Bidimensional Control System through Successive Monitoring for Obstacles Identification

Flor Escuadra, Alonso Hurtado, Marie Imán, Luis Lino, *Students from Ricardo Palma University - Peru*
Advisor Mario Chauca*, member AOTS, IEEE, URP*.

Abstract

The next project is a two-dimensional positioning system of a vehicle. It is based on the usage of infrared sensors to detect and map the obstacles around it and thus to store in system memory a map of the surrounding area.
For this purpose, working with the variables angle and distance is needed and to acquire the required information from these , a number of infrared sensors which are above the vehicle are used, as well as the ability to rotate them to face different directions.
All variables must be processed in the control system which will be managed by a microcontroller, because of its great capacity to manage these information besides having the control system memory.

***Keywords*— Transistor, Photodiode, Sensor, Op-Amp, Angle, Algorithm, Step Motor.**

1. Nomenclature

USA : United States of America.
PIC : Peripheral Interface Controller.
Op-amp: Operational Amplifier

2. Introduction

Parking lots are places where collisions occur often because drivers are less concentrated on driving and more focused on finding a place to park. "[1]

According to a report published by the Department of Transportation and the U.S., in 2005:

- 9,650,000 vehicles were involved in crashes than 1 or 2 vehicles.
- Nearly 300,000 of these accidents are attributed to maneuvers that are commonly performed in parking lots:
  - 27.000 accidents occurred while entering on a parking lot and 198.000 occurred while driving backwards in reverse.
  - 65.000 accidents occurred when leaving a parking lot.

What is sought in this paper is to avoid collisions and that's why we thought about the implementation of this system which is located on the car and by the means of a circuit composed of a stepper motor and an infrared sensor both turning 360 degrees, the system will be able to locate obstacles, in this case cars and pedestrians, and allow it to have an idea of the surrounding place.

What is captured by the sensor is transmitted and processed in the PIC with this programming a mapping of the site can be accomplished. Knowing the distance where the obstacle is, and having the angle of rotation in the stepper motor we can mathematically solve and find the distance.
The parking lot will be divided into two parts: right and left each of 4 m. long and wide, giving a total length of 8x8 m. and if we divide our space into a grid of 16x16 tiles, each table will have a total length of 50 cm.

Once we know the distance, in the PIC programming we use 8 bits to map the left side of the parking lot in a block of memory addresses and a 8 bits more to map the right side in another block of memory, resulting in a table where we'll have two values, a logic "1" when the obstacles have been detected and a logic "0" in case that no obstacle has been detected, getting a response which can be visualized in a LED panel.

The system will use a microcontroller to receive information from sensors that detect how far the obstacles are.

"The step motor behaves the same way that a digital-analog converter and may be governed by impulses from logical systems, such as microcontrollers or computers". [2]

This work was supported in part by the Engineering Faculty of Ricardo Palma University.

F. Escuadra, A. Hurtado, M. Iman, L. Lino, students from the fourth year in electronic engineer is with the Ricardo Palma University, District Surco, Lima - 33 PERÚ (e-mail: 200616923@mail.urp.edu.pe, 200612640@mail.urp.edu.pe, 200616068@mail.urp.edu.pe, 200616076@mail.urp.edu.pe).

Adviser Mario Chauca is with the Ricardo Palma University, District Surco, Lima-33 PERÚ and Association for Overseas Technical Scholarship (e-mail: mchauca@mail.urp.edu.pe).

3. Project development

The two-dimensional positioning system consists of 3 stages. The first is conformed by a powerful infrared sensor and a stepper motor. This stage is responsible for generating the variables "distance to the obstacle" and "angle of rotation".

With these variables we can identify a point in the space surrounding the mobile.

The space can be represented as a plane graph with a width and length determined by the infrared sensor range.

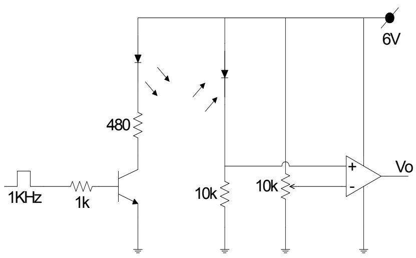

Figure 1. - Infrared sensor circuit

Figure 1 shows that this circuit is based on the principle of rebound of the infrared signal through the infrared LED and the reception of the phototransistor, this signal enters in the input of an op-amp and with a potentiometer on the other input, the Op-Amp would work as a comparator.

When the change in the phototransistor's signal is minimal, the op-amp will emit a positive signal as a pulse train command, the output will be a pulse train due to the frequency on the input of the transistor.

In the second stage takes place the generation of the plane, storing it in the memory of the microcontroller in two tables, one right and one left, which contain the respective positions according to a predetermined distance and angle.

Determination of surface properties:

When a beam of light hits a surface, a part of this is scattered or absorbed and the rest of the energy of light is reflected. Depending on the surface the light beam can be scattered, absorbed and reflected to some extent.

Obviously a black or very dark surface must absorb more energy from the beam that a white surface or much clearer one. Also, we know that a smooth, shiny surface reflect more energy than an uneven surface.

Figure 2 shows that the signal is reflected in all directions according to Lambert's cosine law.

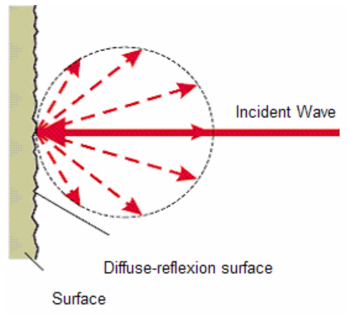

Figure 2. - Diffuse reflection

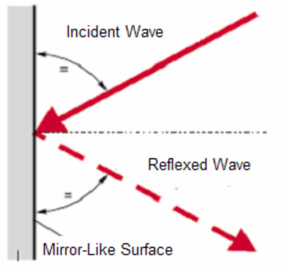

Figure 3. - Mirror-like reflection

In Figure 3, the angle of light beam reflected from the surface equals the angle of incidence. Both beams are in the same plane.

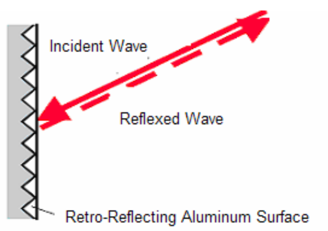

Figure 4. - Retro- reflection

The retro-reflection is the retro-reflected beam which is returned in the same direction it came from. This property is maintained within a range of directions of the incident beam.

Phong's model can provide a simplified description of these effects in four constants: C0, C1, C2 and n. Phong's equation for the energy intensity I, reflected from a surface is:

$$I = C_0(\vec{\mu}_s \cdot \vec{\mu}_n) + C_1(\vec{\mu}_r \cdot \vec{\mu}_v)^n + C_2 \qquad (1)$$

Where $\vec{\mu}_s$, $\vec{\mu}_n$, $\vec{\mu}_r$ y $\vec{\mu}_v$ are the light's source, the normal surface, reflected beam and the vector.

The angle between the source vector and the vector normal to the surface is α . Also, if one assumes that the emitter and receiver are in the same position, then the angle between the initial vector and the reflected vector is 2α .

Thus equation 1 becomes:

$$I = C_0 \cos(\alpha) + C_1 \cos^n(2\alpha) + C_2 \qquad (2)$$

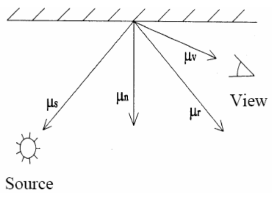

Figure 5. - Phong's model

The energy absorbed by the phototransistors is a function of intensity (I) with a total distance of (2l), and area (A) of the sensor.

$$E = \frac{IA}{(2l)^2} \qquad (3)$$

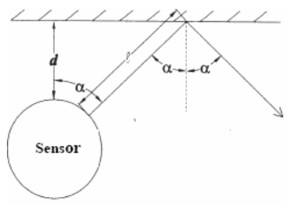

Figure 6.- Distance and sensor's angle.

L can be expressed in terms of d, a and the radius r.

$$\ell = \frac{d}{\cos(\alpha)} + r\left(\frac{1}{\cos(\alpha)} - 1\right) \qquad (4)$$

Combining the above equations and assuming C2=0, n=1 and A=constant, the energy absorbed by the sensor can be expressed as:

$$E = \frac{C_0 \cos(\alpha) + C_1 \cos(2\alpha)}{\left[\frac{d}{\cos(\alpha)} + r\left(\frac{1}{\cos(\alpha)} - 1\right)\right]^2} \qquad (5)$$

Finally C0, C1 indicates the infrared characteristics of an obstacle, one can determine the values by taking readings of the infrared sensor to known lengths (d) and angles (α). Once C0 and C1 are known, E can be obtained for a given angle.

Calculating the distance to an object:

After obtaining the surface properties and the relative angle of the surface, it becomes easy to calculate the distance.

$$d = r(\cos(\alpha) - 1) + \cos(\alpha)\sqrt{\frac{C_0 \cos(\alpha) + C_1 \cos(2\alpha)}{E}} \qquad (6)$$

In the second stage will proceed to map the plane generated in the memory of the microcontroller in two tables, one right and one left, which contain the respective positions according to a predetermined distance and angle.

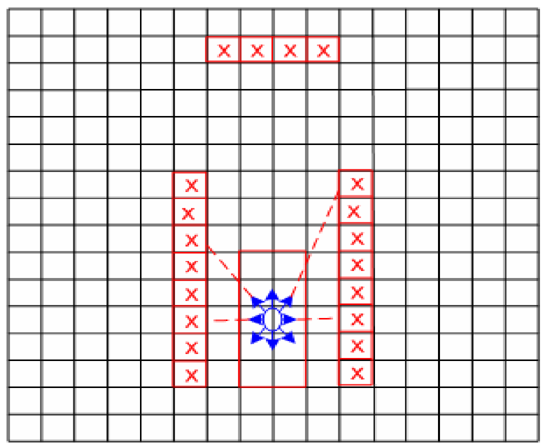

Figure 7.- Bidimensional positioning system

The area of each square of the imaginary map written in the memory depends of the sensor range and accuracy the one can give to it.

In the event that the sensor has a range of 4 meters, each square will have a small side of 8 / 16 = 50 inches. In case you want more accuracy measure, you must increase the number of bits [7 ... 0] and increasing memory locations for the left and right sides, as well as front and rear scope.

The third stage is responsible for moving the mobile according to environmental conditions and logic that are applying for correct movement.

4. Results

The detection level of obstacles is represented by a length and width of 16 squares, where each square represents 50cms by 50cms.

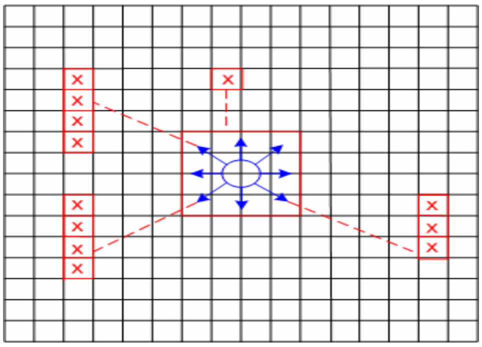

Figure 8.- Positioning map of how the sensor detects obstacles.

In this case, the obstacles are situated on the right and left side of the block which represents the infrared sensor that will detect the distance of the obstacle, this sensor will use a motor that will rotate the block, knowing that this sensor is very quick to detect distances of the obstacles, it means that it possesses a higher speed that will allow that the 360º loop that the motor will do, the sensor is going to make a sweep that will detect any obstacles that is around it and a maximum distance of 4 meter from it.

Each obstacle identified is displayed in the microcontroller memory as one bit, and if there is any hindrance simply keep the bit to zero. As shown below:

Table 1. - Bit's map of the positioning system

ADD	a7	a6	a5	a4	a3	a2	a1	a0
00000	0	0	0	0	0	0	0	0
00001	0	0	0	0	0	0	0	0
00010	0	0	0	0	0	0	0	0
00011	0	0	1	0	0	0	0	1
00100	0	0	1	0	0	0	0	0
00101	0	0	1	0	0	0	0	0
00110	0	0	1	0	0	0	M	M
00111	0	0	0	0	0	0	M	M
01000	0	0	0	0	0	0	M	M
01001	0	0	1	0	0	0	M	M
01010	0	0	1	0	0	0	0	0
01011	0	0	1	0	0	0	0	0
01100	0	0	1	0	0	0	0	0
01101	0	0	0	0	0	0	0	0
01110	0	0	0	0	0	0	0	0
01111	0	0	0	0	0	0	0	0
10000	0	0	0	0	0	0	0	0
10001	0	0	0	0	0	0	0	0
10010	0	0	0	0	0	0	0	0
10011	0	0	0	0	0	0	0	0
10100	0	0	0	0	0	0	0	0
10101	0	0	0	0	0	0	0	0
10110	M	M	0	0	0	0	0	0
10111	M	M	0	0	0	0	0	0
11000	M	M	0	0	0	0	0	0
11001	M	M	0	0	0	0	1	0
11010	0	0	0	0	0	0	1	0
11011	0	0	0	0	0	0	1	0
11100	0	0	0	0	0	0	0	0
11101	0	0	0	0	0	0	0	0
11110	0	0	0	0	0	0	0	0
11111	0	0	0	0	0	0	0	0

Where the letter M represents the space occupied by the mobile in this case is four by four squares occupied each square is represented by a distance of 50 cm, so that would occupy the mobile long as two meters wide, for this case have seen the results in Table II as well as in Figure 8, so that depending on the position of obstacles will have to appreciate the distance of the object which is in memory of the microcontroller through binary code.

It is noteworthy that "M" as the position where the mobile value in the memory of the microcontroller will be in zero in binary, since this is the central point in which they intend to make the measurement.

5. Conclusions

- The two-dimensional positioning system will allow automatic control of a mobile in a surrounding space for applications such as automatic parking lot, or remote military reconnaissance systems.
- Thanks to the system that has sensors around, we can see that in our environment, also has a distance meter that the mobile can make a decision on how to mobilize.
- We may also use other components in addition to infrared light, which would become the ultrasound, in any case, it would have to work longer with the speed of light, but with the speed of sound.
- The receiver voltage changes when it affects the infrared light is minimal, in the order of mill volts, so we use a opamp, in order to amplify this signal and treat it in the best possible way.

6. Recomendations

- The color of the object to be detected also influences the detection distance. The white is detected at greater distances than black.

- If used as an ultrasound sensor, should be taken into account its speed compared to the light and the propagation of light can be directed, but the sound is not as this tends to spread like a wave.

7. Acknowledgments

The authors gratefully acknowledge the contributions of Ricardo Palma University, whose rector is PhD. Ivan Rodriguez, the Faculty of Engineering, whose dean is PhD. Leonardo Alcayhuaman, the Circuits and Devices Laboratory, whose leader is Ing. Rafael Taipe, the entire staff of engineers and to our advisor and professor Ing. Mario Chauca

8. References

Books:

- A. Sedra y K. Smith, "Circuitos Microelectronicos", 5ta ed., México: McGraw-Hill, 2006, pp. 210-211 y 419-420.
- Boylestad, Robert L.: "Electrónica: Teoría de Circuitos", 6ta ed., Editorial Prentice Hall, 1997 p. 130.
- Antonio Máximo, Beatriz Alvarenga (2004). *Física General*. México D.F.: Oxford University Press. ISBN 970-613-147-7.
- Robert Resnick, David Halliday (2004). *Física 4ta. Edición Vol. 1* (en Español). SECSA, México. ISBN 970-24-0257-3.
- P.M Novotny, N.J. Ferrier, "Using infrared sensor and the Phong illumination model to measure distances". Conferencia Internacional sobre Robótica y Automatización. Detroit, MI, vol. 2, April 1999, pp. 1644-1649.
- G. Benet, F. Blanes, J.E. Simo, P. Perez, "Using infrared sensors for distance measurement in mobile robots". Jornada de Robótica y sistemas autónomos, vol. 10, 2002, pp. 255-266.

Links:

- [1] Seguridad en estacionamientos [web headquarters] * México. [Access in October 30 - 2009]. La seguridad en los estacionamientos es importante para todos México [approximately 2 screens]. Available in: http://www.gnrtech.com.mx/seguridad_en_estacionamientos.php
- [2] Neoteo [web headquarters] * España: Ariel Palazzesi; 7 de mayo del 2008 [access in October 29 - 2009]. Motores paso a paso [approximately 3 screens]. Available in: http://www.neoteo.com/motores-paso-a-paso.neo

9. Biographies

Flor Escuadra (November 18 - 1989, Lima - Peru) student of Ricardo Palma University studying the 4th year of Electronic Engineering career.
Finalist of the contest in INTERCON 2008, Trujillo – Peru.
Exponent in V FOINTEC 2008 Ica – Peru.
IEEE society Publication, ISBN 978-0-7695-3587-6 of CONIELECOMP 2009 Puebla –Mexico.
Finalist of the contest in CONEIMERA 2009 Cuzco – Peru.

Alonso Hurtado (May 19 - 1989, Lima - Peru) student of Ricardo Palma University studying the 4th year of Electronic Engineering career.
Finalist of the contest in INTERCON 2008, Trujillo – Peru.
Exponent in V FOINTEC 2008 Ica – Peru.
IEEE society Publication, ISBN 978-0-7695-3587-6 of CONIELECOMP 2009 Puebla –Mexico.
Finalist of the contest in CONEIMERA 2009 Cuzco – Peru.

Marie Imán (August 22 - 1989, Piura - Peru) student of Ricardo Palma University studying the 4th year of Electronic Engineering career.
Finalist of the contest in INTERCON 2008, Trujillo – Peru.
Exponent in V FOINTEC 2008 Ica – Peru.
IEEE society Publication, ISBN 978-0-7695-3587-6 of CONIELECOMP 2009 Puebla –Mexico.
Finalist of the contest in CONEIMERA 2009 Cuzco – Peru.

Luis Lino (December 4 - 1988, Lima - Peru) student of Ricardo Palma University studying the 4th year of Electronic Engineering career.
Finalist of the contest in INTERCON 2008, Trujillo – Peru.
Exponent in V FOINTEC 2008 Ica – Peru.
IEEE society Publication, ISBN 978-0-7695-3587-6 of CONIELECOMP 2009 Puebla – Mexico.
Finalist of the contest in CONEIMERA 2009 Cuzco – Peru.