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Usage of sonar and utrasonic sensors for mobile robots orientation

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Abstract:
This paper investigates the problem of improving the performance of a mobile robot, using sonar and utrasonic sensors in the robot investigation system. It is considered that the mobile robot operates in an unknown, obstacle filled environment that needs to be investigated and/or studied through the "eyes" of a domain expert who either cannot reach it, or it is too dangerous to work in it. Sonar and utrasonic sensors are used to collect informations related to the robots' environment, including obstacle identification. This type of sensors allow the measurement of the different parameters as the distance till the obstacle, their dimensions and speed.

1. Introduction

The goal of autonomous mobile robotics is to build physical systems that can move purposefully and without human intervention in unmodified environments. The development of techniques for autonomous robot navigation constitutes one of the major trends in the current research in robotics. This trend is motivated by the current gap between the available technology and the new application demands. Current industrial robots have low flexibility and autonomy. Typically, these robots perform pre-programmed sequences of operations in highly constrained environments, and are not able to operate in new environments or to face unexpected situations. Possible applications include intelligent service robots for offices, hospitals, and factory floors, maintenance robots operating in hazardous or hardly accessible areas, domestic robots for cleaning or entertainment and semi-autonomous vehicles for help to disabled people [1].

To be useful in the real world, robots need to move safely in unstructured environments and achieve their given goals despite unexpected changes in their surroundings. The environments of real robots are rarely predictable or perfectly known so it does not make sense to make precise plans before moving.

2. The mobile robot navigation system

The navigation system is the most complex and most sophisticated component of an autonomous mobile robot. The navigation tools can be applied to autonomous robot of different kinematics and geometry. The most important navigation modules are:

- Mapping and Localization;
- Path Planning;
- Motion Control.

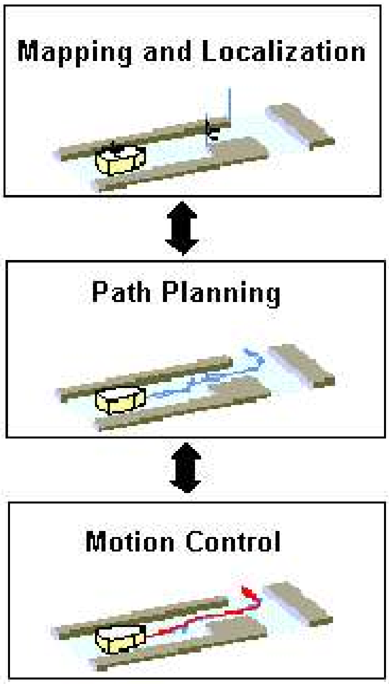

Fig.1 Navigation modules.

2.1. Mapping and Localization. Localization of an autonomous mobile robot is based on two navigation principles. First, dead reckoning is used to estimate the robot position by mathematical integration of the position and orientation increments. However, while using odometric sensors only, small errors are unavoidable and sum up over time. Therefore, environment sensors like laser scanners, sonar or vision are used to detect unique features in the environment. These features are matched with their desired position which is stored on the robot. Finally, the robot position is calculated in relation to the detected environment features.

2.2. Path Planning. Path planning allows an autonomous mobile robot to find a continuous trajectory from a start configuration to a goal configuration. For global planning the previously learned environment map is used together with the current position and the target position of the robot.

2.3. Motion Control. The motion control module ensures the smooth movement of the mobile robot along the planned path [2].

3. The sonar and ultrasonic sensors

Sonar and ultrasonic sensors are useful under poor lighting conditions or when there are many transparent objects such as windows or glass doorways, as this is where traditional vision-based sensors fail.

Sonar, like radar, uses the principle of echo location. Sonar sensors transmitter send out a short pulse within a specific direction. When the pulse hits an object, which does not absorb the pulse, it bounces back, after which the echo can be picked up by a receiver [3]. Some sensors have separate transmitter and receiver components, figure 2.a), while another sensors combines both in a single piezoelectric transceiver. However, the basic operation is the same in both devices, figure 2.b).

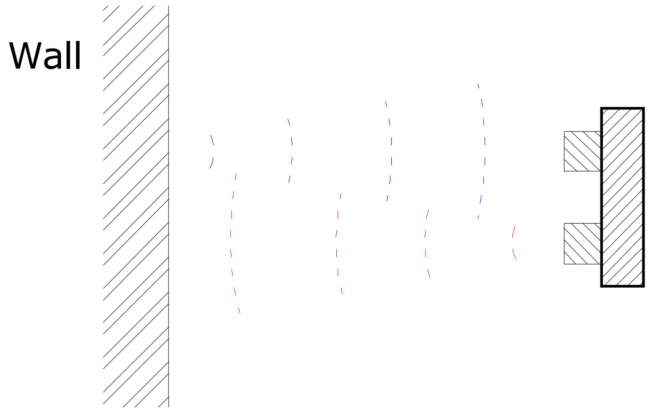

Fig.2.a) Sonar sensor with separate transmitter and receiver components.

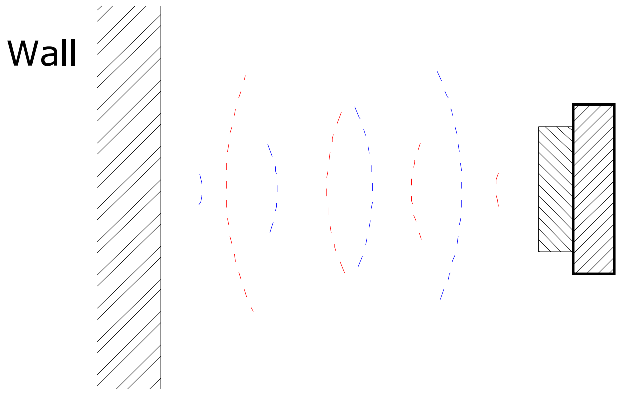

Fig.2.b) Sonar sensor with a single piezoelectric transceiver.

The distance to the object can be determined by measuring the time between sending the pulse and detecting the echo. By multiplying the time between pulse and echo T (in seconds) with speed of sound C, you will get twice the distance d to the object in meters (since the sound traveled the distance twice to get to the object and bounce back) [4].

$$2 \cdot d = C \cdot T \quad \text{or} \quad d = \frac{C \cdot T}{2} \ \text{[m]} \qquad (1)$$

where:

- C = speed of sound;
- T = time between pulse and echo;
- d = distance to object .

The accuracy of the distance measurement is directly proportional to the accuracy of the speed of sound used in the calculation. The speed of sound in air varies as a function of temperature t [ºC] by the relation:

$$C = 331.5 + 0.61 \cdot t \ \text{[m/s]} \qquad (2)$$

Sonic or ultrasonic sound is a vibration at a frequency above the range of human hearing, usually >20 kHz. Most ultrasonic sensors use a single transducer to both transmit the sound pulse and receive the reflected echo, typically operating at frequencies between 40 kHz and 250 kHz.

4. Implementation methods

Sonar and ultrasonics sensors have the emission/reception angles large enough (between 10deg and 120deg), but not enough to permit a complete investigation (360deg). This can be obtained by using more sensors or by mounting one sensor on a rotating platform [5].

4.1. The usage of more sensors. In figure 3 it is represented a mobile robot in an environment with two obstacles (1 and 2). The mobile robot has to move, avoiding the obstacles till it reaches the goal. The first stage is to detect the obstacles. In the first case, figure 3.a), the mobile robot has only one frontal sensor with the emission/reception cone angle of 15 degrees. In this situation, the mobile robot can't detect none of the two obstacles. The same thing also happends in the next case, where the mobile robot has two sensors, figure 3.b).

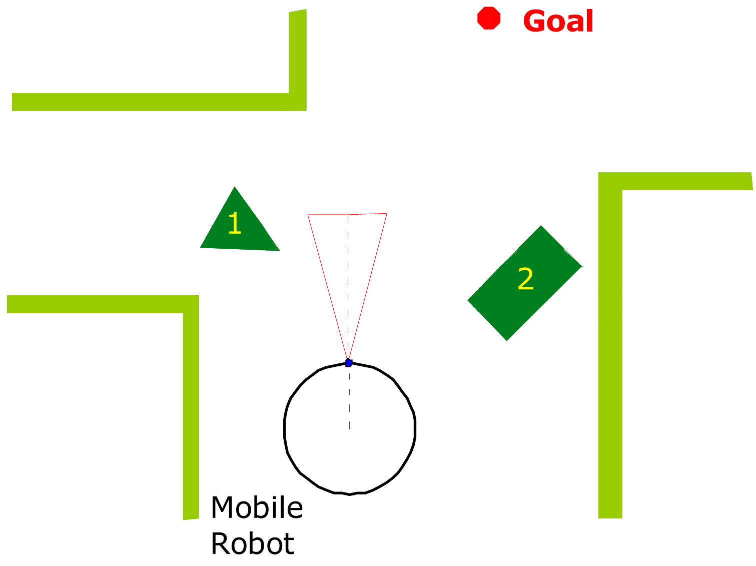

Fig.3. a) Mobile robot with one frontal sonar sensor.

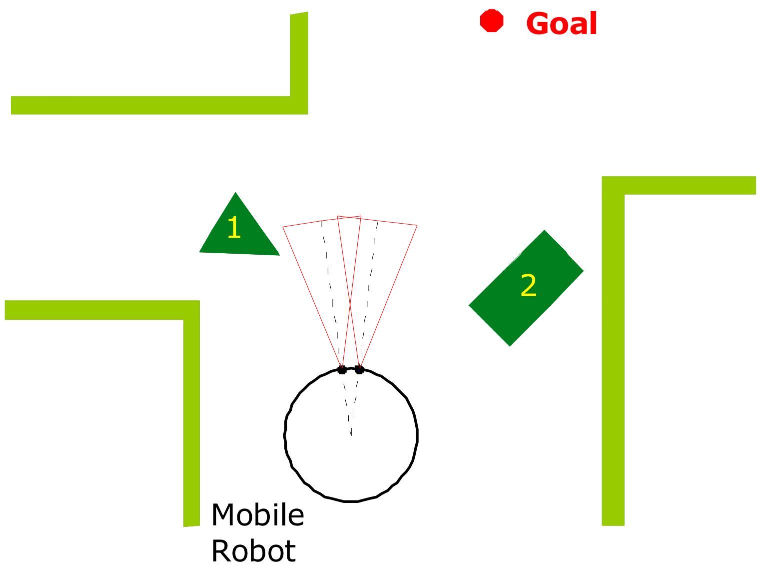

Fig.3. b) Mobile robot with two sonar sensors, located at 7.5 degrees from the main robot axis.

In the third case, figure 3.c), when the mobile robot has four sensors the obstacle 1 is detected, but the obstacle 2 still isn't detected. For a complete investigation, the mobile robot must have sensors all around, twentyfour in all, figure 3.d). The number of sensors is proportional with the emission/reception cone angle dimension. In this case both obstacles are detected and the distances to them can be calculated. So, the mobile robot can start the path planning and motion control stages.

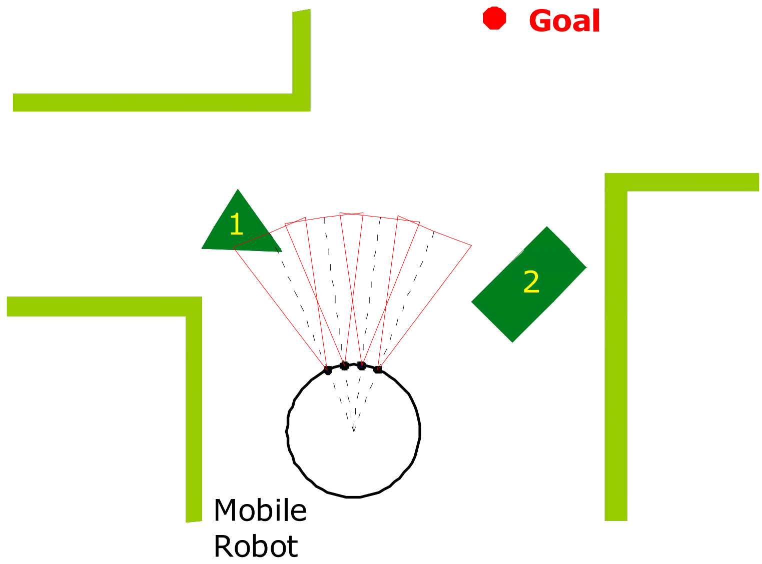

Fig.3. c) Mobile robot with four sonar sensors, located at 7.5 degrees from the main robot axis.

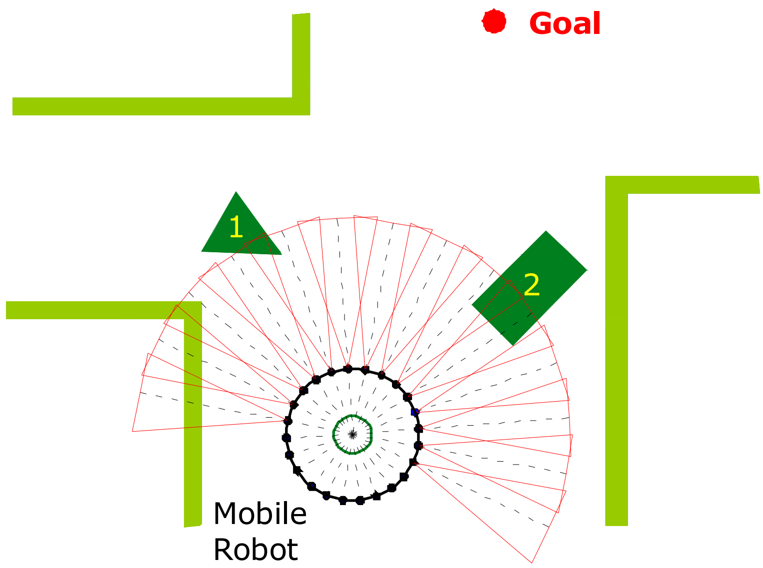

Fig.3. d) Mobile robot with twentyfour sonar sensors, located at 7.5 degrees from the main robot axis.

4.2. The usage of one sensor mounted on a rotating platform. A more simple method is that of mounting only one sensor on a rotating platform, figure 4. In this way it is realised the scaning of the working space. This method it is usually used at the mobile robots equiped with other types of sensors like vision or laser based sensors to confirm the presence of the obstacles.

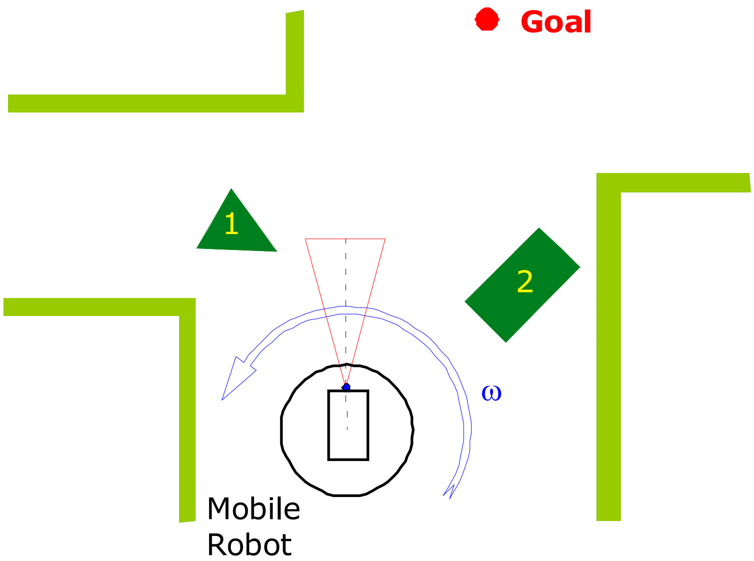

Fig.4 Mobile robot with one sonar sensor mounted on a rotating platform.

5. Conclusions

Sonar sensing is adequate for mobile robots due to its low cost, the simplicity of the required processing, and the rapidity with which it can return results reflecting range measurements over a large region of space. In most of the cases sonar sensors are used together with vision or laser based sensors for a better localization for the mobile robots.

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