 5. The RISCbot base.

smooth operation. With ATS, the front anti-tip wheels work in conjunction with the motor suspension to maneuver over obstacles. As the front anti-tip wheels come in contact with an obstacle, the front anti-tip wheel assembly is drawn upward. At the same time, the motors are forced downward. This allows the motors to push the wheelchair over an obstacle.

- 2) Rear Suspension: The wheelchair is equipped with a rear suspension system to work in conjunction with the ATS and is designed to maintain a smooth ride when driving over rough terrain and up and down curbs.

IV. NAVIGATION AND OBSTACLE AVOIDANCE

A prerequisite task for the autonomous mobile robot is the ability to detect and avoid obstacles given real-time sensor readings. Obstacle avoidance is a crucial issue in robot's navigation. Given partial knowledge about its environment and a goal position or a series of positions, navigation encompasses

TABLE I
SPECIFICATIONS OF THE JAZZY 1122 WHEELCHAIR [3].

Suspension:	ATS and rear suspension
Drive Wheels:	14 in., pneumatic, center-mounted
Caster Wheels:	8 in., solid, rear-articulating
Anti-tip Wheels:	6 in., solid, front-mounted
Maximum Speed:	Up to 6 mph
Brakes:	Intelligent Braking, electronic regenerative, disc park brake
Drivetrain:	Two motor, mid-wheel
Batteries:	Two 12-volt, Group 24 batteries
Component Weights:	Base: 129 lbs. Seat: 40 lbs. (standard seat). Batteries: 53.5 lbs.

the ability of the robot to act based on its knowledge and sensor values so as to reach its goal positions as efficiently and as reliably as possible. The obstacle may be defined as any object that appears along the mobile robot's. The techniques used in the detection of obstacles may vary according to the nature of the obstacle. The resulting robot motion is a function of both the robot's sensor readings and its goal position. The obstacle avoidance application focus on changing the robot's trajectory as informed by sensors during robot motion. The obstacle avoidance algorithms that are commonly used can be summarized as the following: (as described in [4])

- **The bug algorithm:** The basic idea is to follow the easiest common sense approach of moving directly towards the goal, unless an obstacle is found. If an obstacle is found, the obstacle is contoured until motion to goal is again possible. In [4], two approaches are described; Bug1 and Bug2. In Bug1 Algorithm, the robot fully circles the object first, then departs from the point with the shortest distance toward the goal. This approach is very inefficient but it guarantees that the robot will reach any reachable goal. In Bug2, the robot will follow the object's contour but it will depart immediately when it is able to move directly toward the goal.
- **Tangent Bug:** As described in [8], tangent bug algorithm is a variation of the bug algorithm. The robot can move more efficiently toward the goal also go along shortcuts when contouring obstacles and switch back to goal seeking earlier. In many simple environments, tangent bug approaches globally optimal paths.
- **Artificial Potential Fields:** The artificial potential fields (APF) is proposed by Khatib in [9]. The robot is considered as a moving particle in a potential field generated by the goal and by the obstacles that are presented in the environment. In APF method, the robot immersed in the potential field is subject to the action of a force that drives it to the goal. This approach uses repulsive potential fields around the obstacles (and forbidden regions) to force the robot away and an attractive potential field around goal to attract the robot. A potential field can be viewed as an energy field and so its gradient, at each point, is a force. Consequently, the robot experiences a generalized force equal to the negative of the total

potential gradient. This force drives the robot towards its goal while keeping it away from the obstacles (it is the action of a repulsive force that is the gradient of the repulsive potential generated by the obstacles). However, There is a major problem with the APF approach because the local minima can trap the robot before reaching its goal. One of the powerful techniques for avoidance of local minima is the simulated annealing approach which has been applied to local and global path planning as described in [13]

- **Vector Field Histogram:** Borenstein and Koren developed the vector field histogram (VFH) [10]. Borenstein and Ulrich extended the VFH algorithm to yield VFH* [11] and VFH⁺ [12]. As described in [4], the instantaneous behavior of the mobile robot in the bug algorithms is a function of only its most recent sensor readings which may lead to undesirable problems in cases where the robot's instantaneous sensor readings do not provide enough information for robust obstacle avoidance. The VFH algorithm is computationally efficient, very robust and insensitive to misreading. The VFH algorithm allows continuous and fast motion of the mobile robot without stopping for obstacles.

The VFH algorithm [10] permits the detection of unknown obstacles and avoids collisions while simultaneously steering the mobile robot toward the target. This algorithm uses a two-dimensional cartesian histogram grid to represent a local map of the environment around the robot which is updated continuously with the sampled data from range sensors. The VFH algorithm generates a polar histogram to represent the relation between the angle at which the obstacle was found and the probability that there really is an obstacle in that direction based on the occupancy grids cell values. From this histogram, a steering direction is calculated. The polar histogram is the most significant distinction between the virtual force field (VFF) and the VFH method as it allows a spatial interpretation (called polar obstacle density) of the robot's instantaneous environment. In the VFH⁺ algorithm [12], the basic robot kinematics limitations are used to compute the robot possible trajectories using arcs or straight lines. The VFH* algorithm [11] proposes look-ahead verification. The method investigates each possible direction provided by the VFH⁺ approach, checking their consequences concerning the robot future positions. The experimental results [11] shows that this look-ahead verification can successfully deal with problematic situations that the original VFH and VFH⁺ can not handle and the resulting trajectory is fast and smooth.

Given a map and a goal location, path planning involves identifying a trajectory that will bring the robot from the initial location to reach the goal location. During execution, the robot must react to unforeseen events such as the obstacles in such a way to still reach the goal. For some purposes, such as obstacle avoidance, constrained workspace, and time-

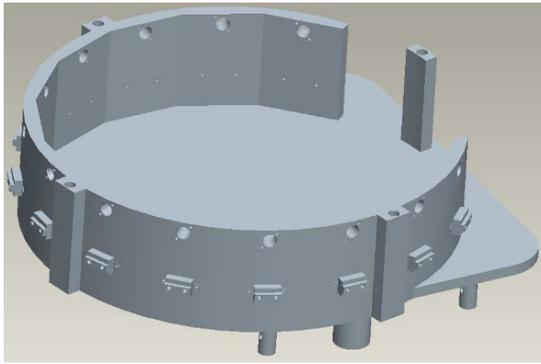


Fig. 7. A closeup view of the sonar and infrared sensors array.

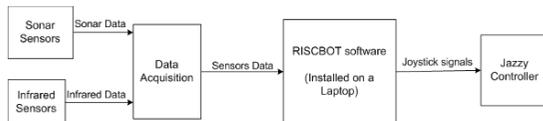


Fig. 8. The components of the RISCbot system.

are used together in a complementary fashion, where the advantages of one compensate for the disadvantages of the other.

As shown in figure 8, the RISCbot software which is written in Visual C# and runs on a laptop reads the values of all sensors at a rate of 10 HZ gathered in the data acquisition. The RISCbot software maps the sensory inputs to a series of actions which is used to achieve the required task. Based on the used algorithm, the RISCbot software responds to the sensor data by generating stream of voltages corresponding to the joystick signals to the wheelchair controller. These voltages control the direction and the speed of the wheelchair to cause the RISCbot to turn in the desired direction.

The experimental result indicates that the RISCbot can detect any unknown obstacle and avoid collisions while simultaneously steering from the initial position toward the target position.

VI. CONCLUSIONS AND FUTURE WORK

In this paper, the mobile manipulation platform RISCbot has been presented. The RISCbot platform differs from any other robotic platform because its mobile platform is a wheelchair base. Thus, the RISCbot has the advantages of the wheelchair. Furthermore, the RISCbot consists of a comprehensive sensor suite, and significant end-effector capabilities for manipulation. In addition, we have used infrared and sonar sensors to monitor if any type of obstruction is in the path of the robot. This research aspires to find online real-time collision-free trajectories for mobile manipulation platforms in an unknown static or dynamic environment containing some obstacles, between a start and a goal configurations.

Path planning for mobile robots is one of the key issues in robotics research that helps a mobile robot find a collision-free path from the beginning to the target position in the presence of obstacles. Furthermore, it deals with the uncertainties in sensor data.

The objective for this project is to implement an autonomous mobile manipulator via Sensor Fusion. There are great benefits in using an autonomous mobile manipulator in dangerous, inaccessible and toxic environments.

In our anticipated future work, there will be an ongoing effort for the development of multiple mobile manipulation systems and platforms which interact with each other to perform more complex tasks exhibiting intelligent behaviors utilizing the proposed manipulability measure.

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