A Review of Literature Related to Robotic Security System Design

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List of Acronyms and Abbreviations

WIFI=Wireless Fidelity
4G= Fourth Generation
RTAB-Map=Real-Time Appearance Based Mapping
PID=Proportional-Integral-Derivative
IMU=Interial Measurement Unit
IR=Infrared
CPP=Coverage Path Planning

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1.0 Literary References

1.1 Overall system

*1.1.1 Mobile Security Robot **[1]***

- This patent describes a mobile robot design that is intended to maintain indoor security.
- The robot is able to receive a map of a patrolling environment and is able to maneuver through this environment based on the information gathered from the map.
- The robot records data of a scene with an imaging sensor. If a person is detected within range of its imaging sensor, then the robot tracks the person by maintaining the imaging sensor's focus on the person. Below is an image outlining the basic function of the security robot.

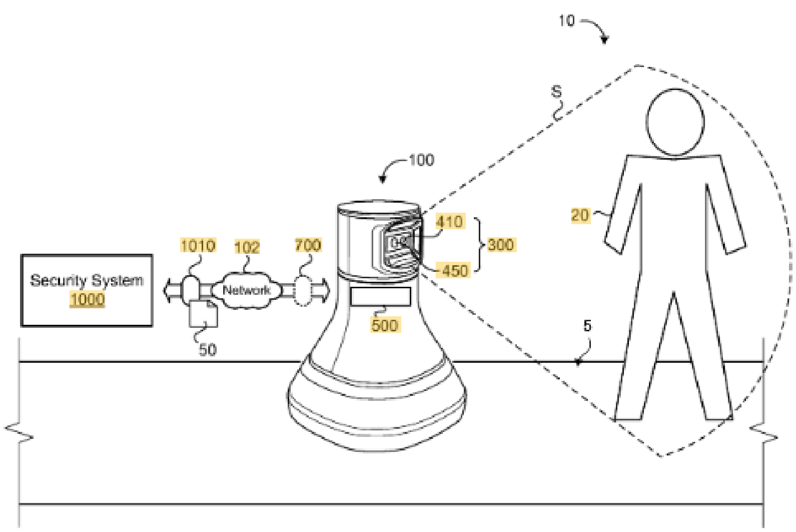

Figure 1.1: Robotic Security System Basic Functions [1]

- *Figure 1.1* shows the basic functions of the robot described in this patent. The robot is shown detecting a human figure and communicating this information with a security system wirelessly.

*1.1.2 A Kind of Multi-Functional Mobile Security Robot **[2]***

- This patent describes a mobile security robot that is intended to maintain public security.
- The robot uses laser radar and depth cameras to sample data related to the terrain it is traversing.
- Using image processing, the robot can also recognize humans and their faces along with identification card information.
- This robot also uses WIFI or 4G wireless communication to communicate with a central control terminal.

*1.1.3 The Development of Intelligent Home Security Robot **[3]***

- This system notifies security threats through internet communication.
- This article outlines a general system architecture which may be useful for starting a robotic design.

- This article outlines a method of remotely controlling the robot and the systems used to do so.

1.1.4 RoboGuard, a Teleoperated Mobile Security Robot ***[4]***

- This article outlines basic software and hardware architectures used to design a computing system for a mobile robot.
- This article also describes tele-operational techniques used to operate a mobile robot.

1.1.5 Safety for Mobile Robotic Systems: A Systematic Mapping Study from a Software Engineering Perspective ***[5]***

- This article outlines concepts related to mobile robotics safety and integration into everyday environments from a software engineering perspective.
- Design architecture and system algorithms related to robotic system operation in unknown environments and cooperation between robotic systems and humans are described in this document.

1.2 Physical mobility

1.2.1 Erect Wheel-Legged Stair Climbing Robot for Indoor Service Applications ***[6]***

- This article presents a triangular wheel configuration to drive up stairs using three wheels driven by a single motor.
- The design presented in the article uses a system of gears and belts to drive all three wheels at once. The operation of this system is shown in *Figure 1.2*.

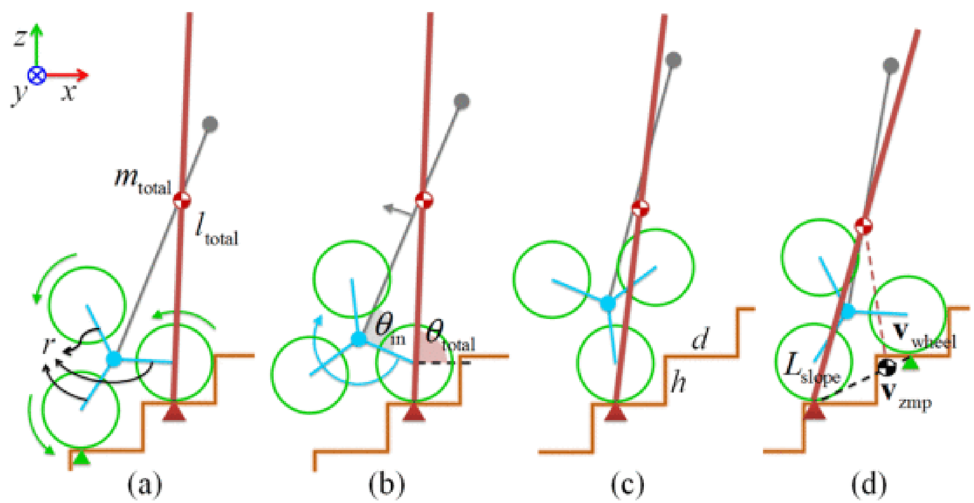

Figure 1.2: Stair Climbing Using a Three Wheeled configuration [6]

- The system presented uses the torque generated by the center shaft, along with the direct drive on the wheels to move up stairs.

1.2.2 Design and Development of Adjustable Stair Climbing Robot ***[7]***

- This article presents a fixed-chassis, four-wheel configuration capable of climbing stairs.
- The robot presented uses a secondary wheel on the front of the chassis to grab the front of a stair to lift the robot's front wheels onto the top of the stair.

1.3 Path Planning

*1.3.1 A Survey on Coverage Path Planning for Robotics **[8]***

- This article is a survey on coverage path planning algorithms (CPP). It describes many different CPP algorithms in detail.
- The article specifically mentions “Watchman” path planning. Watchman algorithms create a path that will cover the entire workspace with a sensor.
- It defines path planning without knowing the environment as “online" or “sensor-based” coverage algorithms. Online path planning algorithms create a path through an unknown environment without information on obstacles in the environment and responds to those obstacles in real-time.
- The authors describe various online algorithms assuming finite (tactile or ultrasonic) or infinite (camera) sensor ranges.

*1.3.2 Robotic Online Path Planning on Point Cloud **[9]***

- This article describes intelligent path-planning in an online environment using point-cloud sensory information.
- The author provides insight into computational algorithms and potential pitfalls with point-cloud sensor errors.

*1.3.3 Path Planning and Navigation of Mobile Robots in Unknown Environments **[10]***

- This article presents a simple online path-planning algorithm using a grid-based network tree method.
- The authors assumed a very small sensor range versus the environment size, such as tactile sensing of obstacles.
- The algorithm presented used a brute force method which takes a longer period of time to execute, but is less resource-intensive.

1.4 Control Systems

*1.4.1 Autonomous Indoor Navigation of Low-Cost Quadcopters **[11]***

- This article explores using an IMU as a part of a control system atop motor feedback in a PID to follow a path in an indoor space.
- The authors designed their system around a Parrot quadcopter, but their algorithm can be applied to wheeled robots.
- The authors used Simulink because the system runs in real-time to apply the control loop.

*1.4.2 Indoor Localization for Skid-Steering Mobile Robot by Fusing Encoder, Gyroscope, and Magnetometer **[12]***

- This article describes a method of sensor fusion and control laws for a tracked robot to perform indoor dead-reckoning navigation using gyroscopes, wheel encoders, and a magnetometer.
- The article includes detailed equations and process diagrams for direct implementation of its algorithm.

1.5 Mapping and Navigation

*1.5.1 Memory Management for Real-Time Appearance-Based Loop Closure Detection **[13]***

- This article describes "loop closure." Loop closure is a method of visual localization where all previous images are compared to a current image to find if a robot has returned to a previous location.
- RTAB-Map uses a modified form where only a subset of previous images are analyzed.
- If a match is found, other images that are spatially and temporarily close to the match are then analyzed to refine the match.
- A subset of images are chosen by using images that already have a relatively higher number of matches, as they are considered more likely to have another match.

*1.5.2 An Hierarchical Approach to Grid-Based and Topological Maps Integration for Autonomous Indoor Navigation **[14]***

- This article describes using a sonar-type sensor and fusing metric and topological mapping techniques to create a coherent map of a large indoor space.
- The algorithm uses a grid-based method to navigate its environment. It fuses odometry and compass sensory information with the map being generated in real-time.

*1.5.3 A Bioinspired Neural Network for Real-Time Concurrent Map Building and Complete Coverage Robot Navigation in Unknown Environments **[15]***

- The algorithm proposed utilizes neural networks to plan a path while mapping unknown environments.
- The algorithm discretizes environments into triangular shapes.
- The article displays both mathematical and geometric representations of mapping algorithms.

*1.5.4 Secondary Processor Management Allowing Deep Sleep of Primary Processor **[16]***

- This article describes how secondary processing units are configured to determine if active state operations are pending.
- Secondary processing units determine if there is a need to power up the host processing unit for execution of active state operations.
- Secondary processing units can track various system parameters such as battery power levels and wireless communications.

*1.5.5 An Optimized Segmentation Method for a 2D Laser-Scanner Applied to Mobile Robot Navigation **[17]***

- This article describes an environment mapping and navigation technique using a two-dimensional laser scanner.
- This article presents a theoretical algorithm with very simple mathematical run-time computations.
- The design presented in this article utilizes a spinning laser as a sensor, but the proposed algorithm can be extended to single-point distance sensors, such as IR or ultrasonic.

1.6 Sensors and Their Implementation

*1.6.1 Active People Recognition Using Thermal and Grey Images on a Mobile Security Robot **[18]***

- The system described in this article makes use of thermal imaging to detect human figures.
- This article describes recognition algorithms and related mathematics used to implement human recognition. This may be useful to refer to when designing image recognition algorithms.

*1.6.2 System for Real–Time Monitoring with Backward Error Correction **[19]***

- This article describes an efficient error correction algorithm for video transmission.
- Instead of acknowledging every single received media packet the algorithm only keeps track of what has been received.
- As media packets contain information that describe how to stitch them back into a single media product, missing segments can be identified without communicating with the source.
- Once a source has finished transmitting data, a receiver then sends a message to the source detailing which packets it needs to re-send.

*1.6.3 Multi-Sensor Motion Detection **[20]***

- The article describes methods of performing motion detection using multiple sensors.
- The algorithm uses a combination of radar, passive infrared, and a camera to identify motion.

*1.6.4 Orientation Analysis through a Gyroscope Sensor for Indoor Navigation Systems **[21]***

- This article compares using compass data vs gyroscope IMU (Inertial Measurement Unit) to measure angular velocity.
- The article concluded that an IMU is much more accurate than a compass when used to measure angular velocity.

1.7 Miscellaneous Content Related to Optional Design Goals

*1.7.1 Autonomous Door Opening and Plugging in With a Personal Robot **[22]***

- This article describes a robotic system capable of navigating an office environment.
- This system can recognize and open doors which is an optional design goal of Heimdallr System's robot.
- This article also outlines the algorithms and sensors used to detect door handles, analyze environments, and find wall outlets to charge itself.

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