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1. Kamil ŽIDEK, 2. Jozef SVETLÍK, 3. Eva RIGASOVÁ

ENVIRONMENT MAPPING AND LOCALIZATION IN MOBILE ROBOTICS

1, 3. TECHNICAL UNIVERSITY OF KOŠICE, FACULTY OF MANUFACTURING TECHNOLOGIES WITH A SEAT IN PREŠOV, PREŠOV, SLOVAKIA
2. TECHNICAL UNIVERSITY OF KOŠICE, FACULTY OF MECHANICAL ENGINEERING, KOŠICE, SLOVAKIA

ABSTRACT: *The aim of this article is basic overview of actual localization and mapping technics and introduction solution for scanning an unknown environment by ultrasonic sensors and localize mobile device by GPS system. The first step was localization of device by GPS system and communication protocol for the ultrasonic sensor to interact with PC. Created algorithm for environment scanning was implemented in the C# development environment. This application creates the graphical output of unfamiliar environment for recognizing the obstacles in front of mobile device. Next algorithm compares the distance between obstacles and dimension of robot to find ideal path. Algorithm output is safe angle for device for movements and proposed navigation path.*
KEYWORDS: *Environment mapping, mobile robot, ultrasonic sensors, SLAM*

INTRODUCTION

Currently, the use of sensors to scan the unfamiliar environment and recognize obstacles in autonomous mobile devices is often implemented. This system can detect each object nearby mobile devices and create the environment map. Chosen recognition method depends in the type of sensors and control software. This technology can be used in various industries, such as in mapping an unknown or partially unfamiliar environment and also to control the shape of parts, respectively of unknown objects in the automotive industry as parking sensors. The first chapter deals with the analysis of existing systems for scanning environment mainly about SLAM algorithms. It describes existing algorithms to scan an unknown environment and their principles of operation. The next chapter deals with our solution with ultrasonic sensor and GPS system to scan the unfamiliar environment. The third chapter is devoted to the description of algorithms to scan the environment. There is a procedure as the algorithm works and scheme of developed algorithm for scanning an unknown environment. There is also implementation of scanning an unknown environment to mobile devices. The conclusion discusses about the possibility of further development of the proposed solution.

MAPPING AND LOCALIZATION THEORY

An important task for local navigation of mobile devices is creating maps in 2D. This map helps to get oriented in space and on that basis it is possible to create an autonomous movement from one position to another without any conflict with environment. To create accurate maps we must know the exact position of the mobile device. There are many available technologies for locating robots, including GPS, active / passive beacons, velocity (Dead Reckoning), accelerometers, etc. The key to successful localization is to use inexpensive and widely available sensors. At present time, there are popular algorithms developed especially for simultaneous localization and mapping [2].

SIMULTANEOUS LOCALIZATION AND MAPPING (SLAM)

SLAM is used by self-controlled robots and vehicles to create maps in an unfamiliar environment or to update maps in a familiar environment (previous known map) and also to record their actual position. Mapping is the problem of integrating the information gathered from the robot's sensors into a given representation. It can be described by the question "What does the world look like?" Central aspects in mapping are the representation of the environment and the interpretation of sensor data. In contrast to this, localization is the problem of estimating the pose of the robot relative to a map. In other words, the robot has to answer the question, "Where am I?" Typically, one distinguishes between pose tracking, where the initial pose of the vehicle is known, and global localization, in which no priority knowledge about the starting position is given. Simultaneous localization and mapping (SLAM) is therefore defined as the problem of building a map while at the same time localizing the robot within that map. In practice, these two problems cannot be solved independently of each other. Before a robot can answer the question of what the environment looks like given a set of observations, it needs to know from which locations these observations have been made. At the same time, it is hard to estimate the current position of a vehicle without a map. Therefore, SLAM is often referred to as a chicken and egg problem: A good map is needed for localization while accurate position estimation is needed to build a map [1].

Most solutions suppose that initial position of the robot is known and only it is a partial knowledge of the area. SLAM is defined as an example of model building leading to a new map or improvement of existing maps at the same time positioning the robot on the map. In practice this means that the answers to two basic questions can be answered independently.

Before the robot can contribute to answering these questions must know:

- *Its own kinematics,*
- *How to separate the collected data from important information.*

Exact (The) estimation of the robot location without a map or without actual direction is very difficult.

TECHNICAL PROBLEMS OF SLAM

SLAM is not served as a compact solution, but like a lot of concepts that contribute to the results. If the next repetition of the construction of maps is created from measured distance and direction with uncertainty (limited accuracy-driven sensors and additional ambient noise), then any properties added to the map will contain corresponding errors. As they grow over time and movement, errors will accumulates and cumulatively distort the map, the robot's lost ability to determine sufficient accuracy in your current position and direction. There are different techniques to compensate these errors, such as recognizing parts of the map and connect two instances of the same part merged into one. Some statistical methods used in SLAM includes Kalman filters, particle filters (also known as Monte Carlo method).

MAPPING, SENSING &Localization

SLAM of mobile robot community refers to the process of creating a geometrically consistent environment map. Topological maps are a method of representation of the environment that captures the environment topology rather than a precise geometric map. SLAM is tailored to available resources, and therefore is not for perfection, but to labor flexibility. Published approaches are used in aerial vehicles, uncontrolled by human, autonomous underwater devices, equipment moving along the surface of planets, the newly developing domestic robots, and even inside the human body. It is generally considered to resolve the issue of SLAM as a significant achievement in the field of robotics research in recent decades. Many problems of data association and computational complexity are still waiting to resolve.

SLAM is usually using several different types of sensors. Statistical independence is a mandatory requirement to deal with metric distortion and disorder in the measurements. SLAM is using usually optical sensors that can be one dimensional or 2D laser or 2D, 3D sonar sensors and one or more 2D cameras. Current methods are applied in wireless range. A special kind of SLAM for pedestrians is used as the main sensor inertia measurement unit mounted in the shoe. In this relies on the fact that pedestrians are able to avoid the walls. This procedure is called FootSLAM and can be used in for automatic construction of road building plans, which can then be further used as an indoor positioning system.

The results of the scan combines algorithms for localization by geometric propositions, any reading must contain at least one iteration (n + 1) that determining equations for the n-dimensional problem. Moreover, it is still needed some additional information about orientation and absolute or relative coordinate system with the rotation and mirroring.

MODELING

Mapping can create 2D or 3D model of environment and 2D environment projection. Kinematics of the robot is included as a part of the model and it is used to improve estimation location and eliminates own noise and noise from environment. Dynamic Model of data from various sensors partially corrects errors in the model and finally improves the location and direction of the robot as a cluster probability in virtual map. Mapping is the ultimate representation of this model; the map is either an abstract concept for a model [3].

SOME EXAMPLES OF ENVIRONMENT MAPPING ALGORITHM

Part below some of SLAM algorithms provides as open algorithms by web pages in [1].

2D ISLSJF – (Filter for joining an incompletes sub maps)

The algorithm combines maps using a filter for scattered information and squares optimization. By entering ISLSJF the sequence of local maps and the output is a global map. Simulation is acquired in Victory Park and corrected data in Fig. 1 left demonstrates the algorithm.

ISLSJF is a new algorithm which combines maps and charts for creating large scale. The algorithm is based on recently developed SLSJF and multiple uses repetition to improve estimation. The input is a sequence of local maps and output of the algorithm is a global map containing all the positions and all movements of the robot as well as the initial and final position of the robot. The amount of simulations and experimental data is generated with MATLAB - source. The user can simply use this code to merge their own local maps.

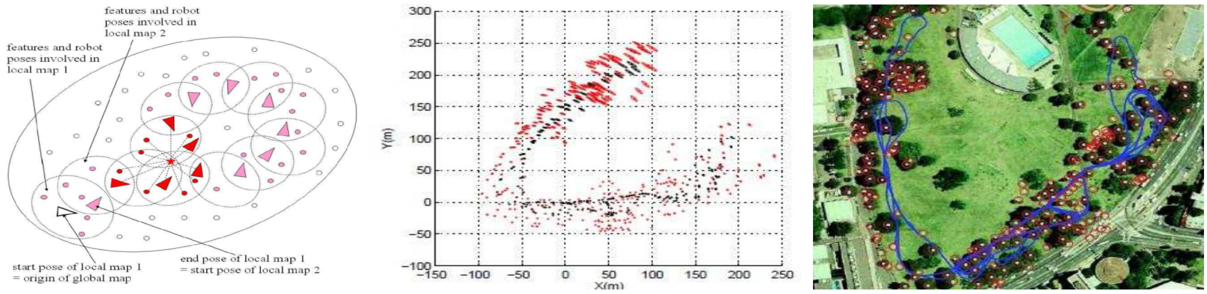

Fig. 1 2D ISLSJF filter for map connection, EKF SLAM

CAS Robot Navigation Toolbox

This software created by Matlab - controls for robot localization and mapping, it is licensed GNU GPL and used for research and education, and regardless of type or kind of sensor data. It is able to import many data files from any sensor. It allows to connect or disconnect feature extraction, model counting passed miles, the strategy of the association data, etc., and attach or detach or locational SLAM approach. It also contains many useful tools and features [1].

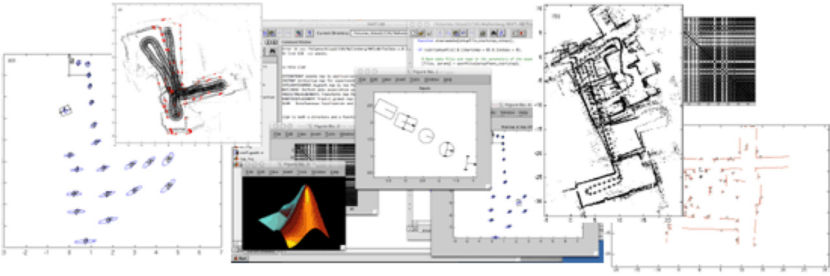

Fig. 2 CAS Robot Navigation Toolbox

GPS Localization and Ultrasonic Environment Mapping

There is described principle of combination global navigation by GPS for localization and environment mapping by local sensor object detection. The complex navigation algorithm consists of combination of four separate parts (technologies, theories) combined to one subject:

1. GPS position data acquiring and transformation.

2. Adequate raster satellite maps download.

3. Local sensor environment mapping.

4. Path search algorithm.

Simplified flowchart is shown in the Fig. 3 left. Loop of the algorithm for navigation is shown in the Fig. 3 right.

There is briefly described navigation algorithm in basic steps. First step is download actual Satellite maps according acquired actual GPS data for start position on maps and selecting manually end position. We must next transfer GPS data to pixels and create vector from start to end point. Next step is measuring distance and create checkpoints for long distances to reduce computing time for breath first algorithm. There is executed scanning by local sensors to estimate position of obstacles in the map. Then there is started breath first algorithm to find ideal plan path. Last step of algorithm is creating optimized navigation path and segmentation. Example task from GPS and path planning is shown in Fig. 4.

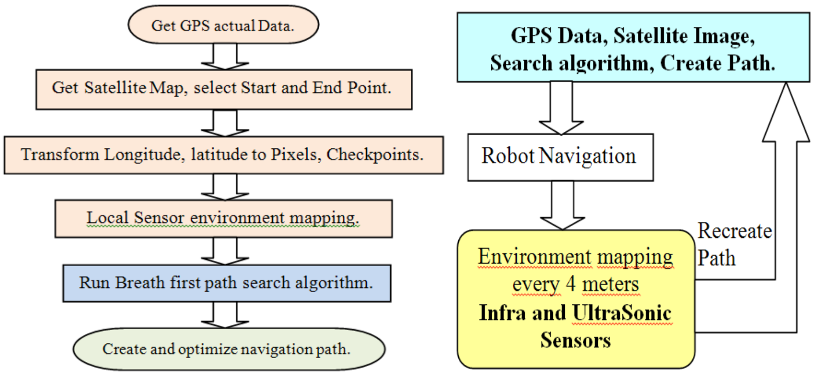

Fig. 3 Algorithm principle, extended loop navigation algorithm

Fig. 4 Example of localization path created by GPS, path planning algorithm

GLOBAL LOCALIZATION & ENVIRONMENT MAPPING

Localization of the mobile robot is realized through the acquiring of the position of the robot based on GPS sensor. This sensor sends data about position in the NMEA protocol. GPS sends several data strings with necessary information about actual position. The introduced solution processes string

RMC, which is providing basic data (position, speed, time). Acquired the position of longitude and latitude is transformed to the Cartesian coordinating system and shown on maps of environments. Planned (selected) trajectory of the mobile robot in the Technical University of Kosice is shown in Fig 3. Global navigation working on comparison real robot angle acquired from GPS and required angle counted from checkpoint on planned trajectory.

There is implemented infra sensor in front and back of mobile robot to detect near obstacles. For environment mapping there is implemented ultrasonic sensor with y axis rotation. There is possible to turn in 120° angle range by Servo. We can measure distance from 30 mm to 4 m. Robot must stop for environment mapping. Infrared and ultrasonic Sensors implementation to robot is showed in Fig. 5 [4].

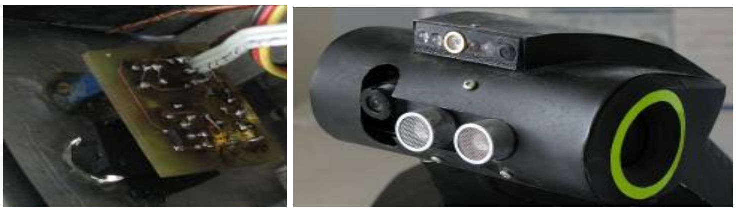

Fig. 5 Infra sensor in robot body, ultrasonic sensor in monitoring head

The output of this sensor consists of pulses with duration of the logical 1 from 0.1 to 25 ms, by which we know to acquire what distance of the detected object. The application calculates an ideal angle of movement between two obstacles. Principle of scanning is shown the Fig. 6.

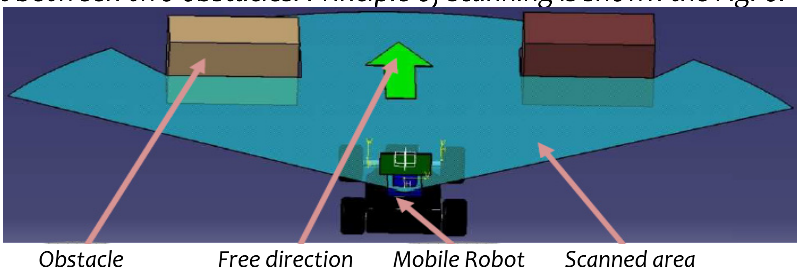

Fig. 6 Scheme of unknown environment scanning

Algorithm for local navigation by infrared sensors was tested in MobotSim application Fig. 7 right. Environment mapping by ultrasonic sensor is shown in the Fig. 7.

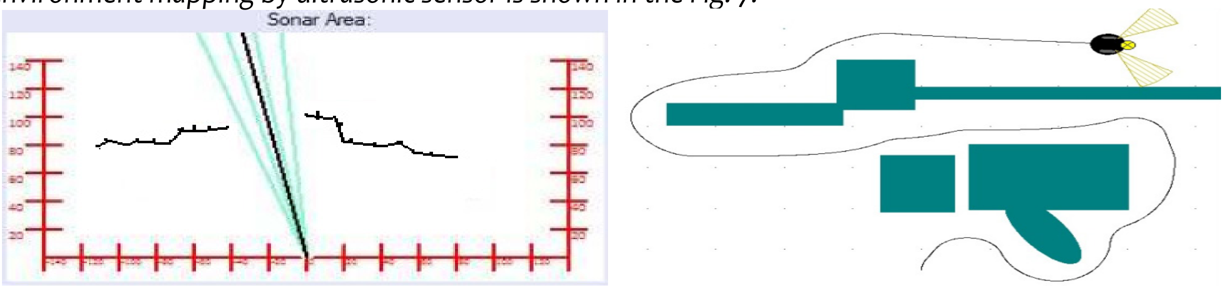

Fig. 7 Simple environment mapping by ultrasonic sensor, simulation of navigation MobotSim based on infra sensors

We can check the actual position on localization maps. There is a possibility to use mobile device navigation only with local sensors and path planner for short time if we have problem with GPS system during very bad weather conditions, when the signal is weak or not available [5].

CONCLUSIONS

The main task of this article was design of simple localization and mapping in unknown environment. There is used ultrasonic sensor for scanning and GPS for localization. The based on GPS and ultrasonic is cheap solution but not so precise like laser scanning. The article introduces hardware and software solution for ultrasonic scanning to 4 meters. Main disadvantage of the solution is that device must stop movements for scanning, it is not possible to scan environment during movements. The error is increasing with measuring distance. Error can be lowering by more measurements in row for long distances. Next works will be implementation of full 360° angle scanning with stepper motor instead of servo and lowering error with some statistical methods after set of measurements. *Contribution was created under grant project KEGA 047TUKE-4/2011.*

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