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Editors

Proceedings TEEM 2022: Tenth International Conference on Technological Ecosystems for Enhancing Multiculturality

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TEEM 2022 Preface

We celebrated the tenth edition of the Technological Ecosystems for Enhancing Multiculturality (TEEM) International Conference in the University of Salamanca, the institution in which it was born. Nine years ago, this academic conference project started. We had the goal to create a new interdisciplinary event in which the new advances in technology would be reflected in the resolution of the problems of Education and the Knowledge Society. We pursued the establishment of a new research community with a strong aim to help Ph.D. students to have opportunities to know and collaborate with consolidated researchers worldwide.

Looking back, we are very satisfied with the obtained results. We are a consolidated research community that has grown, many research projects were born in the previous editions, many collaborative papers in prestigious books and journals have been published, many international internships have occurred, but we are very proud because tens of new Ph.D. participated in the previous editions of TEEM Doctoral Consortium track and contribute to help the future Ph.D. to be part of the TEEM family.

This edition is a reunion event, fully face-to-face, after two editions in virtual and hybrid mode due to COVID-19. More than one hundred and ninety researchers shared their scientific advances in this tenth edition. Some of them were new, but most of them were regular participants in this conference, which reinforces the original idea of forming a solid scientific community.

It is also important to say that this TEEM tenth edition was within the European Campus of City-Universities (EC2U) Alliance (https://ec2u.eu/), co-funded by the Erasmus+ Programme of the European Union. The EC2U is a multi-cultural and multilingual Alliance consisting of seven long-standing, education- and research-led, locally and globally engaged universities from four diverse regions of the European Union: the University of Coimbra, the University of Iași, the University of Jena, the University of Pavia, the University of Poitiers (Coordinator), the University of Salamanca and the University of Turku.

TEEM 2022 has had 210 submissions from which 145 full papers were accepted; that is, there is a 30% rejection rate. These papers have involved 424 authors from 26 countries.

The TEEM 2022 was organized in 16 thematic tracks that covers research areas such as Educational Assessment and Orientation, Human–Computer Interaction, Computers in Education, Communication Media and Education, Medicine and Education, Learning Analytics, Engineering Education, Robotics in Education, Diversity in Education, Gamification and Games for Learning, Smart Learning and Laboratory-Based Education.

In addition to the regular sessions, the TEEM 2022 edition featured three prestigious guest speakers. Firstly, Gema Parreño Piqueras, Developer Advocate at Iterative, gave the inaugural keynote entitled “Alignment of language agents in video games.” Dr. Oriol Borrás Gené, Professor at Universidad Rey Juan Carlos (Spain), gave a keynote entitled

"3 years escaping from a room, learned lessons." The closing lecture was given by Dr. Ricardo Colomo-Palacios, Full Professor at the Østfold University College (Norway), with the title "Academia-Industry collaboration: a view from IT."

We would like to thank the members of the Steering Committee for their counsel and the International Scientific Committee for their accurate and timely reviewing. We would also like to thank the Track Chairs for their efforts in organizing the academic issues related to each track and the Organizing Committee for their huge effort in all the associated tasks that an international conference involves. We would like to do a special mention for the Editors-in-Chief of the linked journals that have offered special issues or slots in their regular issues for those selected and extended papers of TEEM 2022 conference that will have another in-depth review following the guidelines of each journal. Last, but not least, we would like to thank the participating organizations: University of Salamanca, Research Institute for Educational Sciences at the University of Salamanca, GRIAL Research Group and European Campus of City-Universities (EC2U) Alliance for their support.

Next year, we will continue with eleventh edition of TEEM Conference that will be held at Bragança, Portugal, organized by Instituto Politécnico de Bragança.

October 2022

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Abstract. In this paper, it is presented a field of view analysis of a time of flight sensor, that will be applied in a mobile robotics application. The sensor was configured in order to obtain a tradeoff between reactiveness and accuracy. It was used a microcontroller development board to acquire data and a manipulator to perform the movements, assuring repeatability and accuracy in the data acquisition process. The results of this paper will be used as an input to a simulation, in order to assist in the development of a mobile robotics application and also to be applied in educational contexts.

1 Introduction

An approach for distance measurement widely applied in mobile robotics and machine vision industry in recent years is the Time of Flight (ToF) technology, which encompasses precision and low cost in the same component. The applications includes obstacle avoidance, reconstruction of objects and environments, user detection, gesture recognition and others [1,2].

In the Time of Flight principle, a modulated infrared signal is sent to an object, it is backscattered and then a ToF receptor receives the reflected signal. Using the phase shift between the signal sent and the signal reflected it is possible to calculate the distance [1,3,4].

In order to obtain high performance controllers for mobile robots in dynamics environments it is important to characterize a specific sensor or actuator obtaining parameters, which can be important, for example, to a sensory fusion

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or even to a virtual environment, allowing the simulation to be closer to the real parameters and real world [5,6]. The field of view of time of flight sensors it is an important topic to analyze since it can shift depending to the sensor distances and directions [7].

According to [6,8] it is possible to note that industrial robots are a good choice to acquire data from sensors, mainly for the distance sensors which requires a considerable amount of data, allowing to perform repetitive operations with precision and speed, since probably it would be executed by humans with possible errors and in a slower way.

Within the context of mobile robotics the simulation is an important tool to test and develop applications, besides being a tool very useful in educational contexts. The simulation provides a virtual environment where it is possible to design and simulate tests in different conditions with several parameters and components, allowing fast robot software development, being useful not only in industry but also in multidisciplinary classes. Besides that, sometimes the hardware development is separate from software development and with the use of simulator the last one can be tested before the hardware is done [9,10].

In this work it is proposed a field of view analysis of a time of flight sensor which will be applied in a mobile robotics application in order to assist in the robot simulation inside a virtual environment. A previous analysis of the sensor for different colors tones and distances was already presented in a first paper [11].

This paper is structured as follows. The Sect. 2 explains how the sensor works and the Sect. 3 presents the setup applied to collect the data. The Sect. 4 is intended to present the data analysis and discussion about the field of view analysis. Lastly, conclusion and future work are presented.

2 Time of Flight Sensor

The time of flight sensor is a ranging module based on the ToF principle, which basically works illuminating an object with a modulated signal source and according to the time that the signal is reflected the distance can be measured (Fig. 1). This kind of sensor is very precise and compact, the sensing is narrow including a field of view of 25°, unlike sonars that bounce ultrasonic waves.

Usually there is a laser or a LED operating in a spectrum that human eyes can't see, near-infrared range approximately 850nm, and a sensor sensible to the same spectrum and to convert photonic energy to electrical current. This method presents good results to background light, besides that compact construction, easy-of-use and high accuracy. For these reasons it is very applied in many applications, including automotive and industrial fields [1,3,4].

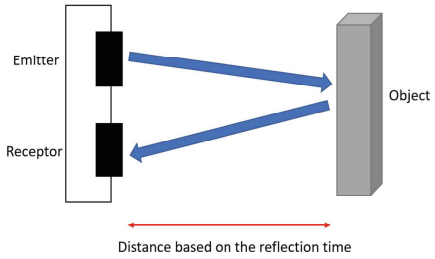

Fig. 1. Time of flight principle illustration.

In this paper, it was used the ToF sensor board VL53L0X from STMicroelectronics, which reach absolute distances for up to 2 m and it operates in three ranging modes, being them default mode, high speed, high accuracy and long range. Taking into account that the sensor will be applied in a mobile robot that is expected to have a high performance, giving its operating environment dynamics, therefore, the default mode, with a range timing about 30ms, is adequate to obtain a tradeoff between reactiveness and accuracy [2].

The long range is not interesting for the proposed application, since the measured distances will be up to a maximum of one meter. In high speed, accuracy is lost and noise is gained, and lastly in high accuracy the reactiveness is lost since the measurement is slower comparing to the other modes [2].

3 Setup for Acquiring Data

In this section it is described the setup created to acquire data from the ToF distance sensor. The Kassow's KR810 collaborative robot was used as a manipulator, performing repetitive and accurate movements. This robot has 7 axes, a payload of 10 kg and a reach of about 1.2 m [12].

The ToF sensor was attached to the robot, through a bracket made using 3D printing technology, as show in Fig. 2 a). In [11], it was confirmed that white color has the best results, due to its higher reflection, this color was chosen to perform the tests related to the field of view of the sensor. One test consisted to move horizontally over a step, as showed in Fig. 2 b), allowing to analyze the sensor and its field of view behavior face a disturbance, an abrupt difference in the measured distance.

Another test included the movement in different angles keeping the distance from the target, as showed in Fig. 2 c). The sensor was positioned to move sideways and to move back and forth in order to verify the sensor behavior and field of view for different sensor directions. Figure 2 d) presents the setup created to visualize the field of view through a camera sensitive to infrared signals and then compare to the datasheet information. In this last test the manipulator moved the sensor in different distances in z-axis and different angles, obtaining images captured for each position.

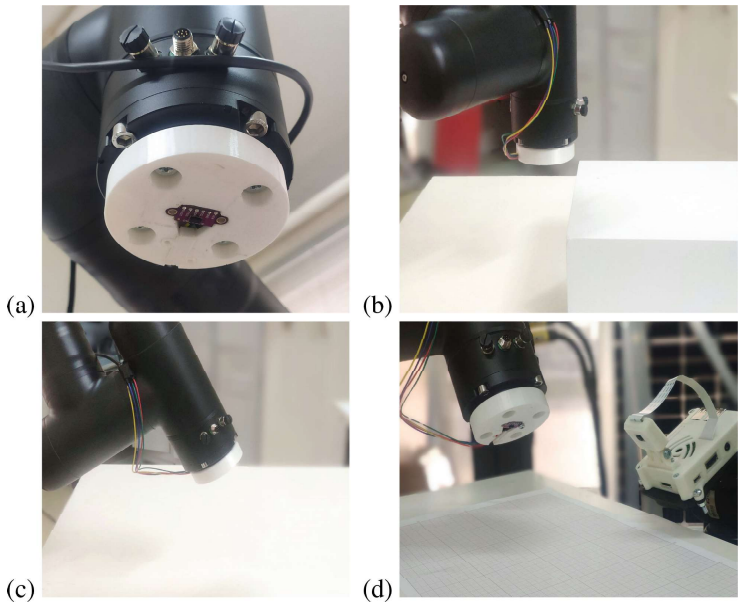

Fig. 2. Setup to acquire data. (a) Sensor attached to the robot (b) Manipulator moving the sensor horizontally over a step (c) Manipulator moving the sensor in different angles (d) Camera obtaining images from sensor field of view.

As explained in the previous section the sensor was configured in the default mode, providing distance measurement in a frequency 30 Hz. An Arduino Uno development board was applied to acquire the distance measurements from ToF sensor through I2C communication and to send the data to a computer through serial communication.

In the computer it was used the Lazarus software, an open source development tool, which uses the Free Pascal compilator and Pascal programming language [13]. The computer program executes the calculation of the manipulator trajectory, sends it to the robot controller and also receives data from robot, communicating using Modbus TCP protocol and Ethernet cable. It are also received the distances measurements from the microcontroller and stores it in a file, which will be applied in a posterior data analysis.

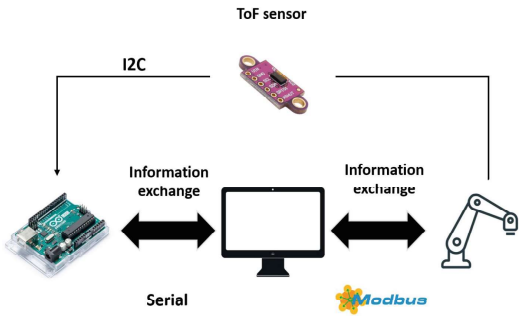

Fig. 3. System data flow.

Figure 3 represents the system data flow composed by the ToF sensor attached to the collaborative robot and connected to the Arduino microcontroller through I2C communication. The microcontroller sends information to the computer using serial communication and the computer communicates with the robot through modbus.

For the data analysis it was chosen to use python libraries, for processing and visualization of data sets. Python has been gaining audience and it is widely applied in data science and statistical modeling due to the stability, quality of documentation, variety of open source libraries, providing an interactive development environment and allowing data manipulation easily and fast [14,15].

4 Results and Discussion

There were performed three tests, being them the sensor moving horizontally over a step, moving in different angles keeping the distance from the target and a camera to visualize the sensor field of view while moving for different distances and angles. Three datasets were collected for each one of the three tests and 100 measurements for each position were captured. After performed the means and the offset correction of 21.81 mm, which was already calculated in the previous published paper [11], some graphics were generated in order to illustrate the sensor behavior.

4.1 Horizontal Movement over a Step

The manipulator was moved horizontally over a paper box with approximately 106 mm of height. The surface had white color and the sensor gone through 300 points, starting from 0 mm to 300 mm, with steps of 1 mm and the box positioned approximately in 155 mm, as illustrated in Fig. 4. This movement was performed for 6 different distances d from the target, from 50 mm to 300 m, with steps of 50 mm. The results from this test are illustrated in the Fig. 5 and the gray line represents from where the object is positioned.

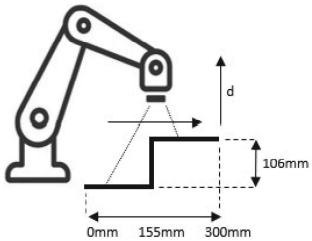

Fig. 4. Horizontal movement over a step.

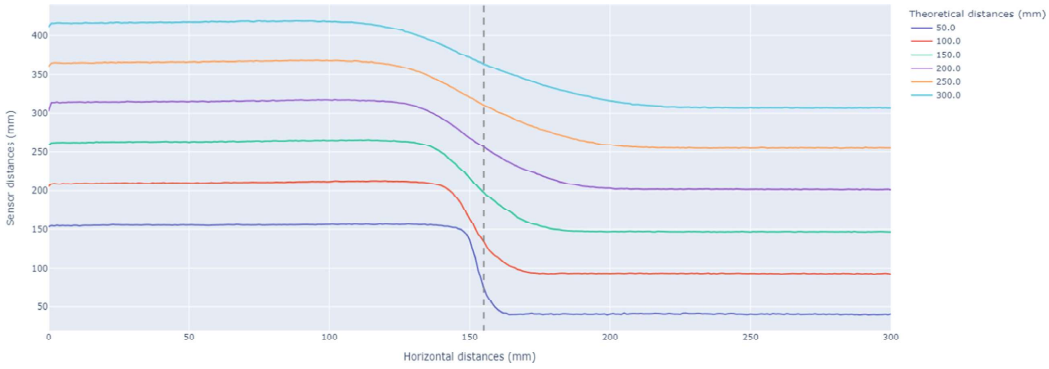

Fig. 5. Sensor moving horizontally over a step.

The caption presented in Fig. 5, represents the calculated distances from the box, which is positioned after the gray line. Therefore, for the measurements before the line, the box height (106 mm) is added, being consistent with the measurements obtained by the sensor, represented by the y-axis. With this test it is possible to see the sensor behavior related to the field of view on the edge of a height difference.

The results for this test were consistent and represented well the height difference facing a step. It is possible to note how the curve is sharp in distances close to the target and how it becomes soft according to the distance increase, which is expected once, greater the distance, greather the field of view opening and consequently, more points outside of the step edge are reached.

The distances between each height also kept themselves approximately the same in both sides, before and after the step, representing a good sensor response. The measurements distortion is a little noticeable according to the distance increase, being consistent with the results obtained in the previous published paper [11], which confirmed that the error grows with the distance increase.

4.2 Angle Effect

The manipulator performed movements, as illustrated in Fig. 6, for different distances d in z axe, from 50 mm to 300 mm, with steps of 50 mm. For each distance the sensor was moved in different angles, starting from $-25°$ to $+25°$, with steps of $2°$, keeping the distance d from the target, being it a table with a white plastic surface. The time of flight sensor was positioned to move back and forth (around x axe, changing α angle) and after sideways (around y axe, changing β angle), in order to verify differences in the measurements related to position of the infrared signal transmitter and receiver.

In Fig. 7 it is possible to visualize the curves inclination when the sensor is not totally perpendicular with the target plane, which is expected and represents the measurements errors due to the inclination. On the center of the graphic, at $0°$, the values are more accurate and closer to the theoretical distances. This

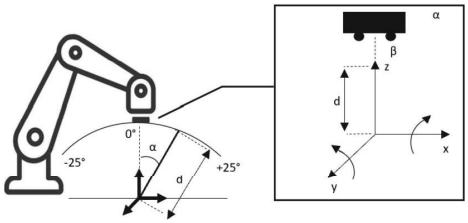

Fig. 6. Movement in different angles keeping the distance from the target.

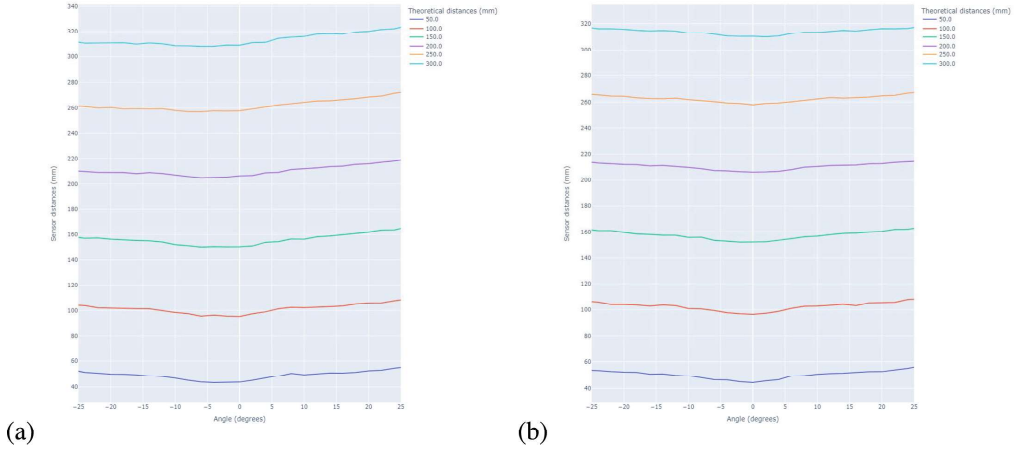

Fig. 7. Sensor moving in different angles. (a) Sensor moving back and forth (α) (b) Sensor moving sideway (β).

phenomenon occurs due to the fact that the slope affects the signal reflected and captured by the receiver that is not fully aligned.

It can be concluded that there is a difference between the sensor moves sideways or back and forth, it is notable that there is more symmetry in the sideway movement, represented in Fig. 7 b), than in the back and forth movement, represented in Fig. 7 a), on account of the position of sensor transmitter and receiver.

In Fig. 7 a), there is a distortion in the right side bigger than left side, which could have been generated by a slight inclination in the sensor board on the 3D bracket, affecting the position of the sensor transmitter and receiver or also a manufacturing asymmetry. A level meter was applied in order to guarantee the alignment of the 3D bracket with the robot flange.

4.3 Field of View Analysis

According to the VL53L0X datasheet, the sensor field of view is 25° [2] and using the concepts of trigonometry, it is possible to calculate the diameter of the view circle depending of the height. The calculation was based on the tangent of half of the viewing angle, since the value of the adjacent peccary (height) is known and it is obtained the opposite peccary, which, multiplied by two, represents the diameter of the sensor's viewing circle.

Table 1. Field of view diameters

Height (mm)	Diameter (mm)
50	22.2
60	26.6
70	31.1
80	35.5
90	40.0
100	44.4
110	48.8
120	53.3
130	57.7
140	62.2
150	66.6

Table 1 presents the diameters calculated based on the different heights that the manipulator moved the sensor and Fig. 8 illustrates the field of view increasing according these heights. The axes x and y represents the position of the viewing circle on the table plane and z axe, the heights from the target. Further away the sensor is from the target, greater your field of view, which, on the other hand, affects the increase in measurement error as well.

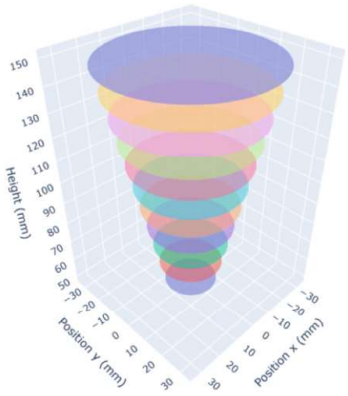

Fig. 8. Field of view according to different heights.

A Picamera [16], sensitive to infrared signal, was applied allowing to visualize the field of view of the infrared signal on the table and it was positioned a squared paper, in which each square includes a distance of 1cm (10 mm), in order to calculate the diameter of the circle and compare with the theoretical diameter. Figure 9 show the sequence of images captured by the camera at different heights.

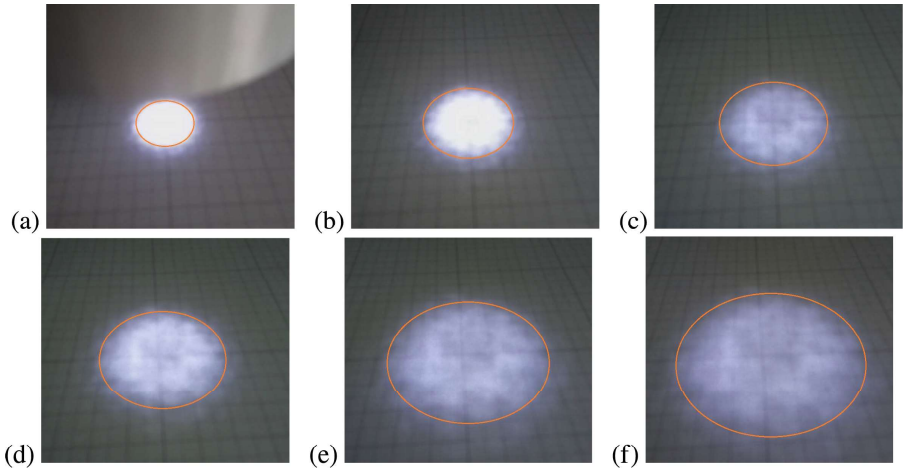

Fig. 9. Field of view according to different heights. (a) 50 mm of height (b) 70 mm of height (c) 90 mm of height (d) 100 mm of height (e) 130 mm of height (f) 150 mm of height

The results were consistent with the theoretical values, once at 50 mm of height the circle covered approximately 2 squares, being closer to the theoretical value of 2 cm (20 mm). At 70 mm reached about 2 full squares and half of square in each side, totalizing 30 mm and at 90 mm of height, the field of view covered 4 squares, representing 40 mm of diameter.

At 100 mm of height, the circle covered 4 squares and half, very close to the theoretical measurement of 44.4 mm. At 130 mm, approximately 5,5 squares were reached, totalizing 55 mm and at 150 mm of height, the circle covered just over 6 squares and half, being all the results presented in Fig. 9 coherent and very close to the measurements of Table 1.

It is also notable that, the circle becomes larger and harder to see as the height from the target increases, and consequently becoming increasingly difficult for the camera to capture, for this reason the tests were done at not so high distances.

Figure 10 represents other images captured by the camera when the manipulator moved the sensor in different angles keeping the height. This test was based in the sensor moving back and forth, that is, around x-axis and changing angle α. In these images the sensor was at a height of 100 m. It is clear the deformation of the field of view in Fig. 10 a) and 10 c), in which the angle inclination is not perpendicular with the target plane. This is expected, once the path for the reflected signal to reach the receiver is slightly longer due to the tilt of the transmitter and receiver of the infrared signal, becoming the circle closer to an ellipse.

Fig. 10. Field of view deformation due to angle inclination at 100 mm of height. (a) $+30°$ (α) (b) $0°$ (α) (c) $-30°$ (α)

5 Conclusion and Future Work

In this paper it was presented a field of view analysis of a time of flight sensor, which will be applied in a mobile robot. The analysis will be useful in simulation, which assists not only in the mobile robot development but also can be applied in educational contexts.

It was possible to analyze the sensor behavior while facing a disturbance, that is, an abrupt difference in the measured distances during the movement sequence, allowing to visualize how the curve of measurements become tenuous according to height increase, because the field of view is larger than for small distances, reaching more points and consequently more space outside the target's edge. For small heights the curve of measurements is more accentuated.

Through movements changing the inclination of the sensor, the best and more accurate results were obtained in $0°$ of inclination, that is, totally in perpendicular with the target plane, which is expected. Measurements variations were verified for another inclination angles, which occurs due to the fact that the slope affects the signal reflected and captured by the receiver that is not fully aligned.

It was also possible to verify that the sensor behavior is more symmetrical for a sideway sensor movement (β) than for a back and forth sensor movement (α), due to position effect of signal transmitter and receiver. This conclusion must be taken in consideration when the sensor will be used in the mobile robotics application. Besides that, the sensor configured in default mode, the best behavior was for short distances, which is totally enough for the proposed application.

A camera sensitive to infrared signals was used in order to visualize the field of view circle and then, to calculate the diameter comparing to the theoretical measurements. The results were excellent and coherent with the datasheet, because the calculation done about the diameter in the images captured by the camera matched with the theoretical diameters. Besides that, it was also possible to confirm the field of view distortion due to sensor inclination, once the path for the reflected signal to reach the receiver is slightly longer due to the tilt of the transmitter and receiver of the infrared signal.

For future work, tests and analysis with different light operating conditions and different types of surfaces will be performed. Besides that, the presented results will be applied in a simulation environment, in order to assist the development and tests of a mobile robot that uses this time of flight sensor.

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References

1. Li, L.: et al.: Time-of-flight camera–an introduction. Technical white paper, no. SLOA190B (2014)
2. Vl53l0x datasheet - stmicroelectronics. https://www.alldatasheet.com/datasheet-pdf/pdf/948120/STMICROELECTRONICS/VL53L0X.html?mo. Accessed 03 Jan 2022
3. Lindner, M., Schiller, I., Kolb, A., Koch, R.: Time-of-flight sensor calibration for accurate range sensing. Comput. Vis. Image Underst. **114**(12), 1318–1328 (2010)
4. Seiter, J., Hofbauer, M., Davidovic, M., Zimmermann, H.: FPGA based time-of-flight 3D camera characterization system. In: 2013 IEEE 16th International Symposium on Design and Diagnostics of Electronic Circuits & Systems (DDECS), pp. 240–245. IEEE (2013)
5. Campos, D., Santos, J., Gonçalves, J., Costa, P.: Modeling and simulation of a hacked neato XV-11 laser scanner. In: Robot 2015: Second Iberian Robotics Conference. AISC, vol. 417, pp. 425–436. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-27146-0_33
6. Gonçalves, J., Lima, J., Oliveira, H., Costa, P.: Sensor and actuator modeling of a realistic wheeled mobile robot simulator. In: 2008 IEEE International Conference on Emerging Technologies and Factory Automation, pp. 980–985. IEEE (2008)
7. Fuchs, S.: Calibration and multipath mitigation for increased accuracy of time-of-flight camera measurements in robotic applications (2012)
8. Malheiros, P., Gonçalves, J., Costa, P.: Towards a more accurate infrared distance sensor model. Manufacturing Systems Engineering Unit (2009)
9. Paulo, C., José, G., José, L., Paulo, M.: SimTwo realistic simulator: a tool for the development and validation of robot software. Theor. Appl. Math. Comput. Sci. **1**(1), 17–33 (2011)
10. Camargo, C., Gonçalves, J., Conde, M.Á., Rodríguez-Sedano, F.J., Costa, P., García-Peñalvo, F.J.: Systematic literature review of realistic simulators applied in educational robotics context. Sensors **21**(12), 4031 (2021)
11. Brancalião, L., Conde, M., Costa, P., Gonçalves, J.: Stochastic modeling of a time of flight sensor to be applied in a mobile robotics application (2022)
12. Kassow robots - kr810. https://www.kassowrobots.com/products/kr810/. Accessed 03 Jan 2022
13. Lazarus homepage. https://www.lazarus-ide.org/. Accessed 03 Jan 2022
14. McKinney, W., et al.: Pandas: a foundational python library for data analysis and statistics. Python High Perform. Sci. Comput. **14**(9), 1–9 (2011)
15. 15 python libraries for data science you should know. https://www.dataquest.io/blog/15-python-libraries-for-data-science/. Accessed 03 Feb 2022
16. Picamera release-1.13. https://picamera.readthedocs.io/en/release-1.13/. Accessed 06 Jan 2022