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Investigación

Remote Control of a Robotic Arm via Bluetooth

Gama H. Manuel et al.

Investigación

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Marvin Ortiz, et al.

Por la divulgación de la ciencia y la tecnología

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Universidad Autónoma de Zacatecas

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Gerardo Miramontes de León

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Gerardo Miramontes de León
Universidad Autónoma de Zacatecas
López Velarde 801, Centro
98000 Zacatecas, Zac. México

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Remote Control of a Robotic Arm via Bluetooth

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Este proyecto consiste en la aplicación de la tecnología de IEEE 802.15.1 para el control de un brazo robótico de dos ejes a través de dos palancas de mando. Este sistema implementa una comunicación Bluetooth con dos módulos de Bluetooth, un transceptor incorporado AppMod EB500 y un módulo Easy Bluetooth de Parallax, como los principales controladores, utiliza dos microcontroladores Parallax Propeller ProRPM. El usuario indica con las palancas de mando cómo cada uno de los tres ejes que se desplazan desde una distancia a otra, estas órdenes viajan a través de un circuito ADC al primer microcontrolador a través de una conexión vía Bluetooth y al segundo microcontrolador que decodifica los comandos y envía la información directamente a los servomotores que mueven cada eje. Para evitar cualquier movimiento no deseado de que no fue ordenado por el usuario usando las palancas de mando, un controlador PID digital se implementó también el uso de dos potenciómetros acoplados a dos de los ejes del brazo robótico. En conclusión, tenemos un brazo robótico que es controlado por un microcontrolador Parallax Propeller que utiliza la tecnología Bluetooth para recibir datos de otro microcontrolador Parallax Propeller que decodifica los comandos del usuario mediante dos joysticks analógicos.

INVESTIGACIÓN

Una técnica de calibración axial para un sistema de medición 3D

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por Marvin Ortiz, et al.

En el presente trabajo se describe una técnica para llevar a cabo la calibración axial en un sistema de medición 3D por proyección de franjas. La propuesta de calibración hace uso de una técnica temporal de cálculo de fase y la técnica de aproximación polinomial por mínimos cuadrados para modelar la correspondencia entre fase y desplazamiento en z . Se presentan varios resultados de mediciones realizadas con objetos reales.

Número especial 1

EN este número especial se incluyen dos trabajos que fueron presentados en el ENINVIE-2010. El Encuentro de Investigación en Ingeniería Eléctrica se ha venido celebrando desde el año 2004, por cinco años consecutivos hasta el 2008, cuando se decidió celebrarlo cada dos años. Así en el 2010 se celebró el sexto ENINVIE.

En este número y en el próximo se presenta una selección de trabajos. Sólo se han seleccionado dos de ellos porque ciertamente no resulta práctico incluir más, pero se espera que los que han sido seleccionados cumplan su misión de difusión.

El primero trabajo trata del control a distancia utilizando la tecnología Bluetooth. El segundo trabajo presenta un trabajo sobre medición tridimensional de objetos. Ambos trabajos resultan muy apropiados para esta revista que promueve la ciencia y la tecnología.

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correo-e: gmiram2002@yahoo.com

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Remote Control of a Robotic Arm via Bluetooth

Gama H. Manuel, Villaseñor G. Isaí, Mondragón C. Carlos, Dr. Moisés Sánchez Adame, M.C. Adolfo Esquivel Martínez

Control remoto de un brazo robótico vía bluetooth

Recibido: enero 6, 2010

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Palabras clave: Brazo robótico; control; bluetooth

Abstract:

This project involves the implementation of the IEEE 802.15.1 technology on the control of a two-axis robotic arm through two joysticks. This system implements a Bluetooth communication using two modules of Bluetooth, an Embedded Blue Transceiver AppMod EB500 Module and an Easy Bluetooth Parallax Module; as the main controllers, it uses two Parallax Propeller ProRPM microcontrollers. The user indicates with the joysticks how each of the three axes should move from a distance to another; these orders travel from an ADC circuit to the first microcontroller which are sent throughout a connection of Bluetooth communication to the second microcontroller, which decodes the commands and sends the information directly to the servomotors that move each axis. To avoid any undesired movement that was

not commanded by the user using the joysticks, a digital PID controller was also implemented using two feedback potentiometers attached to two of the axes of the robotic arm. In conclusion, we have a Robotic Arm that is controlled by a Parallax Propeller microcontroller that uses Bluetooth technology to receive data from another Parallax Propeller Microcontroller that decodes the user's commands using two analog joysticks.

Keywords: Robotic arm; control; bluetooth

S

INCE the dawn of humanity, a fundamental issue regarding the development of progress and evolution has been the ability to communicate with one another to progress.

The main principle of establishing communication is through speech and written language, which is based on the relationship between a sender, a message and a receiver. But technology today does not only refer to the communication of language, it tries instead to address a larger application: the data transmission. Given this need are emerging computer networks like the intranet, extranet and the Internet [1].

Therefore, the application that takes place within this project is the use of computer network communications technology as a demonstrative project in which the purpose is to be able to communicate two microcontrollers using Bluetooth technology, and interchange control instructions between them to manipulate a Robotic arm using analog joysticks controllers.

PRINCIPLES OF DESIGN

BLUETOOTH MODULES AND SERIAL COMMUNICATION

BLUETOOTH MODULES

Bluetooth wireless technology is a short-range communications technology. This was designed to replace the cables connecting portables and or fixed devices using radio frequency, while maintaining high safety standards. The key features of Bluetooth technology are robustness, low power and low cost. The Bluetooth specification provides a standard structure for a wide range of devices that can connect and communicate with each other wirelessly.

Bluetooth technology has achieved global acceptance such that any Bluetooth enabled device, almost everywhere in the world, can connect to other Bluetooth devices in range-wide [2].

**Bluetooth wireless technology
was designed to replace the
cables connecting portables and
or fixed devices using radio
frequency**

The modules that were used for the project were the AppMod EB500 Transceiver Embedded Blue Parallax Module, and the Easy Bluetooth Parallax Module, which both provide Bluetooth connectivity for microcontroller applications.

To simplify the Bluetooth connection between the two microcontrollers, we used only the Bluetooth Technology to transmit and receive the signals wirelessly, but the real protocol made within the technology was the traditional RS-232 Full Duplex Serial Communication.

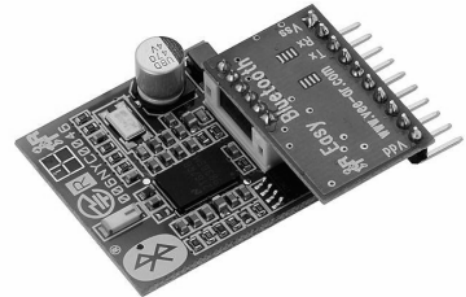
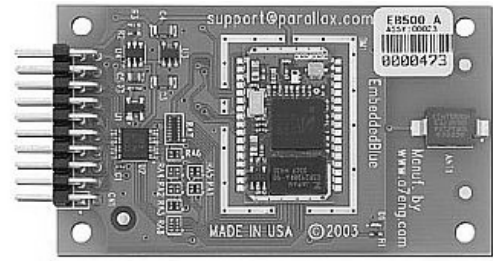


Figura 1. Embedded Blue Transceiver AppMod EB500 and Easy Bluetooth Parallax Module.

SERIAL COMMUNICATION

Serial communication is the most common low-level protocol for communicating between two or more devices. Normally, one device is a computer, while the other device can be a modem, a printer, another computer, or a scientific instrument such as an oscilloscope or a function generator. As the name suggests, the serial port sends and receives bytes of information in a serial fashion – one bit at a time. These bytes are transmitted using either a binary format or a text (ASCII) format. Over the years, several serial port interface standards for connecting computers to peripheral devices have been developed. These standards include RS-232, RS-422, and RS-485 – all of which are supported by the serial port object. Of these, the most widely used standard is RS-232, which stands for Recommended Standard number 232.

The current version of this standard is designated as TIA/EIA-232C, which is published by the Telecommunications Industry Association. However, the term “RS-232” is still in popular use, and is used in this article when referring to a serial communication port that follows the TIA/EIA-232 standard. RS-232 defines these serial port characteristics:

- The maximum bit transfer rate and cable length.

- The names, electrical characteristics, and functions of signals.
- The mechanical connections and pin assignments.

Primary communication is accomplished using three pins: the Transmit Data pin, the Receive Data pin, and the Ground pin. Other pins are available for data flow control, but are not required. [3]

The communication made by the two Bluetooth devices was segmented in a package that contains 6 words of data. The first, third, and fifth data were the data that indicated which axis was moving, while the second, fourth and sixth data were the data that indicated the movement of the servo motors. There were 3 main words that were reserved to contain the information of the movement of the servo. These main words were the numbers 0, 1 and 255; for example, if we wanted to move the servo that corresponded to the X axis, we send a 0 to understand that the reading from the ADCs corresponded to that specific axis, while we used a 1 for the Y axis and the 255 for Z axis for grip arm. The receiver had an algorithm to identify (decode) the command that was sent, and then, it transferred the data to a variable that was used to move that specific servo motor.

ANALOG JOYSTICKS CIRCUIT WITH ADCs

To control the robotic arm, a pair of two-axis joysticks was used, similar to analog joysticks controllers used for the controllers of video game consoles. Each joystick internally consists of an arrangement of two 100 K Ω potentiometers. The directional movements of the two axes of the robot were controlled by one joystick, while the second was used to control the arm grip mechanism that gave the arm the possibility to grab small objects of less than 400 grams of weight.

Because the output signals of the potentiometers of the joysticks are analog, we had to convert these signals in a digital form to be processed by the microcontrollers. In order to transform the analog signal to a digital signal, three ADC0831 integrated circuits were used.

DIGITAL PID CONTROLLER

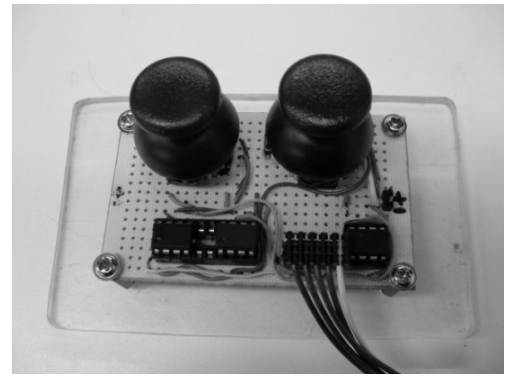


Figura 2. Control Joystick with ADC converters.

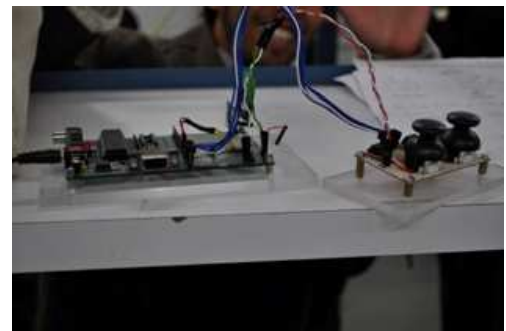


Figura 3. Final Joystick Controller.

PID THEORY

Proportional-Integral-Derivative (PID) control is the most common control algorithm used in the industry and has been universally accepted in industrial control. The popularity of PID controllers can be attributed partly to their robust performance in a wide range of operating conditions and partly to their functional simplicity, which allows engineers to operate them in a simple, straightforward manner. [4]

Proportional-Integral-Derivative control is the most common control algorithm used in the industry and has been universally accepted in industrial control



Figura 4. Implementing de two feedback potentiometers for use with the digital PID.



Figura 5. The Parallax Continuous Rotation Servo used in the project.

IMPLEMENTATION OF THE DIGITAL PID ON THE PROJECT

In order to have control of undesirable movements of the robotic arms that are not originated by the user's joysticks movement, a digital PID controller was implemented in the program of the microcontroller that controls the servomotors of the robotic arm. To have a feedback of the position of the main axis (X and Y), two feedback potentiometers were implemented in the gears of the two axes. The only limitation about this implementation was that the potentiometers don't turn 360 degrees, therefore, the two axis were limited to the physical limit of the two potentiometers.

To implement the PID control, as explained above, we used two potentiometers to read the set point of the last position of the arm. For example, the uC connected to the arm read the position data from the uC that had the Joysticks, and while the joysticks were moving, the PID method was not enabled. In the other case, when the values of any joystick were 127 (center position), a Boolean variable becomes true and then the uC that had the arm started to read the values on each of the two feedback potentiometers that were implemented for the feedback control. These values were stored in two variables and they become the set point of the PID. If any undesirable disturbance was made by any external force that had the sufficient force to move the position of the arm, the PID method will send the a code that will generate a movement to compensate that external movement or disturbance; if the variable becomes false again (this change could only occur if there is a change in the values of any joystick received by the uC) the PID becomes idle, and so on.

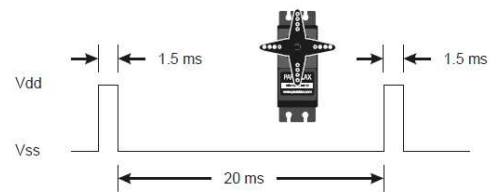


Figura 6. The servo motor is in the center position when the length of the pulse is exactly 1.5ms between the 20 ms pause.

PARALLAX CONTINUOUS ROTATION SERVO

The Parallax Continuous Rotation Servo is a small servo motor that uses 4 to 6 V DC to operate, and a simple communication with a PWM capable device (such as the microcontroller) is done by connecting the PWM pin that each servomotor has (along with the other two pins: ground and Vcc).

The Parallax Continuous Rotation Servo is controlled through pulse width modulation, where the rotational speed and direction are determined by the duration of the pulse. In order for smooth rotation, the servo needs a 20 ms pause between pulses. Below is a sample timing diagram for a centered servo.

As the length of the pulse decreases from 1.5 ms, the servo will gradually rotate faster in the clockwise direction, as can be seen in the figure below:

Likewise, as the length of the pulse increases from 1.5 ms, the servo will gradually rotate faster in the counter-clockwise direction, as can be seen in the figure below [5]:

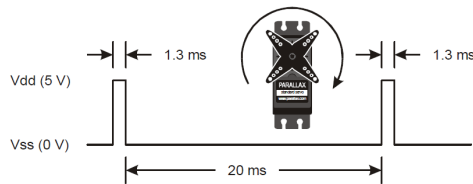


Figura 7. The servo motor is rotating to the right side when the length of the pulse is 1.3 ms or less between the 20 ms pause.

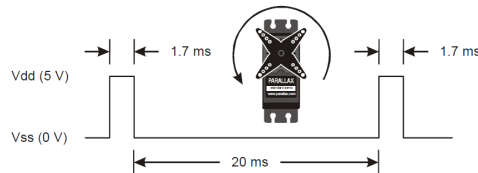


Figura 8. The servo motor is rotating to the left side when the length of the pulse is 1.7 ms or more between the 20 ms pause.

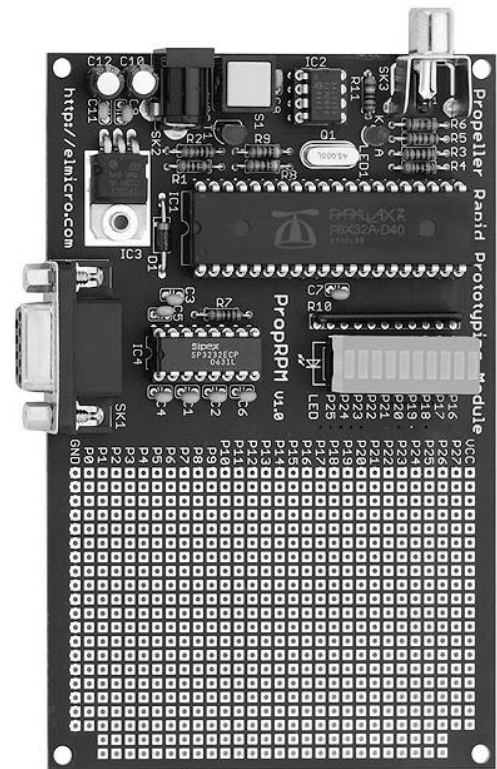


Figura 9. Propeller Microcontroller ProRPM.

PARALLAX PROPELLER PRORPM MICROCONTROLLER

The microcontroller that was used in this project was the Propeller Rapid Prototyping Module (ProRPM), which is used as a high quality solution for project prototyping. The Propeller Microcontroller has eight cores inside, so it can process 8 simultaneous processes at the same time, while the programming languages that it supports are SPIN (A parallax programming language) and Assembly Language. For the purpose of the project, SPIN language was used because of the flexibility and ease of use it presents against assembly language. The ICs are all socketed, making it easy to replace parts if necessary. No extra hardware is required to program the microcontroller, only a DB-e Serial port cable is required to connect the microcontroller to a PC using the integrated RS- 232 interface.

MICROCONTROLLER PROGRAMS

PROGRAM OF JOYSTICK CONTROLLER

First, the program initializes with the constants to be used, as well as the output and input pins, the baud rate used to

transmit the serial signals and the clock signal. Then, the variables to be used are specified in order to transmit and receive the data from each of the axes. Then, a call to use the object Full Duplex Serial is defined, which is an object library that will be used to make the serial communication. This library is property of Parallax. Then, the main program is defined, in which the Bluetooth communication is initialized, the variables needed are defined, and finally, the methods leer and sendValues are called in order to read the digital signals from the ADCs and to send the values thru the Bluetooth Module.

```

PUB Main
  'Inicializar puerto bluetooth
  bluetooth.start (RX_PIN, TX_PIN, 0, BAUD_RATE)
  'Conectarnos de este micro
  ' al otro por bluetooth
  'waitcnt(cnt + 160_000_000)
  'bluetooth.str(string
  ("con 00:0c:84:00:75:c2"))
  'bluetooth.tx(13)
  'waitcnt(cnt + 400_000_000)
  'Inicializar ADC0831's
  dira[DX] := 0
  dira[DY] := 0
  dira[DZ] := 0
  outa[CS] := 1
  dira[CS] := 1
  outa[CLK] := 1
  dira[CLK] := 1
  prevX := 0
  prevY := 0
  prevZ := 0
  repeat
  leer
  'invertir eje Y
  dataY := -1*dataY + 254
  'Reservar los valores
  0,1,255 if(dataX < 2)
  dataX := 2
  if(dataY < 2) dataY := 2
  if(dataZ < 2) dataZ := 2
  if(dataX > 254) dataX := 254
  if(dataY > 254) dataY := 254
  if(dataZ > 254)
    dataZ := 254 sendValues

```

Then, the method leer is defined, which will be the one to be used to read the signals from the ADCs. In order to have the highest efficiency possible, the connections Clock and Control had to be used in order to sample the data from the axes in the shortest time possible.

```

PRI leer
  dataX := 0
  dataY := 0
  dataZ := 0
  outa[CS] := 0
  outa[CLK] := 1
  outa[CLK] := 0
  repeat 8
  dataX <<= 1
  dataY <<= 1
  dataZ <<= 1
  outa[CLK] := 1
  outa[CLK] := 0
  dataX += ina[DX]
  dataY += ina[DY]
  dataZ += ina[DZ]
  outa[CS] := 1

```

Finally, a private method called sendValues is created, which does the primary function to send the data to the

Bluetooth module towards the other microcontroller. The other microcontroller is the one that establishes the Bluetooth connection between the two; therefore, the data is automatically sent once the circuit is turned on.

```

PRI sendValues
  IF prevX <> dataX
  bluetooth.tx(dataX)
  IF prevY <> dataY
  bluetooth.tx(dataY)
  IF prevZ <> dataZ
  bluetooth.tx(dataZ)
  prevX := dataX
  prevY := dataY
  prevZ := dataZ

```

PROGRAM OF ROBOTIC ARM MICROCONTROLLER

First, all the constants are defined:

-
- CLK is the clock to be used to time the ADC converters in order to synchronize them;
- CS is the control to be used in the ADC converters to determine the time that will be triggered in order to release the converted signal to the microcontroller;
- ADCx and ADCy, which are the inputs of the digital input of each of the ADC converters from the two feedback potentiometers used for the digital PID controller;
- centro (Center) is the constant that simplifies the center position of the feedback potentiometers used for the PID;
- PWM1, PWM2 and PWM3 are the output pins used to output the PWMs that control the servomotors;
- from gainX to dt, are constant needed for the operation of the digital PID controller;
- minimo is the constant that helps remember that the this value is the one needed for the servomotor to rotate complete to its left side continuously;

- `centrar` is the constant to remember the center PWM frequency to center the servomotor, or to stop it;
- `escala` is the resolution or scale used for the transformation of the analog signal that the potentiometers output to the ADC (this constant was calculated by dividing 255, which is the maximum data that the ADC could output because it is an 8 bit converter, divided by 8, which are the total bits used for one conversion);
- `veinteMs` is the constant used for the time off (is calculated by dividing the 80 MHz frequency in which the microcontroller runs by 20 microseconds, which is the time that is needed to control the time off of the servomotors);
- `RX_PIN` and `TX_PIN` are the Receive input and the Transmit output pins used for the Bluetooth communication;
- `BAUD_RATE` is the constant used for the Baud Rate that the Bluetooth communication uses;
- finally, the constants `_clkmode` and `_xinfreq` determine the clock used for the microcontroller to operate and the sample frequency used for the input pins.

Then, the variables to be used are defined:

- `currentPointX` and `currentPointY` are the current points used for the two digital PID controllers
- `setPointX` and `setPointY` are the set points used for the two digital PID controllers
- `salidaPIDx`, `salidaPIDy` and `salidaPIDz` are the PID outputs for each axis
- `data` is the variable used to determine the axis to move (it is used for the Bluetooth connection: 0 is used for the X axis, 1 for the Y axis and 255 for the grip arm)
- `dataX`, `data Y` and `data Z` are the variables that represent the bytes that have the information of the movement of each of the joysticks used on the other microcontroller to position the servomotors
- `salidaX`, `salidaY` and `salidaZ` are the variables used for the value of the PWMs to output to each of the three servomotors

- from `cogStack0` to `cogStack4` are the array variables used for each new core that the microcontroller initializes to simultaneously make different processes.
- `controlarX`, `controlar Y` and `controlar Z` are the Boolean variables used to disable the PID digital controllers or to activate them

Then, the Full Duplex Serial library is called in order to use the Bluetooth connection. This same library is used in the other microcontroller to communicate the serial signal via Bluetooth.

Then the Main program is defined. In order to explain this part, which is very long, the explanations will be segmented in parts.

Main program code:

1. The Bluetooth communication is initiated using the Full Duplex Serial library. Then, a waitcount is used to wait for the serial buffer to receive the Receiver Pin, the Transmitter Pin and the Baud Rate to use. After that, a string containing the MAC Address of the other microcontroller is used in order to make the first connection. Immediately after, a Carriage Return (represented by the number 13) is used to seal the connection, and finally, another waitcount is used to began the Bluetooth Communication.

```
PUB Main
bluetooth.start(RX_PIN, TX_PIN, 0, BAUD_RATE)
'Conectarnos de este micro
' al otro por bluetooth
waitcnt(cnt + 160_000_000)
bluetooth.str(string
("con 00:17:a0:01:62:b0"))
'Conectar a MAC Address
bluetooth.tx(13)
'Mandar CR, Carriage Return
waitcnt(cnt + 160_000_000)
```

2. The variables for the PWMs are initiated in the center position, in order for the robot to not move at all once the Bluetooth connection is first terminated.

```
'Inicializar Variables para salidas PWM
dataX := centro
dataY := centro
dataZ := centro
salidaX := 4000
salidaY := 4000
salidaZ := 4000
```

3. 3. The variables for the digital PIDs are replaced by the center position. Both PID outputs are turned to low position, and the variables `controlarX`, `controlarY` and `controlarZ` are set to false because the PID would not be activated at first.

```
currentPointX := centro
currentPointY := centro
setPointX := centro
setPointY := centro
salidaPIDx := 0
salidaPIDy := 0
controlarX := false
controlarY := false
controlarZ := false
```

4. 4. The 5 cores are initialized. One core for reading the two feedback potentiometers to use with the two digital PID controllers; one to move the X axis; on the move the Y Axis; one to move the Z axis, or the grip arm, and finally, one to calculate the two digital PID controllers.

```
'Inicializar 5 coprocesos mas,
' 1 para leer datos, 3
' PWM y 1 PID
cognew(leer(@currentPointX,@currentPointY),
@cogStack0)
cognew(mover(@salidaX,PWM1,@salidaPIDx,
@c ontrolarX),
@cogStack1)
cognew(mover(@salidaY,PWM2,@salidaPIDy,
@c ontrolarY),
@cogStack2)
cognew(mover(@salidaZ,PWM3,@salidaPIDz,
@c ontrolarZ),
@cogStack3)
cognew(PID(@currentPointX,@setPointX,@salida
PIDx,@currentPointY,@setPointY,@salidaPIDy),
@cogStack4)
```

5. 5. The main loop starts. In this loop, the Bluetooth connection is used to determine the bytes used for the axis detection and for the value that the joystick is making. The first byte, `Data`, is used to determine which axis is next to move. Then, the second byte, which could be `dataX`, `dataY` or `dataZ`, is used to determine the position of the joystick. If the position that the joystick sends to this microcontroller is a center position ± 1 , then the digital PID controller is activated for the axis which the data came, if not, then the PID is disabled and the output PWM for each axis is

sent to the servomotors. This logic repeats for each of the three axes.

```
'Loop principal repeat
data := blueTooth.rx
if (data == 0)
'Si se recibe un 0 entonces
' el siguiente byte es el valor
' del eje de las X
dataX := blueTooth.rx
if (dataX == centro OR
dataX == centro+1 OR
dataX == centro-1)
controlarX := true
setPointX := currentPointX
salidaX := dataX*escala
else
controlarX := false
salidaX := dataX*escala
if (data == 1)
'Si se recibe un 1 entonces el
' siguiente byte es el valor
' del eje de las Y
dataY := blueTooth.rx
if (dataY == centro OR
dataY == centro+1 OR
dataY == centro-1)
controlarY := true
setPointY := currentPointY
salidaY := dataY*escala
else
controlarY := false
salidaY := dataY*escala
if (data == 255)
'Si se recibe un 255 entonces el
' siguiente byte es el valor
' del eje de las Z
dataZ := blueTooth.rx
salidaZ := dataZ*escala
```

Then we create the method `leer`, which helps determine the position of the two feedback potentiometers and activates the two ADC converters used for the analog-to-digital conversion. This method is very similar to the method named the same on the other microcontroller that has the two joysticks implemented.

```

PUB
leer(valorX,valorY)| tempX,tempY
'Inicializar ADC0831's
dira[ADCx] := 0
dira[ADCy] := 0
outa[CS] := 1
dira[CS] := 1
outa[CLK] := 1
dira[CLK] := 1
repeat
tempX := 0
tempY := 0
outa[CS] := 0
outa[CLK] := 1
outa[CLK] := 0
repeat 8
tempX <<= 1
tempY <<= 1
outa[CLK] := 1
outa[CLK] := 0
tempX += ina[ADCx]
tempY += ina[ADCy]
outa[CS] := 1
long[valorX] := tempX
long[valorY] := -1*tempY + 255
'waitcnt(cnt + 80_000_000)

```

```

PUB
PID(cur_posX,set_posX,outputX,
cur_posY,set_pos Y,outputY)|
pre_errorX,cur_errorX,pre_errorY,
cur_errorY, e, P, I, D
pre_errorX := 0
cur_errorX := 0
pre_errorY := 0
cur_errorY := 0
repeat
cur_errorX := long[set_posX] -
long[cur_posX]
P := gainX * cur_errorX
I := gainXi * cur_errorX * dt
e := cur_errorX - pre_errorX
D := gainXd * e / dt
pre_errorX := cur_errorX
long[outputX] := 0 - P - I - D
cur_errorY := long[set_posY] -
long[cur_posY]
P := gainY * cur_errorY
I := gainYi * cur_errorY * dt
e := cur_errorY - pre_errorY
D := gainYd * e / dt
pre_errorY := cur_errorY
long[outputY] := P + I + D
waitcnt(clkfreq / 1000 * dt + cnt)

```

Then the method mover is defined. This method is used to calculate the PWMs used for each servomotor.

```

PUB mover(addressSalida,PWM,addressPID,
controlar)| tiempo
outa[PWM] := 0
dira[PWM] := 1 repeat
if long[controlar] == true
tiempo := long[addressSalida] +
long[addressPID] 'if long[controlar] == false
tiempo := long[addressSalida]
outa[PWM] := 1
waitcnt(cnt + minimo + tiempo)
outa[PWM] := 0 waitcnt(cnt + veinteMs)

```

Finally, we have the digital PID controller method which calculates the two digital PID controllers used to stabilize the system when undesirable movements occur to the robotic arm that is independent from the user's commands of the joysticks.

RESULTS

First of all, once the two microcontrollers are turned on, the Propeller microcontroller that controls the movement of the robot connects itself with the other microcontroller via Bluetooth. In order to do that, the MAC address of the microcontroller that uses the analog joysticks has already been written on the communication protocol on the first microcontroller, and this allows the two microcontrollers to start communicating with each other. The operating mode of the robotic arm is then specified by the commands that the user wants using the joysticks control shown in Figure 1. The analog signals from these potentiometers are converted to a digital signal by the ADC0831s. These digital signals are interpreted by the Propeller microcontroller ProRPM, which processes the signals and codifies them to a serial signal that contains the movement of the two-axes of the robot arm, and the robot arm grip. This serial information is then used to transmit the control signals to the other Propeller Microcontroller via the Easy Bluetooth module, which is used as a replacement of a serial RS-232 cable. After the serial signal is directed to the other microcontroller that controls the servomotors of the robot via Bluetooth, this second microcontroller decodes the serial signal using the AppMod EB500

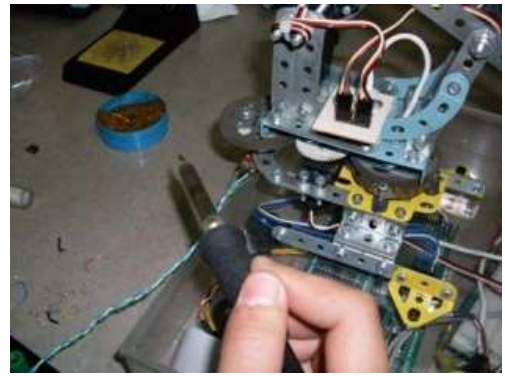
Transceiver Embedded Blue Parallax Module.

In order to know which axis has to move, in the serial code a byte is used to distinguish them. In the codification developed, number 0 was used to distinguish the X-axis, number 1 for the Y-axis, and number 255 for the arm grip or Z-axis. With the interpretation of this data, the servomotors of the robotic arm will move following the commands given by the user from any point, provided within the scope range of Bluetooth modules (which in the most positive case will be a 30 meters ratio).

If the robotic arm is moved undesirably by a force different from the signal of the joysticks (this could include moving the arm manually with a hand or putting more than 400 grams of weight on the grip arm), a digital PID controller is activated on the microcontroller that controls the servomotors and tries to stabilize the system to the last position that the user send using the joysticks. Two feedback potentiometers were used in joint with the Digital PID Controller, and they were implemented in the gear mechanism of the two main axes, X and Y. It is very important to point- out that the PID controller will always be enabled once the robot is not receiving signals from the joysticks because of the relative difficult implementation that a PID controller would have been if we wanted to avoid undesirable movements during the user's movement of the joysticks and therefore, the undesirable movement of the robotic arm during its normal human controlled movement.

CONCLUSION

Diverse knowledge was learned from this project, which was an inter-course project that joined the following courses: Computer Networks, Interface Design and Signals and Systems. The contents of the courses were used almost totally, but the implementation of the microcontrollers programs was a knowledge that was learned separately from these contents. The project did achieved the original objectives, and it also surpassed them because in the original design, a computer was used as an interface instead of one of the Bluetooth modules and the PID digital controller was not concerned also, but the implementation of another Bluetooth module and the PID digital controller were encouraged by the University's professors, so they were then



implemented, but it also added more difficulty to the overall performance of the robotic arm.

In conclusion, the robotic arm has a robust and fast response to the user's commands using the Bluetooth modules and the microcontrollers. Also, the PID digital controller response is very accurate, so the stability of the system is achieved in a high percentage. For the mechanical part, the use of pre-machined construction metal sets helped to assemble the robotic arm with little adjustments, while the use of the continuous servo motors rated at 5V DC helped for the simple implementation of the movement of the arm; if DC motors and un-machined parts were used, the difficulty to achieved the project would have been more difficult and time-consuming (maybe one month more of time would have been needed to use both).

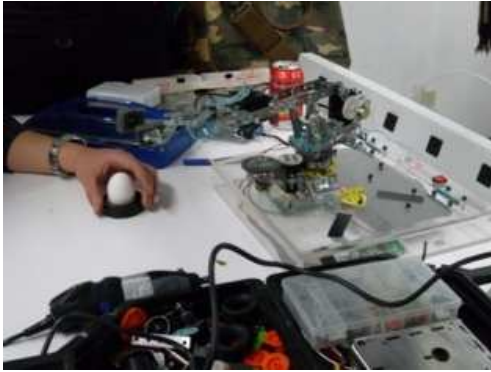
APPENDIX

Figures about the project development

ACKNOWLEDGMENT

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Bibliografía

- [1] Johnatan Zavaleta Milla. (August 20th, 2006) Wireless Technology [On line]
- [2] B. Hopkins, R. Antony, Bluetooth for Java USA 2003.
- [3] <http://www.mathworks.com/access/helpdesk/help/toolbox/instrument/f20-63744.html>
- [4] <http://zone.ni.com/devzone/cda/tut/p/id/3782>
- [5] <http://www.parallax.com/Portals/0/Downloads/docs/prod/motors/900-00008-CRServo-v2.0.pdf>

Acerca del autor o autores

Gama H. Manuel, Villaseñor G. Isaí, Mondragón C. Carlos, Dr. Moisés Sánchez Adame, M.C. Adolfo Esquivel Martínez

CETYS Universidad, CITEDIPN Tijuana, Baja California, CP-22550. TEL: +(664)9031833, correo-e: ingenieromanuelgama@hotmail.com, realktm@gmail.com, moises.sanchez@cetys.mx, adolfo.esquivel@cetys.mx



Una técnica de calibración axial para un sistema de medición 3D

Marvin Ortiz, Jesús Villa y Efrén Gonzalez

A calibration technique for an axial 3D measuring system

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Palabras clave: Calibración axial; medición 3D; proyección de franjas

Abstract:

This paper describes a technique for carrying out the calibration Axial in a 3D measurement system by fringe projection. The proposed approach uses a calibration technique for calculating temporal phase and the technique of least squares polynomial approximation for modeling the correlation between phase and shift in z . We present several results of measurements made with real objects.

Keywords: Axial calibration; 3D measurements; fringe projection

EN metrología es de interés la obtención de medidas de volúmenes mediante el uso de técnicas no invasivas. Con el desarrollo de sistemas de estas características, es posible solventar diferentes necesidades de modelado 3D. Una de las técnicas más poderosas y comúnmente usadas es la de proyección de franjas [1], [2], [3], [4]. En forma genérica, un sistema de medición por proyección de franjas se basa en la utilización de una cámara CCD y un proyector digital como se puede ver en la figura 1. La técnica consiste en obtener una o varias imágenes de franjas proyectadas sobre el objeto a medir, para llevar a cabo un proceso de cálculo de fase, la cual, está relacionada proporcionalmente a la profundidad del objeto a medir. Debido a que la relación fase-profundidad depende de la geometría del sistema, es necesario implementar una técnica de calibración, para poder obtener medidas reales. En la literatura, existe diversidad de técnicas de calibración para este tipo de sistemas [5], [6]. Comúnmente requieren del uso de complicadas herramientas matemáticas y un alto costo computacional. En este trabajo se presenta un método simple y efectivo, basado en un ajuste polinomial por mínimos cuadrados que, puede ser viable para ser usado en muchos casos en los que no se requiere de gran precisión en la medición.

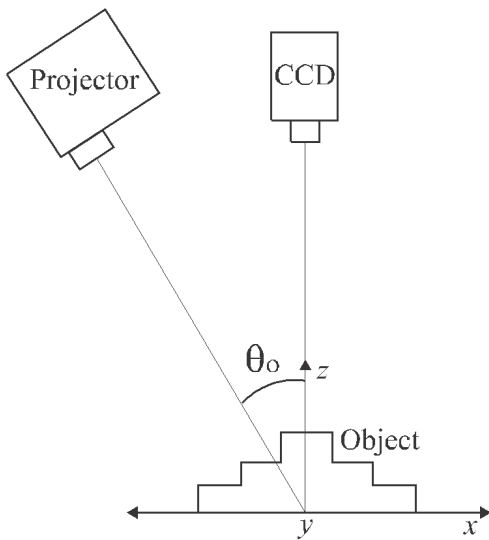


Figura 1. Sistema de visión para medición 3D por proyección de franjas.



Figura 2. Proyección de franjas sobre un objeto.

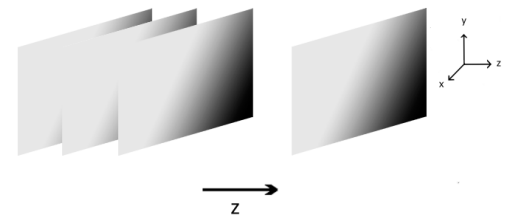


Figura 3. Medición de w en diferentes planos perpendiculares al eje.

MATERIALES Y MÉTODOS

A. Sistema de Visión

El sistema de medición tridimensional por proyección de franjas consiste en un arreglo experimental conformado por una cámara CCD, un proyector LCD y una computadora de uso convencional para el procesamiento de los datos. Entre los ejes ópticos de la cámara y el proyector existe un ángulo como se muestra en la figura 1. Cuando éste se aumenta, la sensibilidad del sistema de medición incrementa, empero, hay que tomar en cuenta que al aumentar dicho ángulo entre los ejes ópticos, se ve reducido el campo de visión para valores válidos y crece la presencia de sombras causando ruido en el sistema. La figura 2 es un ejemplo de imagen de franjas proyectadas sobre un objeto obtenida mediante un sistema de este tipo.

B. Cálculo de Fase y Calibración Axial

La técnica de cálculo de fase usada para este trabajo es la reportada por Huntley et al. [3], la cual consiste en variar temporalmente y de forma exponencial la frecuencia de las franjas proyectadas; para cada valor de frecuencia se generan cuatro patrones desplazados en fase, con el fin de calcular la variación de la fase $\Delta q(t)$ con respecto al tiempo de forma independiente en cada pixel de la imagen. Una vez que se obtienen los valores de $\Delta q(t)$ para cada valor de t en

la secuencia se lleva a cabo una integración discreta y un ajuste a una línea recta $q(t) = wt + \Xi$ por mínimos cuadrados (para detalles vease [3]).

Considérese que al intentar medir la profundidad de un objeto, se obtiene un campo de $w(x,y)$ mediante la técnica descrita en [3], donde (x,y) representan las coordenadas de la imagen. Lo que se pretende ahora, es obtener la distribución de profundidad $z(x,y)$ del objeto a partir de $w(x,y)$. Para describir de forma simplificada la técnica de calibración, en adelante omitiremos las coordenadas (x,y) . La calibración del sistema, se lleva a cabo usando valores de w en cada pixel haciendo incrementos de profundidad (z), mediante un plano que se desplaza sobre un riel graduado como se muestra esquemáticamente en la figura 3.

Dada una serie de datos obtenidos de forma experimental en una serie de planos para diferentes valores de z , en cada pixel, donde cada valor de w_i asume su respectivo valor tabulado en z_i ; se desea hacer una aproximación polinomial por mínimos cuadrados del conjunto de datos (z_i, w_i) , $i = 1, 2, \dots, m$. Para el ajuste de estos datos a un polinomio $z_m(w) = \sum_{k=0}^m a_k w^k$ de grado $n < m - 1$ necesario obtener las constantes a_0, a_1, \dots, a_m que minimizan el error cuadrático

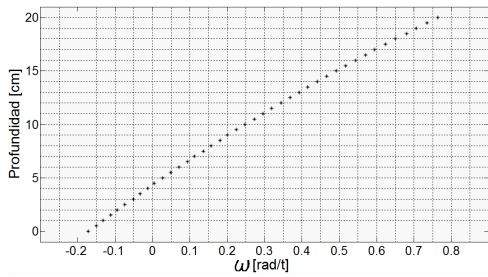


Figura 4. Relación w -profundidad para un conjunto de planos medidos en un pixel fijo.

definido por

$$E = \sum_{i=1}^m (z_i - z(w_i))^2. \quad (1)$$

Para minimizar E es necesario que $\partial E / \partial a_j = 0$ para $j = 0, 1, \dots, n$. Esto es

$$\frac{\partial E}{\partial a_j} = -2 \sum_{i=1}^m z_i w_i^j + 2 \sum_{k=0}^n a_k \sum_{i=1}^m w_i^{j+k} = 0. \quad (2)$$

Esto resulta en $n + 1$ ecuaciones normales en las $n + 1$ incógnitas a_j ,

$$\sum_{k=0}^n a_k \sum_{i=1}^m w_i^{j+k} = \sum_{i=1}^m z_i w_i^j. \quad (3)$$

La calibración en el sistema de visión se ha implementado usando los valores de w en cada pixel y sus respectivos incrementos en la profundidad, tomando como referencia un plano montado sobre un riel graduado, su posición inicial con $z = 0$ cm hasta una profundidad máxima predefinida y con incrementos también predefinidos.

Ejemplo de la relación que existe entre w y z a lo largo de todo un historial de datos capturados en forma experimental para un pixel fijo se muestra en la figura 4.

RESULTADOS EXPERIMENTALES

A continuación mostramos los resultados obtenidos de dos experimentos con la técnica de calibración aquí propuesta. El primero de ellos, se realizó con un objeto en forma de toroide, cuyos resultados de medidas reales se muestran en la figura 5. Un perfil sobre una línea vertical de la distribución de profundidad del mismo objeto, se muestra en la figura 6.

El segundo experimento, se llevó a cabo con la cabeza de un maniquí como el que se muestra en la figura 2. La distribución de medidas reales de profundidad del objeto es

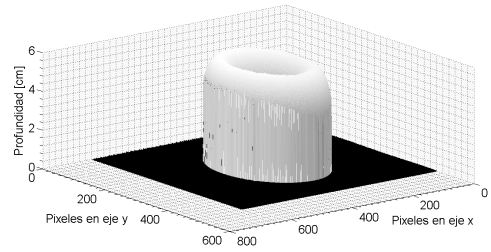


Figura 5. Distribución de profundidad de un objeto 3D en forma de toroide.

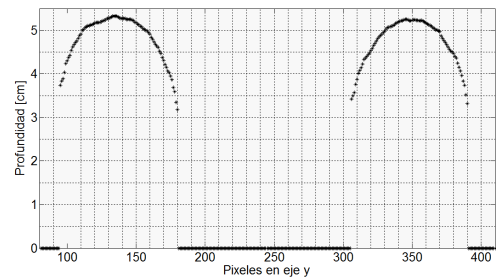


Figura 6. Perfil de profundidad de un objeto 3D en forma de toroide.

mostrada en la figura 7, mientras que un perfil sobre una línea vertical del mismo objeto se muestra en la figura 8. En todos los experimentos realizados se llevó a cabo la calibración usando el ajuste por mínimos cuadrados a un polinomio de quinto grado. Como se puede ver en la figura 4, la variación de z con respecto a w es casi lineal, por lo tanto, encontramos suficiente modelar dicho comportamiento con un polinomio de grado cinco.

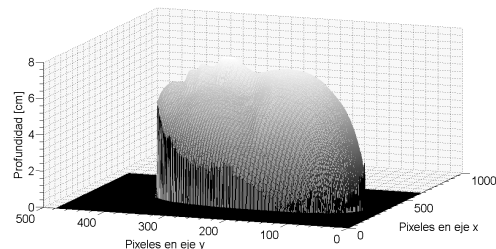


Figura 7. Distribución de profundidad de un objeto 3D en forma de maniquí.

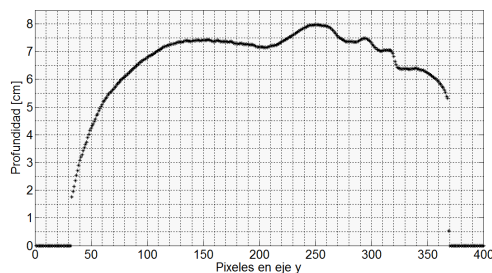


Figura 8. Perfil de topografía de la profundidad de un objeto 3D en forma de maniquí.

CONCLUSIONES Y TRABAJO FUTURO

El comportamiento de la relación w -profundidad son independientes para cada pixel, por lo que la calibración se realiza en cada pixel obteniendo coeficientes polinomiales únicos para cada uno de ellos. En la medición de la profundidad de un objeto 3D, se usa la w obtenida para evaluarse con los coeficientes propios de cada pixel, generando medidas muy aproximadas a las reales. Hablando del costo computacional, durante la obtención del conjunto de coeficientes tarda aproximadamente 15 minutos, sin embargo, hay que tomar en cuenta que esta operación se realiza en cada pixel en una imagen con tamaño de 640 x 480 píxeles, tomando en cuenta que la calibración sólo se realiza una vez para un número indefinido de mediciones puede concluirse, que la técnica de calibración aquí propuesta, es fácil de implementar y rápida desde el punto de vista computacional. Actualmente está en proceso de realizarse un estudio de precisión para la implementación de esta técnica. Ésta, será viable para utilizarse en mediciones que no requieren de extrema precisión. Como trabajo futuro, se pretende continuar con la calibración del sistema en el plano x - y para obtener una correspondencia como la anterior en la altura y anchura de los píxeles; esto permitirá tener una reconstrucción total del volumen. También se desea desarrollar un sistema de control con el riel calibrado, para hacer automáticos los movimientos del plano en el proceso de calibración del sistema de visión. Por último, se buscará implementar un sistema automático rotatorio, para que de este modo el objeto montado sobre éste pueda ser medido sobre todo su volumen.

Bibliografía

- [1] M. Takeda and Kazuhiro Mutoh, Fourier transformometry for the automatic measurement of 3-D object shapes, *Appl. Opt.* 22(24), 3977-3982 (1983). p. 23-26, (1984).
- [2] J. Villa, M. Servín and L. Castillo, Profilometry for the measurement of 3-D object shapes based on regularized filters, *Opt. Comm.* 161, 13-18, (1999).
- [3] J. M. Huntley and H. O. Saldner, Error reduction methods for shape measurement by temporal phase unwrapping, *JOSA A* 14(12), 3188-3196 (1997).
- [4] Fiona Berryman, Paul Pynsent and James Cubillo, A theoretical comparison of three fringe analysis methods for determining the three-dimensional shape of an object in the presence of noise, *Opt. Las. Eng.* 39, 35-50 (2003).
- [5] R. Legarda, T. Bothe and W. P. Jüptner, Accurate procedure for the calibration of a structured light system, *Opt. Eng.* 43(2), 464-471 (2004).
- [6] H. Liu, W. Su, K. Reichard and S. Yin, Calibration-based phase-shifting projected fringe profilometry for accurate absolute 3D surface profile measurement, *Opt. Comm.*, 216, 165-80 (2003).

Acerca del autor o autores

Marvin Ortiz, Jesús Villa y Efrén Gonzalez, Laboratorio de Procesamiento Digital de Señales, U. A. de Ingeniería Eléctrica, Universidad Autónoma de Zacatecas, Zacatecas ZAC-98000. TEL: +(492)9239407, ext. 169 correo-e: acoswt@hotmail.com

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Tutorials: These include new issues, but little known. Alternatively, they may include new approaches to basic knowledge, with a didactic purpose, so that will expand knowledge and encourage its application in engineering/technological projects. Provisional Web site of the Magazine: <http://www.uaz.edu.mx/gmiram/Revista.htm>

Format for submmision: The work can be sent in .txt formats and graphics or pictures in .jpg format with good resolution. It will be acceptable to send a single .zip or .rar file containing both the text and figures. In the case of using word, it must be sent in .doc format without using macros (.docx format is not accepted). It will be also accepted as an OpenOffice file. It is not requested any page format, especially since the text will be brought to the format of the magazine.

The article should include:

1. Title.
2. List of authors.
3. Summary in a maximum of 200 words. The summary is used as the article description in the expanded index, and does not appear in the document body (see a previous issue as a sample).
4. Main body of document. The title of the section will be in UPPERCASE, properly spelled. Subsections must be written in lowercase with the first letter capitalized.
5. The equations should be indicated as clearly as possible, even in txt format. For example:
$$H(\omega_1) = z^2 / (z - 0.5) \text{ where } z = e^{(j)\omega_1}$$
6. Biography of the authors. The actual job position will be included in a section “about the author” which may include a brief description of the position played or had played each author.

The lead author must submit the duly completed and signed form of “transfer of rights”, saying that the work has not been published previously.

EDITORIAL POLICY:

Manuscripts will undergo an editorial process in several phases. First of all the items received will be subject to a preliminary assessment by the Editorial Committee, who will determine the relevance of its publication, based on thematic requirements. In the second phase, items are sent to two external academic peers, who determine anonymously one of the following opinions: a) accept unchanged, b) accept after serving minor corrections, c) accept once it has been fully reviewed, d) reject. In case of discrepancy between the two arbitrators, the text will be sent to a third arbitrator, whose decision will define if it is accepted or rejected. The results of the opinion process are final in all cases.

