Indoor ultrasonic positioning system for mobile objects

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Abstract. At present, automation of many types of works is widely distributed. When solving the automation problem, it is often necessary to use methods for determining the position of individual parts of an industrial or other system, as well as controlling the moving elements of such a system. In the paper, one of the variants of solving such a problem is considered. The determination of the object coordinates is calculating from the computed distances to known points. There are several ways to implement this method. Authors offer a solution that provides real-time control of the mobile device, automatic location control and delivery of the moving part of the system to a specified point with high accuracy. The system provides scalability for solving the problem of positioning in various rooms.

1. Introduction

A positioning system or coordinate system is a system that can determine the object position relative to a known reference point [1].

There are global and local positioning systems. Global positioning systems can determine the position of an object anywhere in the world. However, the price for "globality" is relatively low positioning accuracy. It may be sufficient to determine the coordinates of an object moving over long distances, but it will not be sufficient to determine the movement of the object with greater accuracy. Many tasks require accuracy of a few centimeters. Another significant drawback of such systems is inoperable in the premises.

Local positioning systems positioning locally in a limited space [2, 3]. Such systems, with the right approach, "sacrifice" the advantage of globality for the accuracy and efficiency of navigation in individual rooms.

2. Description of the system modules

The proposed system is modular. There is four type of modules: transport, reception, main and control module. The first three of them are implemented on micro-controllers. Management and visualization module is working on a personal computer.

The transport module installed on a monitored and/or managed object. Its tasks include determining current coordinates and, if necessary, moving along the specified coordinates.

The receiving module must determine the ultrasonic signal time from the transport module and send this data to the main module.
The task of the main module is coordinate the other elements work and transfer data to the visualization and control module. It also receives transport module control signals from the above-mentioned module. More information on the structure and hardware solutions used is in [4, 5].

3. Aspect ratio

Radio modules used for data exchange in the system allow transmitting information in binary code. At the same time, both data (for example, distance measurements by receiving modules) and commands (for example, a request from a transport module to get its coordinates) must be transmit over the same channel. As a result, decided to develop command format that would meet the interaction requirements for the developed system. It is shown in figure 1.

![Figure 1. Format of the system command.](image)

The data field used for transmitting information (for example, the coordinate of the transport module or the results of distance measurement by reception modules), and has a size of 32 bits.

The command field specifies action the module needs to take or data this frame carries. The field is 4 bits long.

The flag field is 1 bit and allow distinguish the receiving module from the transport module by frame. This is necessary for the main module to know the role of a particular module.

Address fields of 5 bits each represent a way to address each specific module in the conditions that all modules are located in the same channel and receive all communications transmitted over the radio. Each module has its own unique address, which entered in the controller's memory at the program loading stage. The recipient address, consisting of five units, is broadcast, and all modules must receive and process this frame.

The placeholder (Fill) field does not carry any information and supplements the frame with bits up to their total number, which is a multiple of an integer number of bytes.

4. Control automaton

Programs for the reception, main and transport modules written with Mif finite state machines.

Transport module state machine (figure 2) is quite simple. When enabled, the transport module wait for initialization, and after receiving the initialization frame, responds to it and goes to the main state. Various modes are possible: ultrasound radiation, calculation of the current coordinates of the transport module, and movement commands.

Main module state machine (figure 3) is the most complex in the system. After enabling, the frame is broadcast with an initialization request, and then information about active modules is collected. After that, the control switches to the main mode, which supports the following actions: processing commands from the control module, processing coordinate requests from the transport, starting the distance measurement procedure, collecting data from the receiving modules, and sending data to the visualization module.

Receiver state machine (figure 4) is the simplest in the system. Its task is to measure the distance to transport, as well as to transmit the measurement results to the main module.
Figure 2. Transport module automat.

Figure 3. Main module automat.
5. Visualization and management module

This module performs transport position calculating, displaying these positions, and managing the objects movement.

There is several classes implemented to provide better extensibility of the program and make it easier.

The Coord class is basic and relatively simple. It stores the X and Y coordinates. The CoordsArr class uses an instances array of the Coord class and implements functions for adding and deleting coordinates using the two-way queue principle. The Transport class contains two instances of the CoordsArr class: for tracking the path of the transport module and for setting destinations. This class also contains a field for the address of the transport module, and a Boolean field that indicates readiness of the measurements from receiving modules. It provides functions for adding and deleting destination points and visited points, as well as drawing them (figure 5).

Figure 4. Receiver module automat.

Figure 5. Movements visualizing window.
The Reciever class contains only four fields and is essentially a structure. It stores the address of the receiving module, its offset relative to the center of local coordinates, and a variable for measuring the distance of this receiving module.

In the global scope, arrays of Transport and Reciever classes instances are created, for sending data to PC after initialization.

The Setup procedure is used to operation prepare, establish a connection to the main module, for example. All incoming characters for receiving data reads in an interrupt. After the line end a flag of new line is set indicating that a data received.

In a mouse click interrupt commands sends to the current transport module to move to the specified point, or cancels the last such command. It is also possible to change the number of the current transport module from the list of available ones.

6. Conclusion

There is the following experiment result:

- Accuracy of the system, provided that the test is performed at a distance of 70 cm from the receiving modules, obtain to 4 cm,
- Position of the transport module updated with a frequency of more than 3 Hz.

Further improvements will apply to the system’s performance in rooms with complex non-convex geometry and in large rooms where not all reception modules can transmit their data directly to the main module, due to distance and/or interference, as well as the simultaneous operation of many transport modules [5].

References

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