ABSTRACT

There is a high interest for indoor localization systems which works without specific infrastructure, since their installation and maintenance cost is minimal and they are available everywhere in shopping malls, public buildings or offices. Using such an indoor localization system we only need a smartphone with the appropriate application. In order the application be able to determine the user’s position it measures some location specific signals, like Wi-Fi, Bluetooth, Earth magnetic field strength and compares this measured value with premeasured field strength map of the building. This field strengths map needs to be created in advance and this is the only time-consuming operation using such an infrastructure less indoor localization system. The location specific field strings data needs to be measured with the appropriate spacing all along the future navigation routes. This measurement activity can be automatized using an appropriate robotic vehicle. The basic requirements and the development of such a robot is discussed in this article.

INTRODUCTION

The indoor positioning methods and algorithms are widely researched topic of nowadays. Since there is no standardized method exists for indoor position determination like GPS for the outdoor localization and since the GPS is usually not available in indoor environment due to the radio wave shielding of the buildings, another method needs to be developed. The indoor localization systems can be divided by into two main groups.

The first type of localization method is relying on some preinstalled infrastructure, like radio transmitters, beacons and some special receivers are required for the operation. One of the most popular infrastructure-based system is the Ultrawide Band Radio localization system [1] which provides very high accuracy (cm error range).

The other type of the indoor localization systems is using some existing location specific information to determine the user’s position. Usually these systems are relying on the sensors of a regular smartphone, since in this case only an appropriate application needs to be installed and no other hardware infrastructure is required. These methods have lower installation and maintenance cost, however usually their precision is lower as well. Usually they can provide location estimation in a meter range (~2...3 meters) which is enough for an average indoor localization system.

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FINGERPRINTING DATA COLLECTION

In order to use infrastructure less indoor localization system a preliminary data collection step is required [2]. In this step a location specific data must be measured which means the Wi-Fi, magnetic Bluetooth beacon field strength need to be measured along the navigational area of the building. The resolution of the measurement should be higher than the required accuracy, in practice every one square meter must contain at least one measurement data of each sensors. The radio wave used for this kind of indoor localization (2.4GHz band) is highly attenuated by the human body so it is advisable to measure all radio wave field strength in several directions and in the localization phase always use the direction which is less covered by the user’s body.

Concluding the requirements, the data collection system for indoor localization system must be able to measure fields strength in several direction at specific positions in meter range density while the location of the measurement must be determined by sub meter accuracy for the correct operation.

A robot designed for this purpose therefore must contain a precise indoor positioning system (obviously using other technique than fingerprinting) and must have the appropriate sensors Wi-Fi, Bluetooth and earth magnetic sensor. For the realistic measurement these sensors must be located at the height of average human waist in order to simulate the position of a mobile phone used for the actual localization.

The robot also must contain some collision avoidance sensor since many obstacles might appear in the operational environment.

THE FINGERPRINTING ROBOT

The figure 1 shows the fingerprinting robot.

![The fingerprinting robot](image-url)
The robot has four independently driven caterpillars which provides a certain level of climbing through barriers and also it gives the capability of turning in place for higher mobility. The chassis contains a LiPo battery as the general power source for the locomotion and the operation of the internal circuitry. The front of the chassis contains the ultrasonic distance sensors for obstacle avoidance and the camera for monitoring the operation of the robot. The top-front contains the LIDAR sensor with the connected processing circuits. The tail part of the robot has the pole made of non-ferrous material in order to not disturb the effect of the Earth magnetic field on the sensor. The sensors are located on the top of the sensor pole together with an interface circuit. This structure is similar to the [3] but it contains the sensor as well not just a platform for holding any sensor. The [4] introduces another concept where the sensors are closely mounted to the chassis, however it might significantly distort the Earth magnetic field especially because of the strong magnets are located in the DC motors.

The tail part of the chassis also contains some additional electronics, like motor driver, battery sensor for voltage and current measurement.

The lower facing side of all four corner of the chassis is equipped with an infrared distance sensor in order to measure the distance between the floor and chassis. If it is higher than the normal height of the chassis it means the robot is about to leave the floor and probably over a stair or other gap. In this case planned measurement route needs to be changed on order to avoid the damage of the robot because of falling off.

Fig. 2 System architecture

The figure 2 shows the overall structure of the onboard electronic. The sensors are located on the end of the pole together with a simple interface circuitry. The interface is responsible for the communication directly with the sensors using their
buses (I2C and UART) and transferring the data to the other module of the system using the USB connection.

The location reference sensor is built around a Lidar sensor. The data from the sensor goes to a Raspberry PI computer which has the floorplan and uses particle filter algorithm to determine the robot position on the given map. This module is also used for storing the fingerprinting data referenced to the building map.

The operation of the robot can be monitored by using a PC based ground-station software. For the monitoring purposes a camera is mounted to the front of the robot, the data stream from the camera is compressed by a software running on an Orange PI computer with the built-in Wi-Fi module All telemetry data is also relayed by this computer using the wireless network connection.

The motion of the robot is controlled by a microcontroller (STM32F4) based hardware. It directly connected to the motor drivers, the speed and direction of the motors on both side of the robot can be independently controlled. The motion control contains a 9 DOF inertial sensor for orientation determination and for directional controlling of the robot. This module is also responsible for the monitoring the battery status (voltage and current).

The collision avoidance sensors (ultrasonic distance and infrared floor level) are controlled by a microcontroller board built around a tiny AVR microcontroller and provides the information to the path planning Raspberry PI computer.

THE GROUND STATION SOFTWARE

The operation of the robot can be monitored by using a “ground station” software. The application can display the telemetry data, the camera video stream, the location of the robot on the building floorplan.
When the data collection is done the ground station software can download the measured fingerprint data from the robot.

The collected fingerprint data can be displayed in the data preparation application for the indoor localization system.

![Fig 4. Fingerprinting result](image)

Once the fingerprint is done and all required data is collected the resulting database can be downloaded to the mobile phone and the indoor localization system is ready to operate.

CONCLUSIONS

The robotic fingerprint collection system is capable of the collection of the required fingerprint data in good quality, resolution within very short time. However, some problems still need to be solved. It is not capable at the moment to use stairs since the caterpillars are too small for a regular size step. So, the data collection can be done only on one floor of the building and it can’t automatically advance to the next floor. The robot works well on large open spaces like corridors and halls. However, in an office environment where there are several obstacles existing, like chairs, desks the collision detection system resolution and coverage is not sufficient for the safe operation. The next development step would be adding machine vision for obstacle avoidance or even for the localization.

REFERENCES

