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Analysis of Sensors as Components of Mobile Robots

Oleksandr Kuzmenko
dept. of computer-integrated technologies, automation and mechatronics
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
oleksandr.kuzmenko@nure.ua

Valeriia Chumak
ORCID 0000-0002-2403-020X
dept. of Microprocessor Technologies and Systems
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
valeriia.chumak@nure.ua

Ivan Shevtsov
ORCID 0000-0003-0597-1589
dept. of Microprocessor Technologies and Systems
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
ivan.shevtsov@nure.ua

Natalia Boiko
ORCID 0000-0002-7524-729X
dept. of Microprocessor Technologies and Systems
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
natalia.boiko@nure.ua

***Abstract*—Given the current trends in robotics, the paper provides an overview of sensors for use in robotics. It is given what characteristics the sensors must meet for further integration into mobile works.**

Keywords—robot, sensor, sensor, device, characteristics of sensors, types of sensors.

I. Introduction

Sensor systems of robots are the main part of information and measurement systems, the purpose of which is to generate and publish information about the state of objects and processes in the environment and about the robot itself, for the operation of which this information is required.

In many industries and environments, there is a growing demand for rigid multi-purpose work that is easy to operate. Now robots need sensors to understand the context and intuitive interfaces for ease of use. Some applications, for example, may use gesture recognition to control a physical device.

IoT protection, low power consumption, security and reliability - all these are certain requirements and lead to the use of sensors to monitor electricity, temperature and other parameters to ensure that the system operates efficiently and safely. In the near future, robotics will increase the number of engines and the versatility of the environment, and more social robots will appear around the world. The number of sensors used by robots will increase with the development of more control systems and settings [1-5].

II. Sensors in Robots and their Characteristics

The sensor is a primary transducer that responds to the value (temperature, pressure, displacement, current, etc.) that is subject to control, and converts it into another value, convenient for further use, giving a signal of its presence and intensity [6]. This signal can be of any physical nature, which can be measured using different principles of operation of the sensitive element of the device.

The characteristics of the sensors allow you to choose the appropriate sensor to work in different situations. Some of the basic attributes of robot sensors are analyzed below [6]:

- precision is this characteristic of the sensor refers to the proximity of the registered value of the sensor to the actual value. It is often called a range of values;
- calibration is the accuracy and resolution of robot sensors can also be improved by calibrating them;
- resolution is this parameter refers to the smallest variable of the input signal that the sensor can detect and reliably specify;
- linearity is this information becomes useful when presenting sensor output to a low-level computer that cannot perform many calculations and compose calibration equations;
- frequency is the peculiarity of robot sensors is that they must give the same result every time the measurement is performed under the same conditions;
- dead zone and hysteresis it's what in mechanical systems such as robots, some error in the gears always causes different values depending on the direction of movement or the dead zone, when the robot sensors do not detect any movement;
- drift;
- temperature range;
- field of vision (FOV) it's what indicates which area (usually angular) can be detected by robot sensors. Horizontal is often mentioned (hFOV) and vertical (vFOV) components;
- the size of the stain is this mainly applies to lasers, but it is important to know how large the spot size is at a given distance. This spot size is crucial to determine the size of visible objects. A small spot size is required to observe through dust, rain and snow. To

do this, you can use both horizontal and vertical scale of spots;

- the shape of the output signal;
- reliability.

III. Types of Sensors and Features of their Use in Robots

A. *Contact sensors, pressure sensors*

Tactile pressure sensors are useful in robotics because they are sensitive to touch, force and pressure. An example of such a sensor is shown in Fig. 1. If there is a development of a hand (manipulator) robot and it is necessary to measure the force of capture and the pressure required to hold the object, then use this sensor.

Fig. 1. Pressure sensor C7.5B.

Contact sensors include push-button switch, limit switch, etc. These sensors are mainly used for robots that avoid interference. Contact sensors can be easily implemented, but their disadvantage is that they require physical contact. In developing modern humanoid robots, manufacturers are equipping them with these sensors to make devices even more "spiritual", able to perceive information about the world around them literally by touch. There are also capacitive contact sensors that respond only to human touch.

B. *Optical sensors and display sensors*

These sensors work with a photoresistor. The display sensor (emitter and receiver) allows you to detect white or black areas on the surface, which allows, for example, a wheeled robot to move along a drawn line or to determine the proximity of an obstacle. The light source is often an infrared LED with a lens, and the detector - a photodiode or phototransistor.

The light sensor is used to detect light and create a voltage difference. The two main light sensors are photoresistors and photovoltaic cells. Other types of light sensors, such as phototubes, phototransistors, charge-coupled devices, and so on, are rarely used.

C. *Photoresistor*

An example of a photoresistor is shown in Fig. 2. These inexpensive sensors can be easily implemented in most robots that depend on lighting.

Photovoltaic cells convert solar radiation into electrical energy. This is especially useful if you plan to build a solar robot. Although the photocell is considered a source of energy, an intelligent implementation in combination with transistors and capacitors can turn it into a sensor.

Fig. 2. Photoresistor LDR.

D. *Sound sensors*

Sensors are used to safely move robots in space by measuring the distance to the obstacle from a few centimeters to several meters. The sensor detects sound and emits a voltage proportional to the sound. An example of a module with such a sensor is shown in Fig. 3.

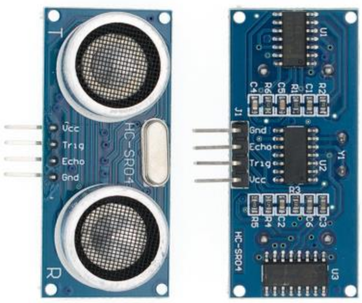

Fig. 3. Ultrasonic module HC-SR04.

These include a microphone (allows you to record sound, voice and noise), rangefinders, which are sensors that measure the distance to nearby objects and other ultrasonic (US) sensors. Ultrasound is especially widely used in almost all fields of robotics.

The operation of the ultrasonic sensor is based on the principle of echolocation. The speaker of the device emits an ultrasonic pulse at a certain frequency and measures the time until it returns to the microphone. Sound locators emit directional sound waves that are reflected from objects, and some of this sound comes back to the sensor. The time of arrival and the intensity of such a return signal provide information about the distance to the nearest objects. These include a microphone (allows you to record sound, voice and noise), rangefinders, which are sensors that measure the distance to nearby objects and other ultrasonic (US) sensors. Ultrasound is especially widely used in almost all fields of robotics.

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Robotic systems, which are part of autonomous submarines, mainly use underwater sonar technology, and on the ground sound locators are mainly used to prevent collisions only in the immediate vicinity, as these sensors are characterized by a limited range.

A number of other devices alternative to sound locators include radars, lasers and lidars. Instead of sound, this type of rangefinder uses a laser beam reflected from an obstacle. These sensors are more widely used in the development of autonomous vehicles, as they allow the vehicle to cope more efficiently with traffic.

E. Position, tilt, proximity and distance sensors

These types of sensors are used mainly in unmanned vehicles, industrial works, as well as devices that provide self-balancing.

GPS. Satellites orbiting the Earth transmit signals, and a robot receiver receives and processes these signals. The processed information can be used to determine the approximate position and speed of the robot. These GPS systems are extremely useful for robots outdoors, but they do not work indoors. Another disadvantage is their high cost.

Digital magnetic compass. Like a hand-held magnetic compass, a digital magnetic compass provides directional measurements using the Earth's magnetic field, which directs work in the right direction to achieve a goal. An example of a digital compass is shown in Fig. 4. These sensors are cheap compared to GPS modules, but the compass works best with it.

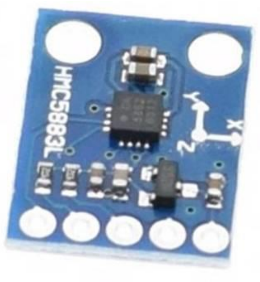

Fig. 4. Digital compass, magnetometer HMC5883L GY-273.

Localization. Artificial landmarks or beacons are placed around the robot, and the robot sensor captures these signals to determine its exact location. Natural landmarks can be doors, windows, walls, and so on, which are perceived by the robot sensor / technical vision system (camera). Localization can be achieved with beacons that generate Wi-Fi, Bluetooth, ultrasound, infrared, infrared, radio, visible light or any other similar signals.

Gyroscope. The gyroscope is used to measure the speed of rotation around a certain axis. This device is especially useful when you need the robot to be independent of gravity to maintain orientation, unlike the accelerometer.

Tilt sensors. They are responsible for balancing and stabilizing any device. And due to the fact that this part is relatively inexpensive, it can be installed in any homemade robot.

IMU. An example of such a module is shown in Fig. 5. IMUs are able to provide feedback, detecting changes in the orientation of the object (pitch, roll and jerk), speed and gravitational forces. Some IMUs go further and integrate a GPS device, providing positional feedback.

Fig. 5. IMU BMI160.

There are different types of proximity sensors, but in this paper we will consider only some of them, which are most often used in works.

Infrared (IR) sensor. The most accessible and simplest type of sensors used in the work to determine the approximation. An example of such a sensor is shown in Fig. 6. In the "beacon" mode, this sensor sends constant signals by which the robot can determine the approximate direction and distance of the beacon. This allows the robot to be programmed so that it always moves in the direction of this beacon. The low cost of this sensor allows you to install it on almost all home-made work, and thus equip them with the ability to move from obstacles.

Ultrasonic distance sensors. The sensor emits an ultrasonic pulse received by the receiver. Since the speed of sound in the air is almost constant and is approximately 344 m/s, the time between sending and receiving is calculated to obtain the distance between the revolution and the obstacle. Ultrasonic distance sensors are especially useful for underwater robots. It is also proposed to use sensors in the JY 450F type machine system [7].

Fig. 6. IR distance sensor E18-D80NK.

Laser distance sensor. The distance is measured by calculating the speed of light and the time required for the light to be reflected from the receiver. These sensors can be used when measuring long distances. An example of this sensor is shown in Fig. 7.

Fig. 7. Laser distance sensor GY-530 on VL53L0X.

Encoders. A transparent and opaque pattern (or black and white pattern) is applied to the rotating disk. When the disk rotates with the wheel, the emitted light is interrupted, generating an output signal. The number of breaks and the diameter of the wheel allow you to determine the distance traveled by the robot.

Stereo camera. Two cameras facing each other can provide depth information via stereo vision.

There are other tensile and bending sensors that are also able to measure distance. But their range is so limited that they are practically not used in the design of mobile robots.

F. Temperature sensors

Temperature sensor is used to automatically measure the temperature in different environments. They provide the voltage difference when the temperature changes. As in computers, the device is used to control the temperature of the processor and its timely cooling.

G. Voltage sensors

Voltage sensors convert low voltage to high or vice versa. One example is an operational amplifier that accepts low voltage, amplifies it, and generates higher voltage at the output. Few voltage sensors are used to determine the potential difference between the two ends (voltage comparator). Even a simple LED can be used as a voltage sensor that can detect a voltage difference and signal it by flashing.

H. Current sensors

Current sensors are electronic circuits that monitor the flow of current in the circuit and emit either proportional voltage or current. Most current sensors emit analog voltage in the range from 0 V to 5 V, which can be processed by a microcontroller.

I. Capacitive sensors

The sensitive surface of a capacitive sensor is formed by two concentrically arranged metal electrodes. If an object approaches the sensitive surface of the sensor, then it enters the electric field in front of the electrode surfaces and contributes to an increase in the coupling capacitance between the plates. In this case, the amplitude of the generator begins to increase. Such sensors are often used in medical robotic systems and devices [8-11].

J. Other sensors for robots

Today, there are a large number of sensors that can detect many technological parameters, and it is almost impossible to list all available sensors. In addition to those analyzed above, there are many other sensors that are used for specific applications. For example: humidity sensors measure humidity; gas sensors are designed to detect certain gases (useful for robots that detect gas leaks); potentiometers are so versatile that they can be used in many different applications; magnetic field sensors determine the strength of the magnetic field around it [12].

Conclusion

So the more complex the robot, the more sensors are used. A combination of different sensors may be required to perform one technical task, or different technical tasks may be solved using a single sensor. It is necessary to correctly determine which sensor is best to install on the robot, based on availability, cost and ease of use.

References

[1] Основи робототехніки: навчальний посібник / Н.В. Морзе, Л.О. Варченко-Троценко, М.А. Гладун. – Кам'янець-Подільський : ПП Буйницький О.А., 2016. – 184 с.

[2] "Автоматизированний завод. Сучасна промисловість", *Robotics.ua*, 2022. [Online]. Available: https://robotics.ua/shows/modernity/2215-the_automated_factory_modern_industry.

[3] Робототехніка та мехатроніка: навч. посіб. / Л.І. Цвіркун, Г. Грулер ; під заг. ред. Л.І. Цвіркуна ; М-во освіти і науки України, Нац. гірн. ун-т. – 3-тє вид., перероб. і доповн. – Дніпро: НГУ, 2017. – 224 с.

[4] Основи автоматики та робототехніки [Електронний ресурс] : навчальний посібник для здобувачів професійної (професійно - технічної) освіти / А. М. Гуржій, А. Т. Нельга, В. М. Співак, О. С. Ітякін. – Електронні текстові дані (1 файл: 11,04 Мбайт). – Дніпро : «Гарант СВ», 2021. – 244 с.

[5] Пелевін Л.Є. Синтез робототехнічних сис-тем в машинобудуванні: Підручник / Л.Є.Пелевін, К.І. Почка, О.М. Гаркавенко, Д.О.Міщук, І.В. Русан. – К.: ТОВ "НВП "Інтер-сервіс"", 2016. – 258 с.

[6] Ніколайчук, В. М. Основи робототехніки: Навчальний посібник. – Рівне: НУВГП, 2008. – 76 с.

[7] Чумак В. С. Розрахунки для вимірювання відстані до об'єкта за допомогою ультразвукового датчика HC-SR04 для перспективного використання до машин типу JY 450F / В. С. Чумак, І. В. Свид // Збірник доповідей XII Всеукраїнської науково-практичної конференції «Ефективні процеси та обладнання хімічних виробництв та пакувальної техніки». – К.: КПІ ім. Ігоря Сікорського, 2020. – С. 35.

[8] V. Semenets, V. Chumak, I. Svyd, O. Zubkov, O. Vorgul and N. Boiko, "Designing the Structure of a General-Purpose Telemedicine Complex", *2021 III International Scientific and Practical Conference Theoretical and Applied Aspects of Device Development on Microcontrollers and FPGAs*, 2021. doi: 10.35598/mcfpga.2021.016.

[9] Аналіз принципів побудови телемедичних комплексів широкого призначення / В. С. Чумак, О. Г. Аврунін, Є. А.Чугуй, І. В. Свид // АСУ та прилади автоматики. 2021. № 177. С. 80-85.

[10] O. Zubkov, I. Svyd and O. Maltsev, "Features of the Use of Pid Controllers when Controlling Evaporators", *MC&FPGA-2020*, 2020. doi: 10.35598/mcfpga.2020.001.

[11] O. Zubkov, I. Svyd and O. Vorgul, "Features of the Digital Filters Implementation on STM32 Microcontrollers", *2021 III International Scientific and Practical Conference Theoretical and Applied Aspects of Device Development on Microcontrollers and FPGAs*, 2021. doi: 10.35598/mcfpga.2021.001.

[12] "Robot Platform | Knowledge | Types of Robot Sensors", *Robotplatform.com*, 2022. [Online]. Available: https://www.robotplatform.com/knowledge/sensors/types_of_robot_sensors.html.