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Development of an IR Distance Calibration Tool Using a Wheeled Mobile Robot

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***Abstract*:-- One of the recognition tools used in the robotic researches is the IR distance sensor. The main reason of choosing this sensor is the availability in the market and affordable price. Besides IR distance sensors, laser scanning range finder is the other solution. Laser scanners can also be easily accessible in the market but the price of them may not be reasonable for the engineering students and individual researchers. The important challenge in the use of IR sensor is the calibration. Before adapting it into a real system, a calibration system and procedure should be created. Then, the calibration parameters are to be integrated into the system. To make a contribution in this subject, a calibration tool for IR sensors is developed in this study. The system developed includes an IR sensor, a 4-wheeled mobile robot and a laser scanner range finder. The mobile robot is driven by 2 dc actuators equipped with high resolution encoders. The control of the robot's motion is achieved by the use of motor controllers, encoder interface card, microprocessor and a computer. The laser scanner is directly connected to the base computer where the related data decoding processes are performed. The data coming from IR sensor, which provides distance data up to 5m, is processed in the microprocessor. The integration of the subsystems gives the opportunity to calibrate the IR sensor. The steps of the methodology proposed are given in detail in this paper.**

***Index terms:* IR Sensor, Calibration, Mobile Robot.**

I. INTRODUCTION

Mobile robots have been used in different areas in the last decade and their usage is dramatically increasing. The areas are broadening from industrial to defense use, from agricultural to unmanned ground operations. Mobile robots can perform their tasks with maximum accuracy and precision. They can work for long hours without any interruption. While they perform a task, they have to observe their surroundings, learn the current situation and predict the near future. According to the information that is collected from the working environment and processed for doing the tasks, the robot should be suited with some sensorial subsystems. They are like cameras, laser scanning range finders, ultrasonic sensors, infrared sensors, radars, sonars, etc. Choosing the appropriate sensors in a mobile robotic application depends on some conditions; budget, connection type, process time and load, programming requirements etc. The output accuracy is also the other factor during a proper sensor selection process. IR sensors are the ones used in mobile robotic applications due to their low-price, low-level programming requirements, low-level computational load and easy-to-use and easy-to-adapt capabilities. The only challenge in the use of IR sensors is the calibration procedure. They don't provide the distance output data in a regular form. In other words, the voltage output data is not proportional to the distance information. The voltage output is kind of exponential and should be understood just before a real use. The output should be calibrated then integrated into the real robotic system. In this study, an IR distance calibration tool is developed. The system is constructed based on an IR sensor, a laser scanning range finder and a 4-wheeled mobile robot. The mobile robot is driven two dc actuators on which high resolution encoders are mounted. The control of dc actuators is achieved by the use of motion controllers. The required commands are generated via an Atmel based microprocessor. In order to count the pulses coming from the high resolution quadrature encoders, an encoder interface card is also adapted to the system. The IR sensor used in this study can provide distance data up to 5m. To conduct verification tests, a laser scanning range finder having capability of reading distances up to 4m is run simultaneously. All communication and control issues are handled in a slave computer placed in the mobile robot. The laser scanner range finder and IR sensor are located in a fixed location and connected through a base computer. While the mobile robot is in motion, the required data is collected and the control processes are achieved simultaneously. The outline of this paper is constructed as follows: the next section is about the literature studies. Section 3 gives the information about the problem statement. The experimental system developed is introduced in Section 4. Experimental studies and their results are provided in Section 5. Conclusion and analysis of the study is given in the last section.

II. RELATED STUDIES

The literature studies can be briefly summarized as follows: An IR sensor calibration procedure is presented in [1]. IR sensor is mounted on a wheeled mobile robot. The obstacle positioned in different angles could be tried to detect. A mathematical representation is constructed to be used for calibration purposes. In [2], it is stated that in case calibration is not perfectly handled, the expected accuracy can't be obtained. To find a solution for such a problem, an infrared camera calibration approach is proposed. The system proposed involves an inexpensive calibration target and mathematical methodology. In [3], a methodology to combine the infrared sensors using a fixed network is introduced to be able to estimate the crop canopy conductance and evaporation rate. A calibration procedure is used first, then the sensors are integrated into the system developed. The system is experimentally tested and the results are presented. In [4], a digital method is proposed in order to remove the unwanted noises from the data coming from an IR sensor. The noise removal operation is one of the key factors in the calibration process; therefore, the gains obtained in the study can be integrated into the calibration systems. In [5], a technique for obtaining accurate motion of a shaft used in small automotive turbochargers is proposed. The system is developed based on infrared sensors. The methodology introduced is experimentally tested and verified. Results obtained in the experimental studies are presented. In [6], a study related to constructing a mathematical model and developing a calibration procedure for a tactile sensor used for robust grasping is introduced. The system developed is presented with the results of experiments. By this way required verifications are also provided. A short literature survey is presented above. As seen from the studies related to IR sensor calibration tools used in robotic applications, the calibration of IR sensors is the key factor for the accurate and precise control. Higher quality of the IR sensors makes available more precise feedback control. This affects the system performance, safe working area and proper model-based real-time applications.

III. PROBLEM STATEMENT

Mobile robots should be able to observe their surroundings to have information about the current state. The correctness and quality of the observation give ability to generate accurate reference trajectories, detect objects and obstacles and avoid doing crash/accident events. There are many different alternatives to find a solution for such objectives. They can be listed as cameras, laser scanner, ultrasonic sensors, infrared sensors, sonars, radars, etc. One of the easiest methods is to use IR sensors. So many literature studies related to IR sensors in different industrial applications can be found. The only challenge while using these sensors is the calibration. In this study, an easy-to-adapt calibration procedure is developed. The problem and the solution proposed are represented in the following figure.

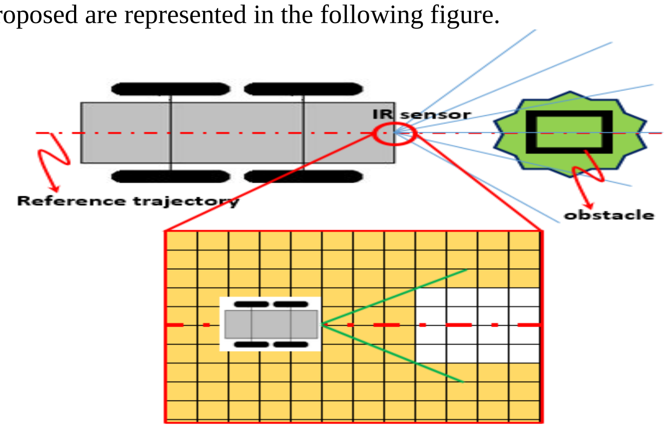

Figure 1: Problem statement representation

In Figure 1, a mobile robot tracks a reference trajectory. An obstacle is just located in its route. An IR sensor is mounted at the front-mid-center of the mobile platform. It scans the robot's surrounding during the motion. The obstacle is detected and the area highlighted with the green-colored-zone is marked in the map. The updated map is used to re-generate of the reference trajectory.

IV. EXPERIMENTAL SETUP

Experimental setup developed in this study consists of a 4-wheeled mobile robot. The wheel diameter is 12cm. Mobile robot is equipped with two dc motors which need 12-24V, 5A power. To achieve a good torque-speed relationship, 1:10 gearheads are coupled to the dc motors. High resolution quadrature encoders are also mounted on the dc motors so that angular position and angular velocity of the motor could be obtained. Motion control units (48V, 10A) are also used to control the dc motors. PWM or analog input can be used for driving the motion controllers used. Required commands are generated by the use of an Atmel based microprocessor. An encoder interface card is also adapted into the system so that high speed encoder data could be counted. The IR sensor used in this study can measure distances up to 5m. Its output is between 0 and 5V and processed using the microprocessor. A laser scanning range finder is also integrated into the system. By this way, real-time distance information could be collected from the system. The laser scanner used in this study works with 10Hz and gives data up to 4m. Besides the distance data coming from the laser scanner, dead reckoning that uses the encoders' data is also adapted to the system for getting distance covered during motion. DC motor control, IR sensor data process, high speed encoder reading and microprocessor coding algorithms are developed using C/C++ program. The decoding process of the laser scanner range finder is achieved using an environment that is

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developed under Matlab/Simulink. General views of the experimental setup are shown in Figure 2. The details of the sub-units are illustrated in Figure 2-top with zoomed-in-view. A plate is located at the front of the mobile robot in order to get the distance information (coming from both laser scanner and IR sensor) during the motion (Figure 2-bottom).

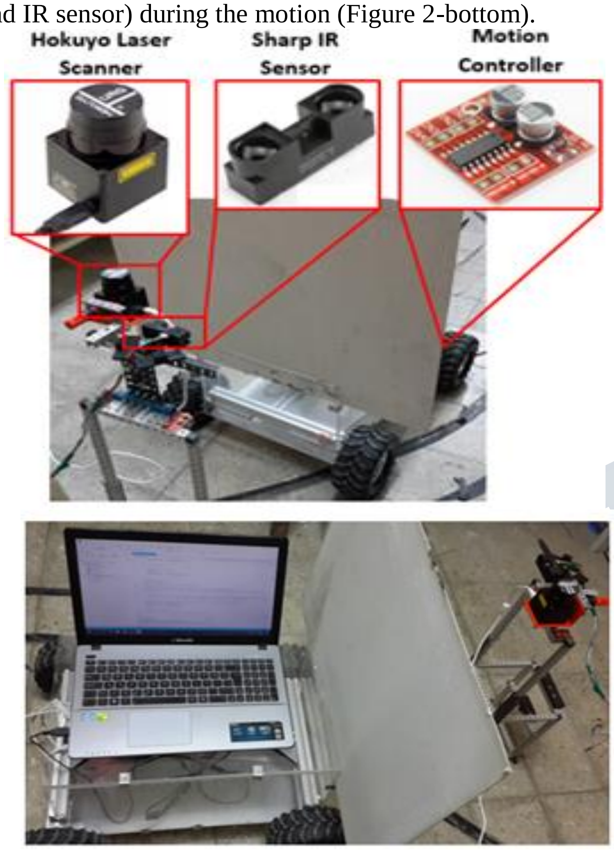

Figure 2: General views of the experimental setup

V. EXPERIMENTAL STUDIES AND CALIBRATION PROCEDURE

Mobile robot and the calibration system developed are tested on smooth-surface. The surface is inclination free. Mobile robot is commanded with a constant forward velocity in a straight reference trajectory. While the mobile robot moves in the desired route, the data coming from IR sensor, laser scanning range finder and encoders are collected. The laser scanner and encoders data are demonstrated in Figure 3. In this figure, measured laser scanning range finder data is shown with solid-blue-line. Right and left encoder data are separately presented. Total journey is about 4m and takes nearly 12s.

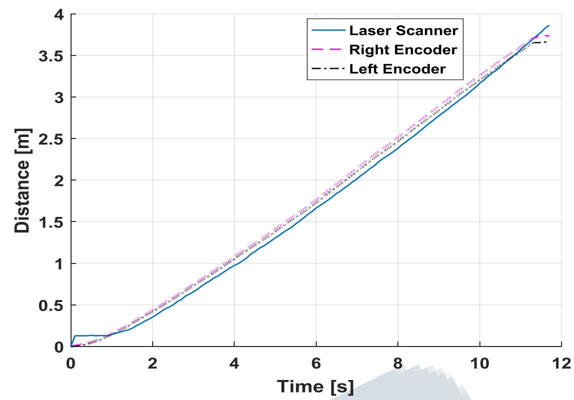

Figure 3: Data collected during the motion

The data coming from IR sensor is given with red-dots in Figure 4. In order to calibrate this data in a mathematical form, an exponential function is used to make a fit. The behavior of the fitted data is also shown in Figure 4 with blue-solid-line. The fitting equation is given in Equation (1).

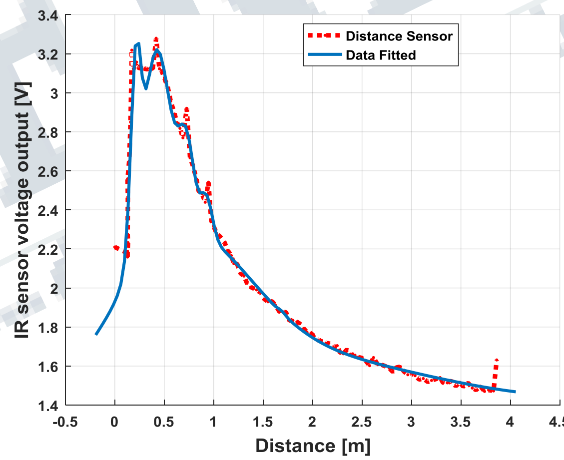

Figure 4: IR sensor data

$$y = \sum_{i=1}^{8} \left(a_i e^{-\left(\frac{x-b_i}{c_i}\right)^2} \right) \qquad (2)$$

where a1=1.01, b1=0.41, c1=0.20, a2=0.82, b2=0.21, c2=0.06, a3=0.42, b3=0.72, c3=0.11, a4=0.20, b4=0.92, c4=0.08, a5=0.01, b5=1.69, c5=0.05, a6=2.18e+05, b6=1339, c6=386, a7=0.77, b7=0.6394, c7=0.98, a8=0.28, b8=1.8, c8=1.8.

VI. ANALYSIS AND CONCLUSION

IR sensors are frequently used in automation and robotics applications. They are not so expensive and easily accessible in the market. Driving the data coming from an IR sensor may not need to have high level of mechatronics, robotics and signal processing knowledge. The only problem in the usage of IR sensors is the calibration. They should be calibrated before they are adapted into a system. In this study, it is aimed that an easy-to-use and easy-to-adapt calibration procedure is proposed. The calibration tool proposed includes an IR sensor, a wheeled mobile robot and a laser scanning range finder. The hardware units are combined into a programming environment and required calibration parameters are successfully obtained. Experimental results highlight that the calibration tool setup can be adapted into any robotic system which needs to use an IR sensor.

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