IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

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To cite this article: B Nalepa *et al* 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **400** 052007

IOP Conf. Series: Materials Science and Engineering **400** (2018) 052007 doi:10.1088/1757-899X/400/5/052007

Investigation of movement of mobile robot work

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Abstract. The purpose of this article is to present the possibilities of robot localization in local coordinates. The first chapter discusses the local location system as well as the flow diagram of signals between devices. The system consisted of a mobile robot Starter Kit 2.0, Raspberry Pi 3 and a DWM1001 system. First, parameters were defined that will be measured during the experiment. Next, a local location system was presented consisting of a module enabling communication, among others after Ultrawideband (UWB). The next step was to present the configuration of the measurement position and the analysis of the control algorithm. The program was written in a Python node and data sent from navigation devices was read through the serial port (UART). The robot's position was measured at the starting point and after the specified movement. The final stage of this article was to determine the mathematical model of the studied phenomenon and to determine its application in issues related to mobile robotics.

1. Introduction

In issues related to the control of robots [1 – 3], the method of their positioning in small rooms, where the GPS system is ineffective, is often analysed. The system for local robot navigation can be useful not only in the case of operation of the device in a hazardous environment as a locator, but also as an element supporting the control algorithm and vision system. The latest cameras enabling the image to be obtained in three dimensions it can be a component together with navigation devices to create an environment map. The robot positioning element is necessary to generate an image that is a projection of the room in which the robot is located. The use of only encoders to describe the coordinates of the robot in the local system is insufficient. Information on the engine speed does not include, for example, wheel slip.

This article in particular analysed the possibilities of using the local location system in mobile robotics. A measurement system consisting of a Starter Kit 2.0 mobile robot was created containing the sbRIO9632 control system, with which the Raspberry Pi 3 was connected via TCP / IP 3. A Kinect sensor and a DWM1001 device configured to read data from other network elements were connected to the microcontroller. The described system was presented in figure 1, 2.

The system can be used to determine the position of the robot [1 – 3] or workpiece [4].

The measurement system presented in figures 1, 2 is sufficient to investigate the location in mobile robotics. The obtained results will allow to determine the suitability of such a system, among others to control a group of robots or to build environment maps.

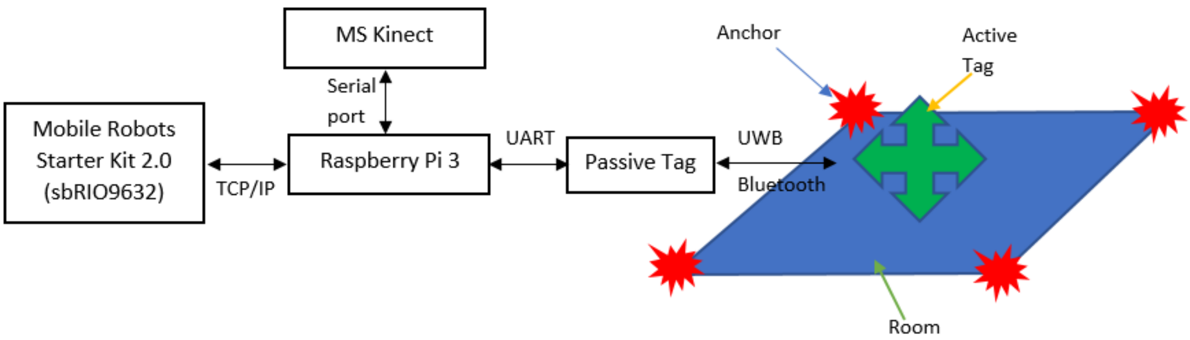

Figure 1. Diagram of the measurement system.

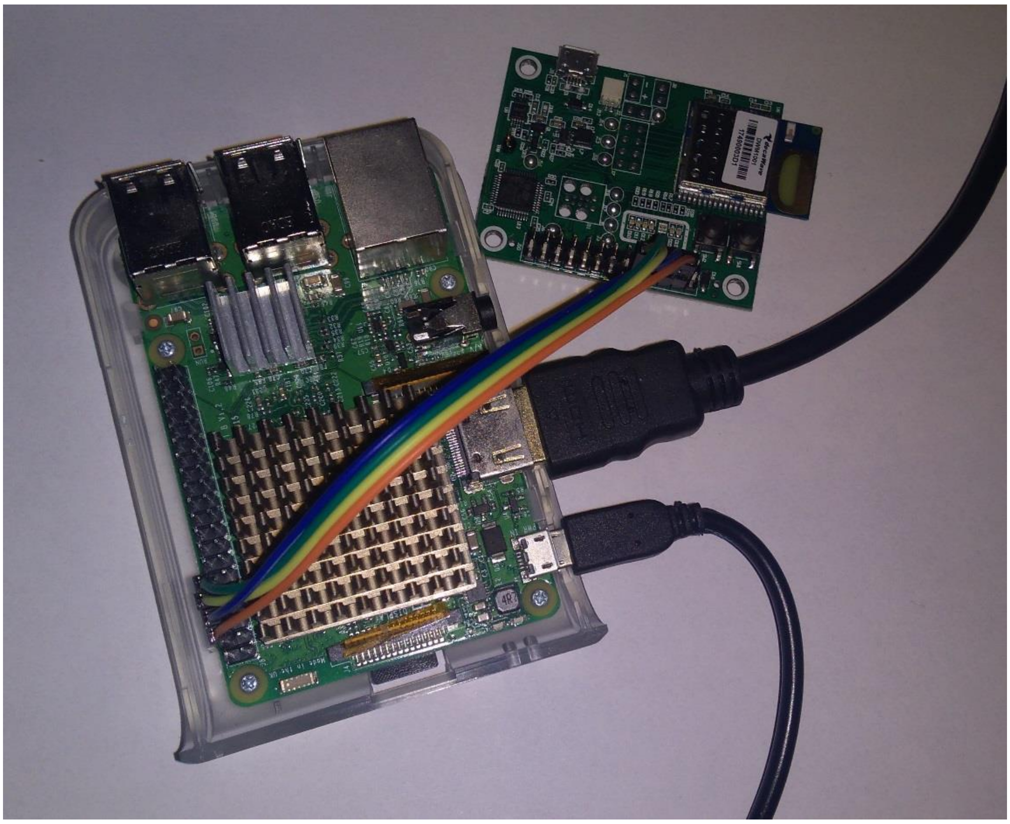

Figure 2. Fragment of measuring system containing Raspberry Pi 3 and DWM1001 (passive).

2. System RTLS

The RTLS system is a system that performs real-time location of an object and then determines its location in local coordinates. The devices of the RTLS system used in the system are DWM1001 element from decaWave. Elements of the RTLS system are based on Ultra-wideband (UWB) technology. The devices are designed to determine the location of the target using the appropriate frequency bands and algorithms for calculating the coordinates in the local system. The system performs calculations of distances between individual modules using one of the estimation methods to which they belong, among others Time Difference of Arrival (TDoA) and Angle of Arrival (AoA) [5, 6].

The decaWave DWM1001 modules were used to investigate the position of the mobile robot. One device was selected that will move with the robot (Tag). Then the characteristic points of the given room were determined - still (Anchors). A module for obtaining information about the location of the active element was also designated, which was connected to Raspberry pi 3 and the data was read by the serial port (UART) [7, 8]. The program flow diagram is shown below.

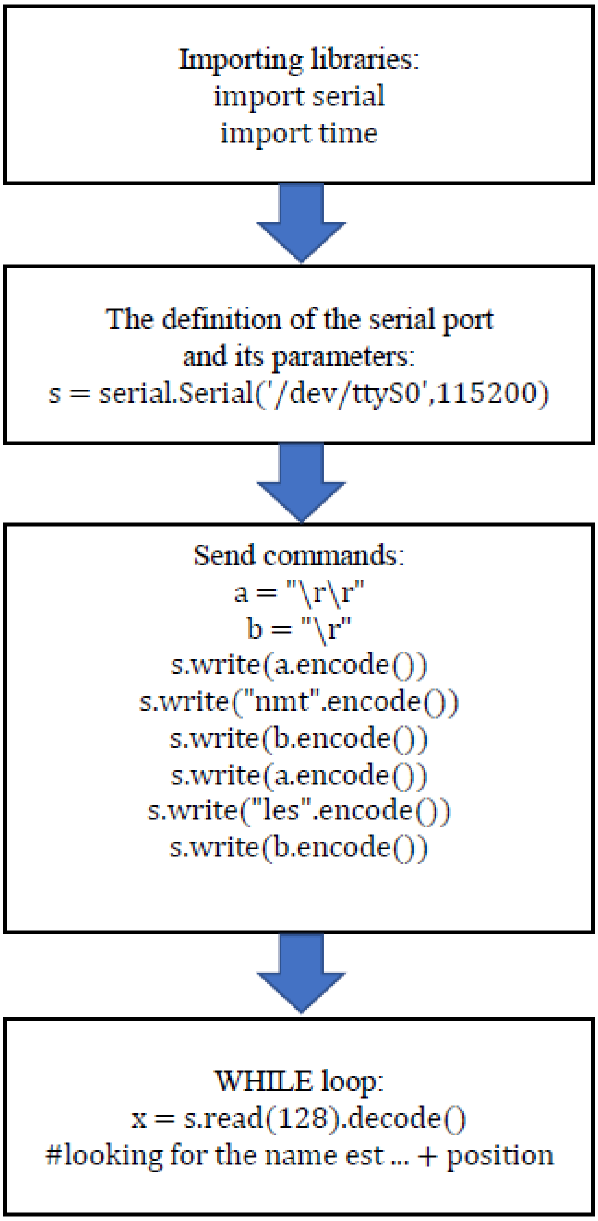

Figure 3. The scheme of the program.

In the first lines of the program, the libraries are downloaded. In subsequent commands, the serial port is configured and commands in accordance with the documentation [7] are sent. The last element is the WHILE loop, which reads the data from the port and looks for a device with the name that begins with symbols "est ...".

3. Analysis of test results

Table 1 presents defined parameters that can affect the error of measurements. Static two-level plans were selected for the experiment. As the result of the experiment an error was assumed between the set value and the received value [9 – 13].

Table 1. States of defined variables [9 – 13].

The name of the variable	Symbol	Level of volatility (-)	Level of volatility (+)
Distance (D)	x_1	1 point (0.42m)	2 point(1m)
Number of anchors (N)	x_2	4	8

Variable coding and decoding are presented using unit change (u_i) and midvalue of variable (m_i) [9 – 13]:

$$u_1 = \frac{D_{max} - D_{min}}{2} \tag{1}$$

$$u_1 = \frac{1 - 0,42}{2} = 0,29$$

$$m_1 = \frac{D_{max} + D_{min}}{2} \tag{2}$$

$$m_1 = \frac{1 + 0,42}{2} = 0,71$$

$$x_1 = \frac{x_1 - m_1}{u_1} = \frac{D - 0,71}{0,29} \tag{3}$$

$$u_2 = \frac{N_{max} - N_{min}}{2} \tag{4}$$

$$u_2 = \frac{8 - 4}{2} = 2$$

$$m_2 = \frac{N_{max} + N_{min}}{2} \tag{5}$$

$$m_2 = \frac{8 + 4}{2} = 6$$

$$x_2 = \frac{x_2 - m_2}{u_2} = \frac{E - 6}{2} \tag{6}$$

As the result of the experiment, the location of points in space was examined depending on the changed sensitive parameters. The results of the tests are presented in diagrams (figures 4, 5, 6, 7) with the device error ranges.

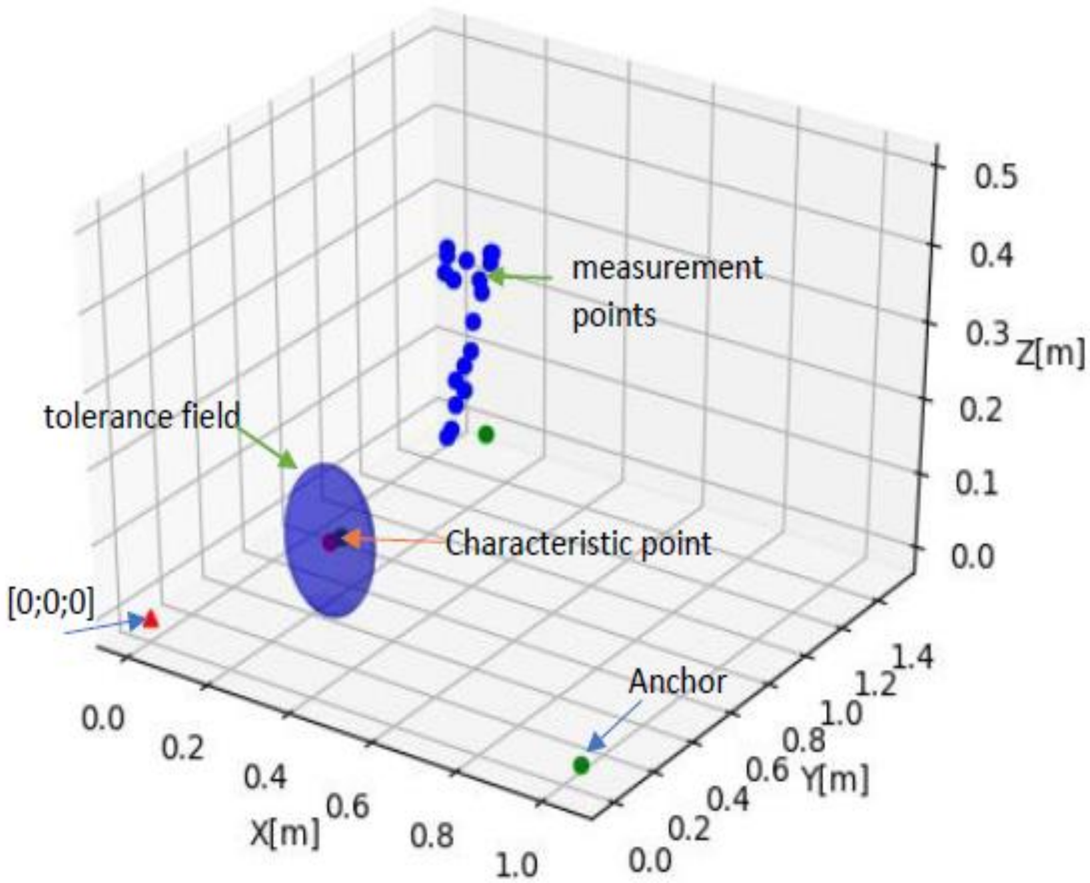

Figure 4. Graph showing the measured points with respect to the characteristic point (1) and the tolerance field - 4 anchors (Python program and Matplotlib library).

In figures 4, 5, 6, 7 all system components are listed. The red triangle ("[0; 0; 0]") means the Tag that is the beginning of the coordinate system. The blue sphere means "tolerance field" and is the measurement accuracy (+/- 10cm). "Characteristic point" means the point at which the position of a mobile robot was measured. The anchors were marked with the location of the remaining anchors. Blue points ("measurement points") mean the measurements taken by the device collecting the Tag location data.

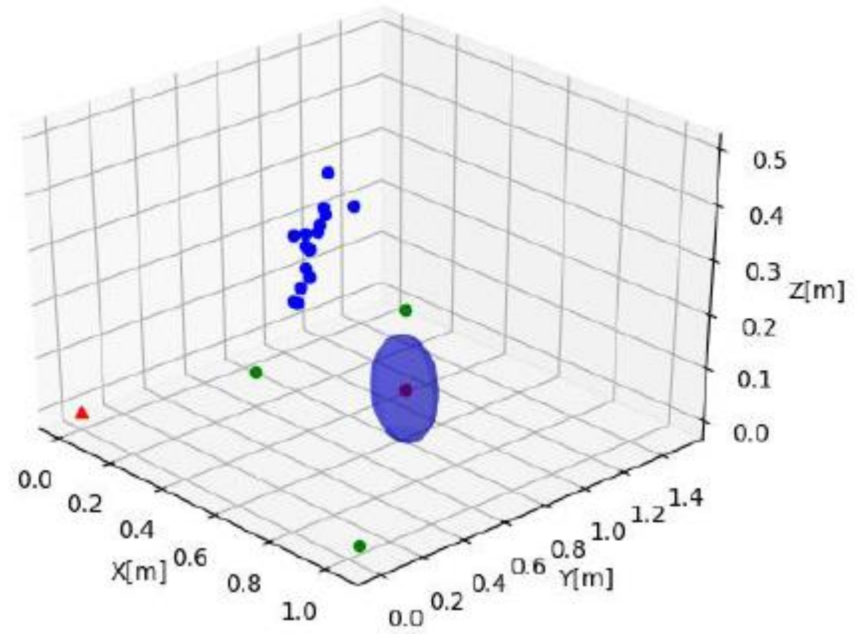

Figure 5. Graph showing the measured points with respect to the characteristic point (2) and the tolerance field - 4 anchors (Python program and Matplotlib library).

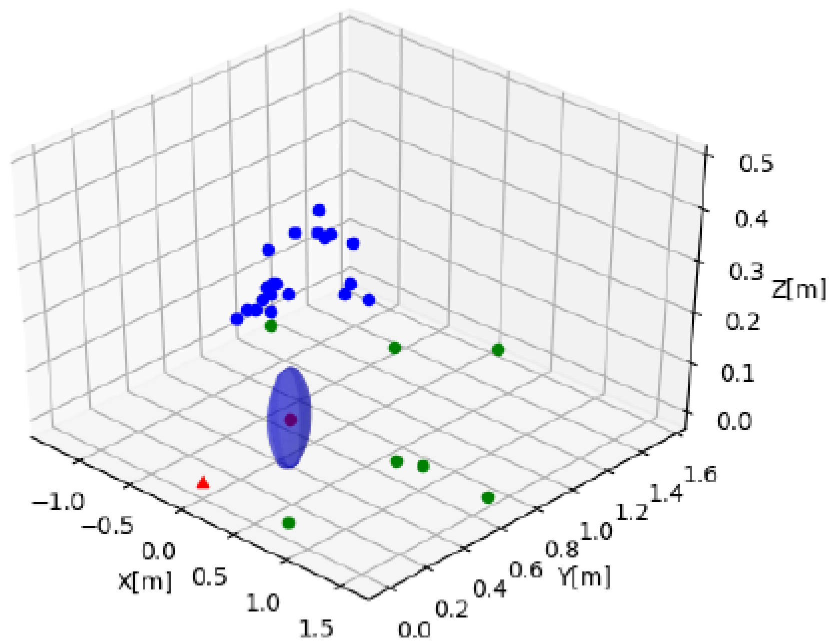

Figure 6. Graph showing the measured points with respect to the characteristic point (1) and tolerance field - 8 anchors (Python program and Matplotlib library).

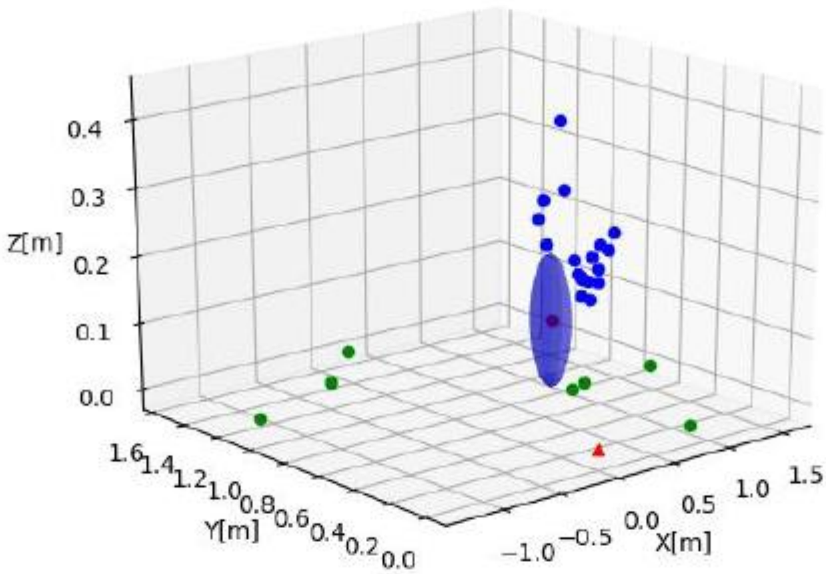

Figure 7. Graph showing the measured points with respect to the characteristic point (2) and tolerance field - 8 anchors (Python program and Matplotlib library).

Table 2. Static two-level plan [9 – 13].

Experience number	x_0	x_1	x_2	x_{12}	$\bar{y}_x$	$\bar{y}_y$	$\bar{y}_z$
1	+	+	+	+	0.26	0.32	0.14
2	+	+	-	-	0.03	0.06	0.26
3	+	-	+	-	0.15	0.24	0.27
4	+	-	-	+	0.27	0.13	0.31

Creating a mathematical model based on the regression equation [9 – 13]:

a) The mathematical model of the x coordinate of the localised object:

Character coded:

$$x = 0{,}18 - 0{,}03x_1 + 0{,}03x_2 + 0{,}09x_1x_2 \tag{7}$$

Decoded character:

$$x = 0{,}18 - 0{,}03\left(\frac{D - 0{,}71}{0{,}29}\right) + 0{,}03\left(\frac{E - 6}{2}\right) + 0{,}09\left(\frac{D - 0{,}71}{0{,}29}\right)\left(\frac{E - 6}{2}\right) \tag{8}$$

Test of significance of regression equation coefficients on the basis of t- Student statistic on the significance level $\alpha = 0{,}1$:

- b_0 – important coefficient,
- b_1 – important coefficient,
- b_2 – important coefficient,
- b_{12} – important coefficient.

b) The mathematical model of the y coordinate of the localised object:

Character coded

$$y = 0{,}19 + 0{,}002x_1 + 0{,}09x_2 + 0{,}04x_1x_2 \tag{9}$$

Decoded character:

$$y = 0{,}19 + 0{,}002\left(\frac{D-0{,}71}{0{,}29}\right) + 0{,}09\left(\frac{E-6}{2}\right) + 0{,}04\left(\frac{D-0{,}71}{0{,}29}\right)\left(\frac{E-6}{2}\right) \tag{10}$$

Test of significance of regression equation coefficients on the basis of t- Student statistic on the significance level $\alpha = 0{,}1$:

- b_0 – important coefficient,
- b_1 – important coefficient,
- b_2 – important coefficient,
- b_{12} – important coefficient.

c) The mathematical model of the z coordinate of the localised object:
Character coded

$$z = 0{,}25 - 0{,}05x_1 - 0{,}04x_2 - 0{,}02x_1x_2 \tag{11}$$

Decoded character:

$$z = 0{,}25 - 0{,}05\left(\frac{D-0{,}71}{0{,}29}\right) - 0{,}04\left(\frac{E-6}{2}\right) - 0{,}02\left(\frac{D-0{,}71}{0{,}29}\right)\left(\frac{E-6}{2}\right) \tag{12}$$

Test of significance of regression equation coefficients on the basis of t- Student statistic on the significance level $\alpha = 0{,}1$:

- b_0 – important coefficient,
- b_1 – important coefficient,
- b_2 – important coefficient,
- b_{12} – important coefficient.

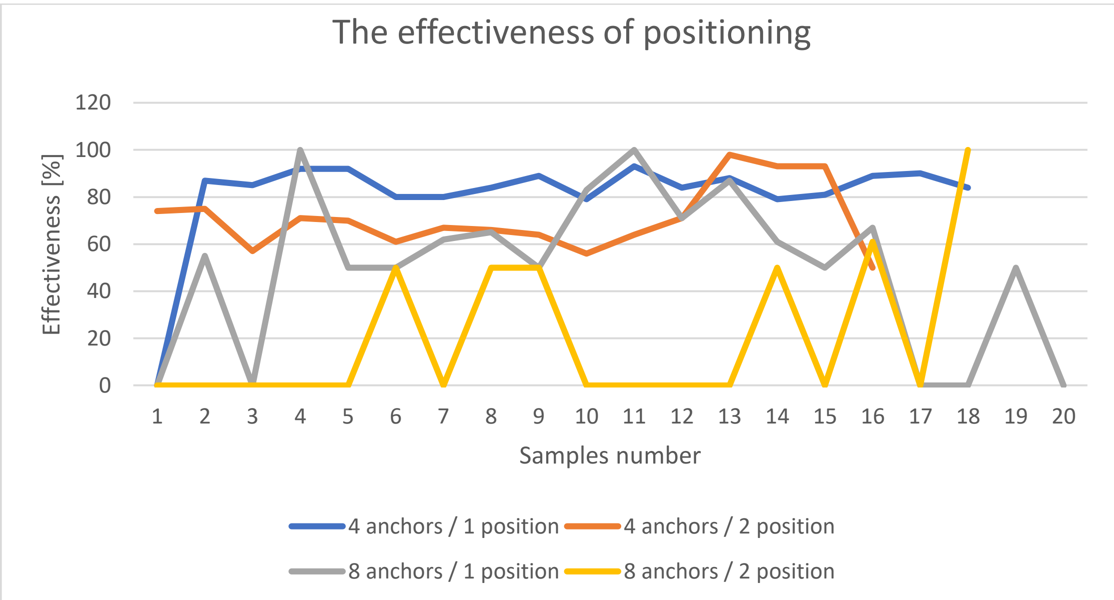

Figure 8. A graph showing the probability of a proper location.

As a result of measurements and determination of measurement errors and their introduction to algorithms related to planning the experiment, mathematical models for three coordinates were obtained. The conducted research has shown that each defined parameter is important for the obtained results. The obtained equations enable entering into the variables D, E appropriate values from the adopted interval described in the table 1 and then determining the coordinates of the object. Figure 8 presents a parameter describing the probability of a correct measurement. This is mainly due to the correct reception of signals from other devices. The highest effectiveness in making measurements was recorded when using fewer anchors.

4. Conclusion

In this work, the positioning of a mobile robot using the RTLS system was investigated. The system consisted of Raspberry Pi 3, DWM1001 and Robot Starter Kit 2.0. The research was carried out changing the two parameters of the system, the number of passive elements - anchors and position measurement points, and comparing it with the reference distance. In the measurements carried out, all the results were outside the tolerance field designated by the manufacturer (+/- 10cm). However, this does not mean inaccurate device operation. The producer in the programmed device has set the sending of the parameter specifying the probability of performing an exact measurement. As a result of the analysis of the accuracy of the measurement, it was found that in the case of close (up to 2m) setting of anchors, a better solution is to use a minimum amount of 4. The device is a good solution in the case of industrial use, but it will not be effective as a map-building aid and robot navigation in real time.

As a result of the conducted research, it was decided to carry out tests on RTLS integration with the robot vision system. It was also decided to design a new system that could work in real time.

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