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Presentation of the Content

In the first article we present, *Application to monitoring a USB control with Python in Windows, Mac OS and Raspbian OS*, by ABRIL-GARCÍA, José Humberto, ALCANTAR-MARTINEZ, Adelina del Carmen, LÓPEZROMO, José Alonso and MEZA-IBARRA, Iván Dostoyewski, with adscription in the Universidad Tecnológica de Hermosillo, as the next article we present, *Design and construction of an Alfa Type Stirling Engine as a teaching prototype*, by PÉREZ-GONZÁLEZ, Marco Antonio, PÉREZ-GUTIÉRREZ, Alma Noemí, RAMÍREZ-VILLASEÑOR, Edgar Noel and GONZALEZ-LOPEZ, Juan Miguel, with adscription in the Universidad de Colima, as the next article we present, *Management of SMS Messages with GSM Modem and C # Language in WPF*, by ELIAS-ALVAREZ, Edwin, LÓPEZ-ROMO, José Alonso, MEZA-IBARRA, Iván and ABRILGARCÍA, José Humberto, with adscription in the Universidad Tecnológica de Hermosillo, as the next article we present, *A Survey of Performance Models for LTE-WiFi Wireless Heterogeneous Networks*, by HERNANDEZ-OCHOA, Martha & TORRES-LOPEZ, Alfredo, with adscription in the Universidad de Guadalajara.

Content

Article **ECORFAN Journal Democratic Republic of Congo**
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Application to monitoring a USB control with Python in Windows, Mac OS and Raspbian OS

Aplicación para monitoreo de un control USB con Python en Windows, Mac OS y Raspbian OS

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Abstract

The present work shows the development of an application in Python to detect the actions carried out on a USB control, with the aim of achieving a multiplatform application that can be used as a base for the creation of more robust and complex applications such as the development of video games or control and monitoring of devices. The methodology used was SCRUM in the first sprint a program was written for CLI that prints messages based on the buttons pressed, in the second sprint a GUI was developed to show a USB control and to indicate graphically when a button was pressed, in the last sprint a single application was integrated, the necessary tests were made and the code was published in a repository in GIT for reference and future use. The application was developed for Windows, macOS and Raspbian to test Python portability.

Python, Windows, Mac OS, Raspbian, USB gamepad

Resumen

El presente trabajo muestra el desarrollo de una aplicación en Python para detectar las acciones realizadas sobre un control USB, con el objetivo de lograr una aplicación multiplataforma que puede ser usada como base para la creación de proyectos más robustos y complejos, como el desarrollo de video juegos o control y monitoreo de dispositivos. La metodología utilizada fue SCRUM, en el primer sprint se escribió un programa para CLI que imprime mensajes dependiendo de los botones presionados, en el segundo se desarrolló una GUI que mostrara un control USB y que indicara de manera gráfica cuando se presionara un botón, finalmente se integró una sola aplicación, se hicieron las pruebas necesarias y se publicó el código en un repositorio en GIT para referencia y uso futuro. La aplicación fue desarrollada para Windows, macOS y Raspbian para probar la portabilidad de Python.

Python, Windows, Mac Os, Raspbian, Control USB

Citation: ABRIL-GARCÍA, José Humberto, ALCANTAR-MARTINEZ, Adelina del Carmen, LÓPEZ-ROMO, José Alonso and MEZA-IBARRA, Iván Dostoyewski. Application to monitoring a USB control with Python in Windows, Mac OS and Raspbian OS. ECORFAN Journal-Democratic Republic of Congo 2019, 5-8: 1-6.

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Introduction

Today the use of Python to develop several kinds of application is growing at a high rate, we can use Python for Web and Internet Development, scientific and numeric computing, education Desktop GUIs, software development, video games, and Business Applications like ERP and e-commerce systems, are examples of the multiple uses of Python. In this work we present an application to monitoring a USB control on Windows, Mac OS and Raspberry Pi (Foundation R. P., 2018). Our aim in this paper is to develop an application that can be used like a start point in more complex and robust aplications. Figure 1 shows the general diagram of the project.

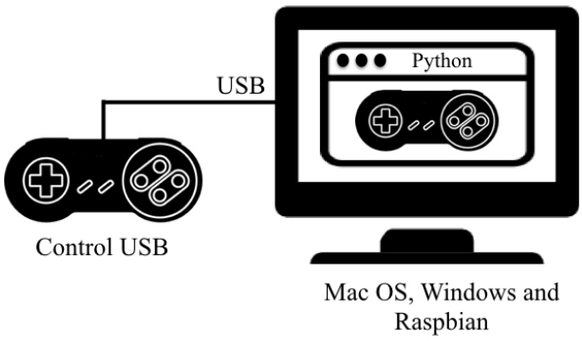

Figure 1 General Diagram

In the literature, we can find applications that make use of Python and Pygame for the development of applications in wireless networks (Cherry, 2015) and in the development of video games (Rachana Kumari, 2017). The main contribution of this work is the development of a base prototype that allows the students to know the main characteristics of the Python programming language, as well as to have a guide for the development of more complex projects that allow the integration of multiple technologies. The rest of the paper is organized as follows: Section 2 describes the tools used for this project; Section 3 gives conclusion to this work. Furthermore, analysis and future use for this application are provided.

Description of tools

Python (Foundation P. S., Welcome to Python.org, 2018) (Nagar, 2018) is an object-oriented, high-level programming language with integrated dynamic semantics primarily for web and app development.

It is extremely attractive in the field of Rapid Application Development because it offers dynamic typing and dynamic binding options. Python is a cross-platform language, a program written on a Macintosh computer will run on a Linux system and viceversa. Python programs can run on any computer, as long as the machine has the Python interpreter installed

Pip (Foundation P. S., pip · PyPI, 2018) is a package management system used to install and manage software packages written in Python. Pip was used to upgrade and install packages required on this project.

Pygame (pygame, 2018) is a cross-platform set of modules designed for writing multimedia applications like games built on top of the SDL library. It includes computer graphics and sound libraries designed to be used with the Python programming language.

Raspbian (FOUNDATION, 2018) is a free operating system based on Debian optimized for the Raspberry Pi hardware. An operating system is the set of basic programs and utilities that make Raspberry Pi run.

Github (Conservancy, 2018), (GitHub, 2018) is a web-based hosting service for version control using Git. It is mostly used for computer code. It offers all of the distributed version control and source code management (functionality of Git. It provides access control and collaboration features such as bug tracking, feature requests and task management, in this project we use Github to make the code avaible for any user.

Hardware and Software specificications

The hardware used in this project was:

– Pentium(R) Dual-Core CPU E5700 @ 3.00 GHz, 4 GB RAM, 32 bits.

– 2.7 GHz Intel Core i5, 8 GB 1867 MHz DDR3
– Raspberry Pi (c) 2011.12

The software used in this project:

– macOS High Sierra version 10.13.5
– Python 2.7.10 for Mac Os
– IDLE 2.7.10 for Mac Os
– Windows Home Basic 32 bits Service Pack 1

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– Python 3.6.5 for Windows
– IDLE 3.6.5 for Windows
– Raspbian GNU/Linux 9 (stretch)
– Python for Raspbian 2.7.13
– IDLE 2.7.13

Methodology

After installing all the tools required developing on Pyton, and using SCRUM team methodology; A Command Line Interface CLI application was developed to identify the control pad and buttons on sprint 1. On sprint 2, two Graphical User Interfaces were developed for SNES and NES. Finally on sprint 3, integration was done to merge the prototypes made on sprint one and two.

Sprint 1: The code generated on this stage runs with modifications for each platform.

Windows code:

```
# Get joystick axes for Win

x = joy.get_axis(0)

if(str(x)!="-0.00784301757812"): print(x)

y = joy.get_axis(1)

if(str(y)!="-0.00784301757812"): print(y)
```

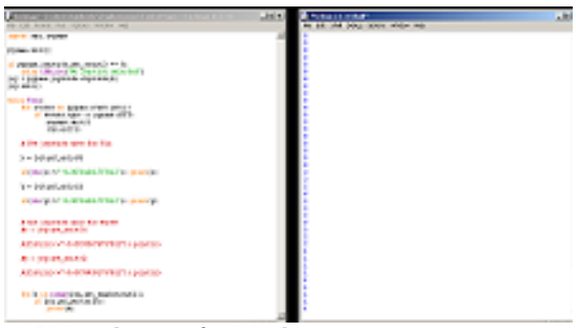
Mac OS code:

```
# Get joystick axes for MacOS

x = joy.get_axis(3)

if(str(x)!="-0.00393676757812"): print(x)

y = joy.get_axis(4)

if(str(y)!="-0.00784301757812"): print(y)
```

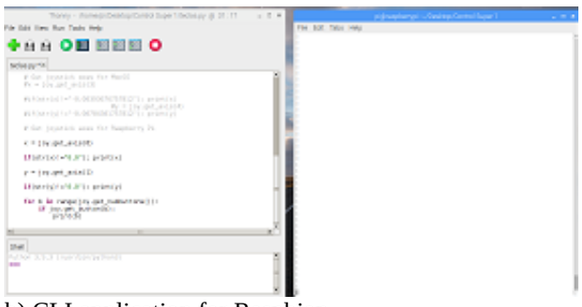
Raspbian code:

```
# Get joystick axes for Raspberry Pi

x = joy.get_axis(0)

if(str(x)!="0.0"): print(x)

y = joy.get_axis(1)

if(str(y)!="0.0"): print(y)
```

Figure 2 shows the code in execution on each platform.



a) CLI application for Windows



b) CLI application for Raspbian

c) CLI application for macOS

Figure 2 Python CLI application for a) Windows, b) Raspbian and c) macOS

Sprint 2 The code generated could be executed without modifications in all the platforms; two GUI's were designed for NES and SNES. On figure 3 we can see the GUI's running on Windows, MacOs and Rapsbian.

a) Windows NES GUI

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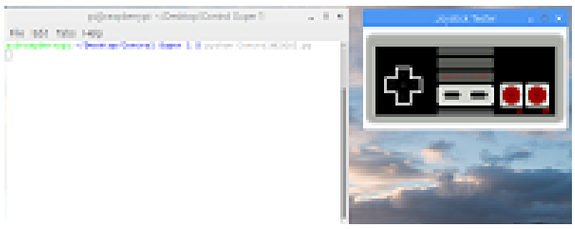
b) macOS SNES GUI

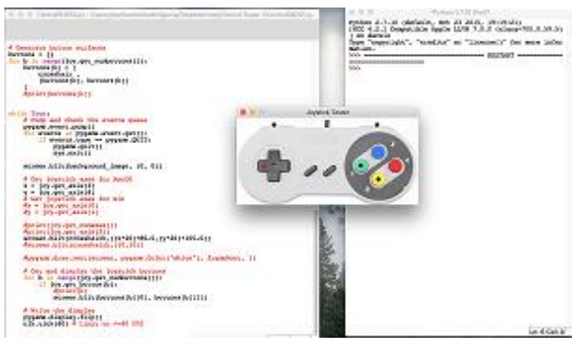


c) macOS NES GUI

Figure 3 Python GUI application for a) Windows NES, b) masOS SNES GUI and c) Raspbian NES GUI

Sprint 3: Finally, the prototypes developed on sprint 1 and 2 were merged on a final version; this version requires small changes on each platform. On Figure 4, we can see the programs running while the user presses key pad left, Y, B, L and R buttons for SNES control and key pad left, key pad up, select, start, A and B buttons for NES control.

a) Windows SNES



b) macOS SNES GUI

c) macOS NES GUI

Figure 4 Python application for a) Windows SNES, b) masOS SNES GUI, c) Raspbian NES GUI, while the user presses some buttons

Results and Conclusions

With the development of this work a Python application compatible was created with any platform that supports the language, and has served as a guide to be able to venture into the development and creation of various types of applications such as video games, in the same way a repository where students and the general public can download the code freely, study it and adapt it to their needs. In the same way, Python's multi-platform capabilities were tested, obtaining applications that with minimal modifications offer the same result in different platforms. Figure 5 shows the final version running on macOS. On appendix A we see the code for SNES and on appendix B the code for the NES applications.

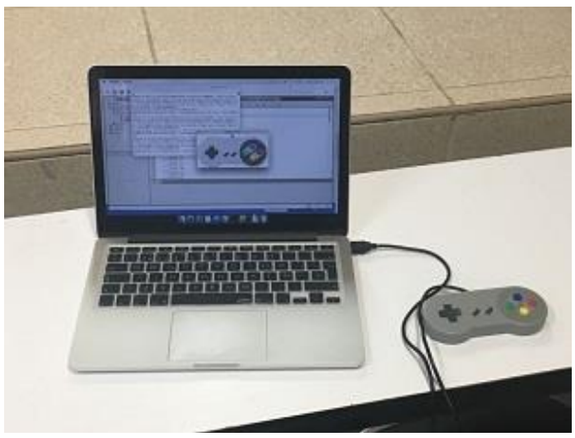


Figure 5 Application for macOS

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Appendix A: SNES Code

```
import sys, pygame, os
os.environ['SDL_VIDEO_CENTERED'] = '1'
pygame.init()

clk = pygame.time.Clock()

if pygame.joystick.get_count() == 0:
   raise IOError("No joystick detected")
joy = pygame.joystick.Joystick(0)
joy.init()

def buttonX(boton):
   if(boton==0): return 298
   elif(boton==1): return 335
   elif(boton==2): return 298
   elif(boton==3): return 260
   elif(boton==4): return 75
   elif(boton==5): return 295
   elif(boton==8): return 154
   elif(boton==9): return 195

def buttonY(boton):
   if(boton==0): return 70
   elif(boton==1): return 98
   elif(boton==2): return 127
   elif(boton==3): return 98
   elif(boton==4 or boton==5): return 11
   elif(boton==8): return 108
   elif(boton==9): return 110

size = width, height = 389, 187
screen = pygame.display.set_mode(size)
pygame.display.set_caption("Joystick Tester")
background_image =
pygame.image.load('cnes1.png').convert()
frameRect = pygame.Rect((0, 0), (width, height))

crosshair = pygame.surface.Surface((10, 10))
crosshair.fill(pygame.Color("magenta"))
pygame.draw.circle(crosshair, pygame.Color("black"),
(5,5), 5, 0)
crosshair.set_colorkey(pygame.Color("magenta"))

crosshairb = pygame.surface.Surface((10, 10))
crosshairb.fill(pygame.Color("magenta"))
pygame.draw.circle(crosshairb,pygame.Color("red"),
(5,5), 5, 0)
crosshairb.set_colorkey(pygame.Color("magenta"))

buttons = {}
for b in range(joy.get_numbuttons()):
   buttons[b] = [
      crosshair ,
      (buttonX(b), buttonY(b))
   ]

while True:
   pygame.event.pump()
   for events in pygame.event.get():
      if events.type == pygame.QUIT:
         pygame.quit()
         sys.exit()
   screen.blit(background_image, (0, 0))

   # Get joystick axes for MacOS
   #x = joy.get_axis(3)
   #y = joy.get_axis(4)

   # Get joystick axes for Win and Raspberry
   # x = joy.get_axis(0)
   # y = joy.get_axis(1)

screen.blit(crosshairb,((x*20)+80-5,(y*20)+105-5))

for b in range(joy.get_numbuttons()):
      if joy.get_button(b):

         screen.blit(buttons[b][0], buttons[b][1])


   pygame.display.flip()
   clk.tick(40)
```

Appendix B: NES Code

```
import sys, pygame
pygame.init()

clk = pygame.time.Clock()

if pygame.joystick.get_count() == 0:
   raise IOError("No joystick detected")
joy = pygame.joystick.Joystick(0)
joy.init()

def buttonX(boton):
   if(boton==1): return 295
   elif(boton==2): return 250
   elif(boton==8): return 148
   elif(boton==9): return 193

def buttonY(boton):
   if(boton==1 or boton==2): return 112
   elif(boton==8 or boton==9): return 112

size = width, height = 350, 175
screen = pygame.display.set_mode(size)
pygame.display.set_caption("Joystick Tester")
background_image =
pygame.image.load('image.png').convert_alpha()

crosshair = pygame.surface.Surface((10, 10))
crosshair.fill(pygame.Color("magenta"))
pygame.draw.circle(crosshair, pygame.Color("blue"),
(5,5), 5, 0)
crosshair.set_colorkey(pygame.Color("magenta"))

crosshairb = pygame.surface.Surface((10, 10))
crosshairb.fill(pygame.Color("magenta"))
pygame.draw.circle(crosshairb,pygame.Color("red"),
(5,5), 5, 0)
crosshairb.set_colorkey(pygame.Color("magenta"))

buttons = {}
for b in range(joy.get_numbuttons()):
   buttons[b] = [ crosshair , (buttonX(b), buttonY(b))]
```

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```
While True:

    pygame.event.pump()
    for events in pygame.event.get():
        if events.type == pygame.QUIT:
            pygame.quit()
            sys.exit()
    screen.fill([255, 255, 255])
    screen.blit(background_image, (0, 0))

    # Get joystick axes for MacOS
    # x = joy.get_axis(3)
    # y = joy.get_axis(4)

    # Get joystick axes for Win and Raspberry
    # x = joy.get_axis(0)
    # y = joy.get_axis(1)
    screen.blit(crosshairb,((x*20)+64,(y*20)+96))


    for b in range(joy.get_numbuttons()):
        if joy.get_button(b):
            screen.blit(buttons[b][0], buttons[b][1])

    pygame.display.flip()
    clk.tick(40)
```

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Article **ECORFAN Journal Democratic Republic of Congo**
June 2019 Vol.5 No.8 7-13

Design and construction of an Alfa Type Stirling Engine as a teaching prototype

Diseño y construcción de un Motor Stirling Tipo Alfa como prototipo didáctico

PÉREZ-GONZÁLEZ, Marco Antonio†*, PÉREZ-GUTIÉRREZ, Alma Noemí, RAMÍREZ-VILLASEÑOR, Edgar Noel and GONZALEZ-LOPEZ, Juan Miguel

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Abstract

This paper shows the design and construction of a Stirling engine prototype as an alternative to generate electricity as well as a teaching tool to be used with mechanical electrical engineering students. The engine will be coupled with a DC generator feeding a LED. The projected outcome power is 6W at a 12 V operation level.

Alpha-type Stirling engine, Stirling Cycle, Piston

Resumen

En este artículo se presenta la experiencia obtenida con el proyecto diseño y construcción de un Motor Stirling tipo Alpha, como una alternativa de generación de energía eléctrica y una herramienta de apoyo didáctico para estudiantes de la carrera Ingeniero Mecánico Electricista. El prototipo desarrollado se acoplará con un generador CD el cual alimenta a una carga eléctrica, en este caso un led. La potencia esperada es de 6 W operando a una tensión nominal de 12 V.

Keywords: Motor Stirling tipo alpha, Ciclo Stirling, Pistón

Citation: PÉREZ-GONZÁLEZ, Marco Antonio, PÉREZ-GUTIÉRREZ, Alma Noemí, RAMÍREZ-VILLASEÑOR, Edgar Noel and GONZALEZ-LOPEZ, Juan Miguel. Design and construction of an Alfa Type Stirling Engine as a teaching prototype. ECORFAN Journal-Democratic Republic of Congo. 2019, 5-8: 7-13.

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† Researcher contributing first author.

Introduction

The Stirling engine is a thermal machine with low noise levels and toxic emissions. This engine can use any external energy source (solid, liquid and gaseous fuels, nuclear energy, solar, geothermal sources, etc.), reaching zero emissions when using solar energy. In the near future, these engines will probably have different applications, even including replacing internal combustion engines in some applications. (Agüero V., 2006)

The thermal efficiency of a well-designed Stirling engine is relatively high (Khaled et al, 2018). Due to the characteristic of obtaining heat from an external source, this motor is a good option to take advantage of thermal sources that are the waste or waste of other processes (Ahmad et al, 2017) and (Asnaghi et al, 2012).

Theoretical Foundation

The work is obtained by expanding the hot gas confined to high pressure. To complete the cycle, the gas cools before being compressed to begin the next cycle. The main components of the Stirling engine are; the heat source, heater, regenerator, cooler, piston / displacer and chambers. Heat transfer processes are the key parameters that affect engine performance. The effectiveness of the regenerator has a strong effect on the performance of the Stirling engine Khaled et al, 2018).

The gap between the two pistons causes the air to pass from one cylinder to another by heating or cooling and performing the work that allows the operation of the motor as shown in the figure. one.

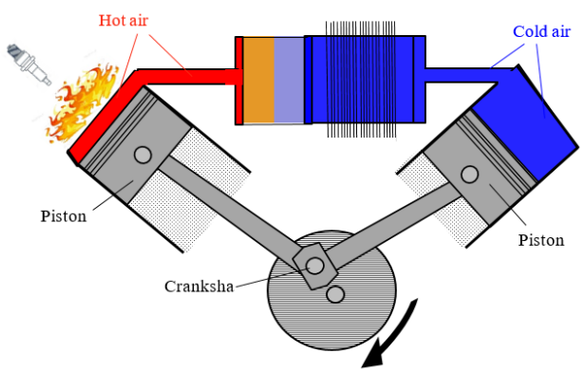

Figure 1 Operation of Stirling Engine
(http://motorstirlingyadyrtecsup.blogspot.com/)

This type of motors are also called hot air motors. This term is given to the thermal machines that make use of the expansion and compression of air under the influence of a change of temperatures, having a high temperature reservoir and a low temperature reservoir, it manages to convert the thermal energy of itself into mechanical energy. As shown in figure 2.

In this type of engine, the air is heated and cooled repeatedly inside the cylinder, such effect produces an expansion and compression of the air causing the movement of the piston; thus producing useful work. There are different types of air motors, among which we can highlight: Motor Carnot, Motor Ericsson, Motor Stirling.

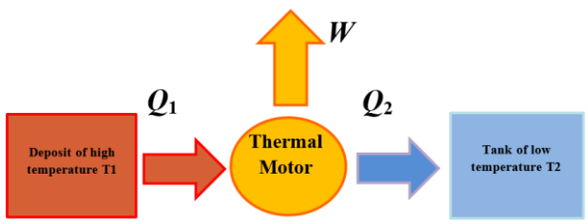

Figure 2 Diagram of a hot air motor that produces mechanical energy (W), by a temperature difference
(http://motorstirlingyadyrtecsup.blogspot.com/)

Carnot engine or carnot cycle

In 1824 Sadi Carnot studied the efficiency of the different thermal machines that work transferring heat from one source of heat to another and concluded that the most efficient machines are those that work in a reversible manner. For this he designed a fully reversible thermal machine that works between two heat sources of fixed temperatures. This machine is known as the Carnot machine and the basis of its operation is called the Carnot cycle, whose main characteristics are shown in figure 3.

Inequality $\oint \frac{dQ}{dt} \leq 0$ represents the Clausius Theorem and only applies to the ideal cycle or Carnot cycle. Since the integral represents the net change in entropy in a complete cycle, the most efficient motor cycle is attributed a zero entropy change. The Clausius inequality applies to any real cycle motor and assumes a negative change in entropy for the cycle.

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That is, the entropy given to the environment during the cycle is greater than the entropy transferred by the heat from the hot focus to the motor. In the simplified heat engine, where all the heat QH is added to the temperature TH, then to complete the cycle an amount of entropy ΔS = QH / TH, which is obtained from the environment, is added to the system. In general, the engine temperature will be less than TH at least during the part of the time when heat is being added, and any temperature difference is an irreversible process. In any irreversible process an excess of entropy is created, and therefore more heat must be thrown to the cold focus, to get rid of this entropy. This leaves less energy to do work.

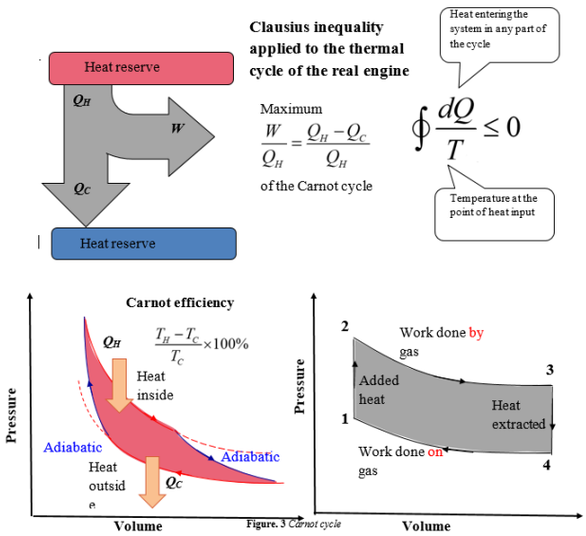

Figure 3 Carnot cycle
(http://hyperphysics.phy-astr.gsu.edu/hbasees/thermo/clausius.html)

The Carnot cycle is an ideal thermodynamic cycle reversible between two temperature sources, in which the maximum performance is. The cylinder contains a certain amount of ideal gas and the machine works by exchanging heat between two constant temperature sources $T_H > T_C$. The heat transfers between the sources and the cylinder gas are made isothermally, that is, keeping the temperature constant, which makes that part of the process reversible.

Engine performance is defined by expression:

$$\eta = \frac{T_H - T_C}{T_H} \quad (1)$$

$$\eta = 1 - \frac{T_C}{T_H} \quad (2)$$

How is observed from the expression (2) the efficiency relates the hot and the cold temperature. Therefore, the lower this ratio, that is, the higher the T_H with respect to T_C, the better the efficiency.

Stirling cycle

The basic principle of the Stirling engine consists of a gas enclosed in an airtight cylinder that has a hot end and a cold end. Inside the cylinder is a displacement piston and a power piston. The purpose of the power piston is to prevent the gas from escaping and to transmit the work to the outside of the cylinder. The function of the displacer is to make the air move from the cold to the hot zone and vice versa.

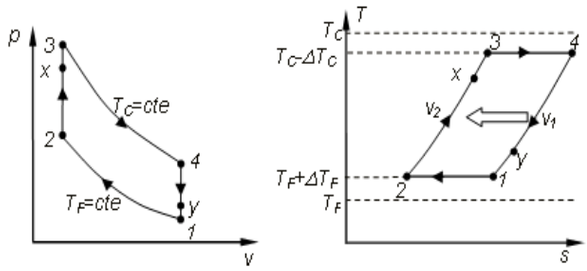

Figure 4 Stirling cycle
(González-Baylon et al, 2011)

The gas is displaced towards the hot part of the cylinder expands increasing the internal pressure which allows to obtain work. Then the gas is displaced to the cold part where its temperature drops and the pressure decreases. The cycle consists of four processes as shown in figure 3, two isometric processes in which the gas passes through the regenerator absorbing or yielding heat and two isothermal processes in which the gas is in contact with a high temperature reservoir (T_H) or one of cold temperature (T_C).

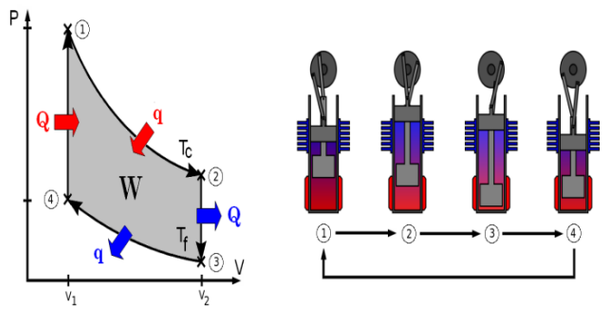

Figure 5 Stirling engine performance

PÉREZ-GONZÁLEZ, Marco Antonio, PÉREZ-GUTIÉRREZ, Alma Noemí, RAMÍREZ-VILLASEÑOR, Edgar Noel and GONZALEZ-LOPEZ, Juan Miguel. Design and construction of an Alfa Type Stirling Engine as a teaching prototype. ECORFAN Journal-Democratic Republic of Congo. 2019.

At the start of the cycle, the air inside the cylinder is compressed, with high temperature and high pressure (1). These conditions, added to the heat input, cause the air to expand and, through the power piston, perform work moving from volume V1 to volume V2 (2). Immediately after this occurs, the displacement piston rapidly falls to the hot region of the cylinder allowing the temperature and air pressure to drop because it is exposed to the cold region of the cylinder (3). At this point, the flywheel connected to the crankshaft that synchronizes the movement of the power and displacement cylinders carries enough inertia to cause the power piston to work on the system compressing the air (4). Once the power piston reaches the volume V1, the displacement piston rises rapidly towards the cold region of the cylinder in order that the air is exposed to the hot region of the cylinder and thus increases its temperature and pressure to reach the state initial where the cycle is repeated.

Materials and methods

The prototype design was developed in a CAD environment, using the Solid Works ® tool. The manufacturing was implemented using the Faculty 's infrastructure, a conventional lathe, conventional milling machine, closing - tape, and welding machine. The materials used, as well as the mechanical elements that make up the design are shown in tabls 1 and 2:

Quantity	Material
1	Round section of aluminum 3.5 inches in diameter x 15 cm.
1	Iron plate 1/4 15x15x1 / 4
1	Round section of steel 3.5 inches in diameter x 10 cm thick
1.5	Asparagus meters of ¼ inch
24	¼ nuts
4	Toners with nut and 5/16 washer
2	Thermal packaging 3.5 inches
1	40cms plastic hose

Table 1 Used material

Components	Quantity
Container	1
Pistons	2
Connecting rod	2
Crankshaft	1
Balero	6
Steering wheel	1
Electric generator	1
Pulley	1
LED bulb 12V-10W	1

Table 2 Mechanical elements of the prototype

Due to the requirements established in the project protocol, a redundant design was followed, so all the pieces were modeled in both SolidWorks ® and AutoCAD ® for each of the elements of the prototype.

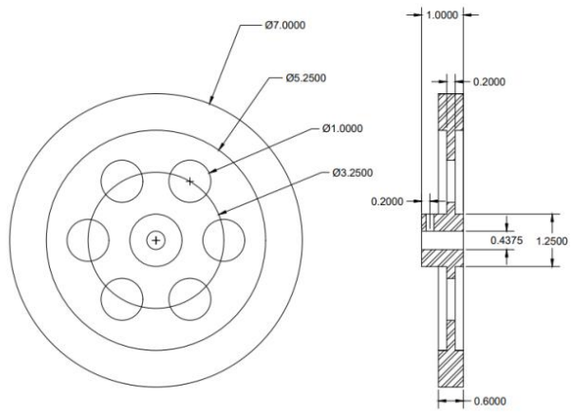

Figure 6 Model of the flywheel with dimensions and designed in AutoCAD

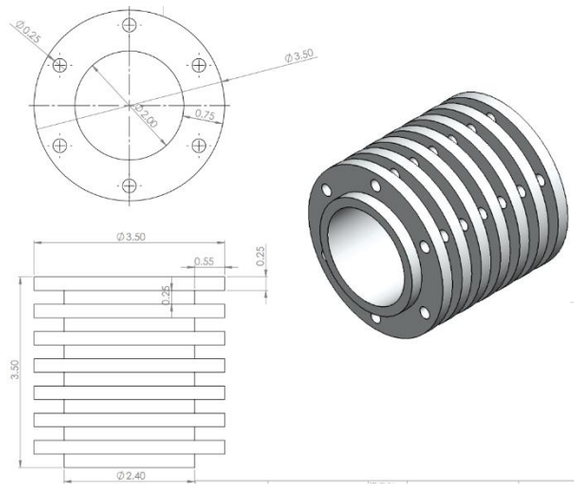

Figure 7 Cooling cylinder model with dimensions and designed in AutoCAD

Figures 6 to 9 show different views of the prototype design. Floor and 3D views of the flywheel (figures 6 and 8), of the heat sink (figure 7), of the assembled prototype seen from two different angles (figures 8 and 9), as well as details of the connecting rod - crank mechanism (figure 9) to show some of the key elements in the design of this type of thermal machines.

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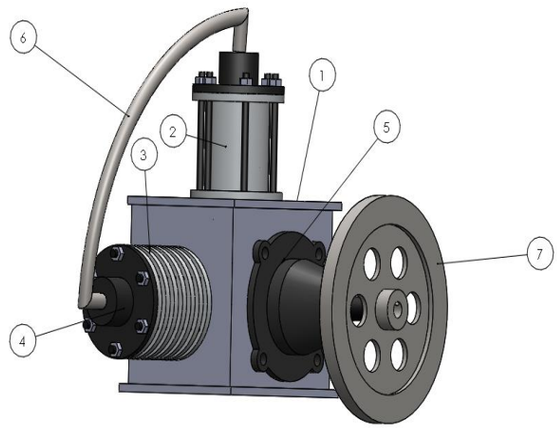

Figura 8 Prototype of the engine in SolidWorks ®. 1. housing. 2. Heating cylinder. 3. Cooling cylinder. 4. Cylinder cover. 5. Crankshaft bearing shaft. 6. Hot-cold connection tube. 7. Flywheel

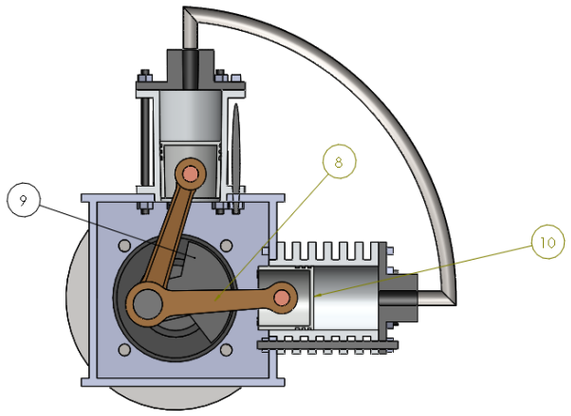

Figure 9 Prototype of the engine in SolidWorks ®. 8. Connecting rod 9. Crankshaft 10. Piston

Although these models were generated in CAD environment, the manufacturing process was carried out in both conventional and semi-automatic machines. This required making adjustments and a heuristic process that finally were also reflected in the models presented in this paper. Figure 10 shows some aspects of the construction of the prototype using different types of machines and tools.

Figure 10 Stage of construction of the prototype in the faculty laboratory

Results

Every manufacturing process must consider that there will always be a need to make adjustments and changes of any magnitude in the machining technique as well as in the design to seek to ensure that the developed prototype works properly. As (Church et al, 2016, Chen et al, 2014 and Lockhart, et al, 2017) mention, this stage of the project turns out to be the one that presents the most challenges for the fulfillment of delivery dates. During the period assigned for the development of the prototype, the pieces manufactured were analyzed and improved. Once all the parts were manufactured, the engine was assembled, making different tests.

In the tests the movement of the piston turned out to be partial, that is to say, the operation of the engine was not adequate, since after a couple of cycles where the exchange of air was made in both chambers, the movement ceased. Although different solutions were tried, such as material modifications, tolerances and adjustments, it was not possible to achieve continuous operation of the prototype. Among the problems that could be detected, the following are considered:

– Overcoming the inertia of the steering wheel proved to be a challenge, since with the initially supplied energy it was apparently not enough.

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– The piston that admits the air at a lower temperature presented difficulty in the movement, which made difficult the movement of the other that could be moved freely manually.
– There were leaks that were then successfully corrected
– Since piston rings were crucial to seal the cylinder, as well as to reduce metal-to-metal contact, this was a problem that needed to be addressed. However, when the diameters of the piston and cylinder rings were measured with the calipers, it was found that the piston and the rings should have a slightly looser fit.

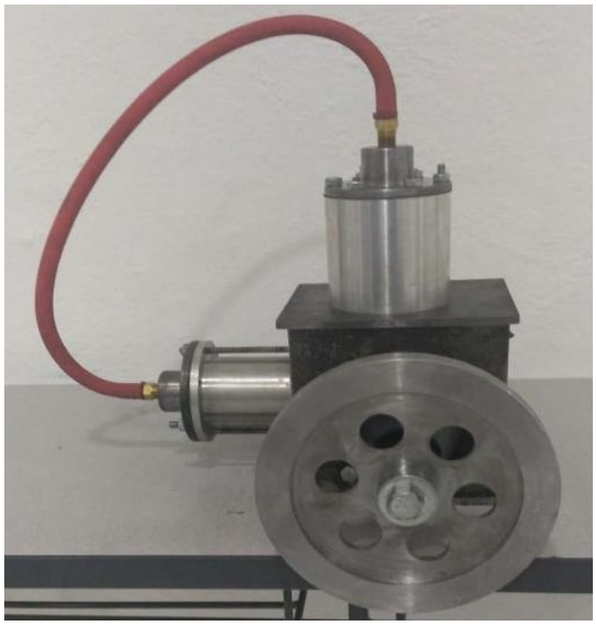

Figure 11 Finished prototype of a Stirling engine previous view

Figure 12 Finished prototype of a Stirling engine rear view

The images shown in figures 11 and 12 show the finished prototype, seen from two different angles. The design of the flywheel is noted, as well as the finishes of the working fluid exchange chambers and the mechanism that allows continuous movement.

Acknowledgments

To the University of Colima for the support provided for the preparation of this research work among students and academics.

Conclusions

The authors consider that the experience that the students obtained in the whole process has been of great benefit. At a cognitive level, it allowed students to develop a project from the theoretical conception and fundamentals of operation of the thermal machine. In the practical aspect, the students were able to identify very sensitive aspects in all mechanical metal manufacturing processes, that is, adjustments, tolerances, quality of finishes, relationship between machining speed and finished quality, etc. As well as the design of the virtual instrument that together with the design stage in CAD environment allow the student to interact in a more intense way with the different computational platforms that were used in these stages of the project.

Finally, in the methodological aspect, all the stages of the project pay directly to the understanding of what is a project of these characteristics.

It is necessary that there is a closer feedback between the design and manufacturing processes since the experience achieved indicates that if there is no adequate design no matter how precise the manufacturing and in the same way if the manufacturing is deficient the advantage of having a design optimal is lost.

Future work

It will work on a redesign that allows to reduce the weight in the flywheel and in the pistons. These can be drilled to obtain "hollow" pistons with or that the weight would drop by a considerable percentage. Make a more precise manufacturing to achieve a more relaxed fit between the pistons and cylinders so that better movement is possible.

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Another aspect to consider is to improve the design and type of heat sink material that allows and heat exchange in a more efficient manner. A stage that is considered is to monitor in real time the temperature of the working fluid, the speed of rotation, as well as the instantaneous output power. The aim is to design a virtual instrument in any of the existing computational platforms in order to have a graphical interface that shows in real time the performance of the thermal machine.

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Management of SMS Messages with GSM Modem and C # Language in WPF

Gestión de Mensajes SMS con Modem GSM y Lenguaje C# en WPF

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Abstract

In this project a system with graphical interface in Windows Presentation Foundation was proposed and realized, which was written in C # programming language, in which the sending of text messages using the available GSM (Global System Mobile) networks is allowed, with GSM modems of different compatible brands that connect to these GSM networks, in order to carry out the process of sending text messages, without keeping record of it in the sending team, with a process in the simplest way possible, that allows to have a greater agility to increase the productivity, all this from a Windows environment in which the text message must be entered and the telephone number to which the message will be sent and the result of this operation will be shown on the screen, in addition to allow the system to be portable, since it does not save configuration information.

Messages, GSM, Networks

Resumen

En este proyecto se planteó y se realizó un sistema con interfaz gráfica en Windows Presentation Foundation el cual se escribió en lenguaje de programación C #, en el que se permite el envío de mensajes de texto usando las redes GSM (Global System Mobile) disponibles, con modems GSM de distintas marcas compatibles que se conecten a estas redes GSM, para realizar de esta manera el proceso de envío de mensajes de texto, sin guardar registro de ello en el equipo de envió, con un proceso de la manera más sencilla posible, que permita tener una mayor agilidad para aumentar la productividad, todo ello desde un entorno Windows en el cual se debe ingresar el mensaje de texto y el número telefónico al cual se enviara el mensaje y se mostrara el resultado de esta operación en pantalla, además de permitir que el sistema que sea portable, ya que no guarda información de configuración.

Mensajes, GSM, Redes

Citation: ELIAS-ALVAREZ, Edwin, LÓPEZ-ROMO, José Alonso, MEZA-IBARRA, Iván and ABRIL-GARCÍA, José Humberto. Management of SMS Messages with GSM Modem and C # Language in WPF. ECORFAN Journal-Democratic Republic of Congo. 2019, 5-8: 14-17.

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† Researcher contributing first author.

Introduction

Currently there are systems for sending SMS messages (nd) through GSM networks from desktop devices, which are paid, are easy to find on the Web, but the vast majority charge for the amount of messages sent and / or a monthly or annual subscription. Taking as reference the above, we decided to develop an open system that used the existing GSM networks through a modem compatible with them, which allows messages to be sent using AT commands, so that the costs would be only those that the network operator applies. for each message sent and the cost of the hardware used for this purpose, which would facilitate the client to have a more precise control of the messages sent without incurring extra costs.

In the development of this project we used Visual Studio 2017 (2017 Microsoft Corporation) with the .Net Framework 4.7, C # language (2017, April 17) 5.0 and Windows Presentation Foundation (2018, February 25) for the development of the interface in environments Windows (version 7 or higher), which can be downloaded at no cost on the official website.

Figure 1 Message sending process

Development of the program with user interface for sending messages

Once the user interface with Windows Presentation Foundation has been designed and written in C # language, it is made in a single form in two tabs, the first one manages the connection to the GSM modem and the second one sends the message.

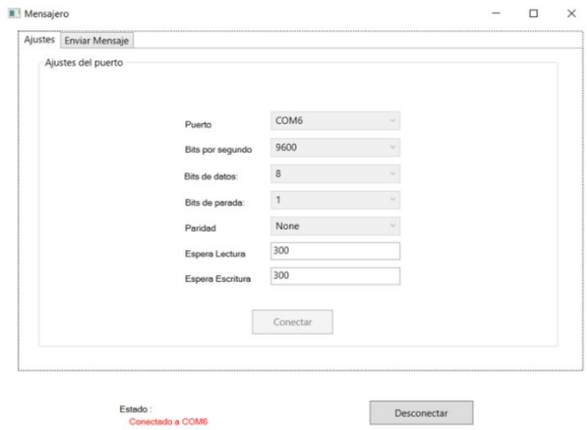

Figure 2 Settings Tab

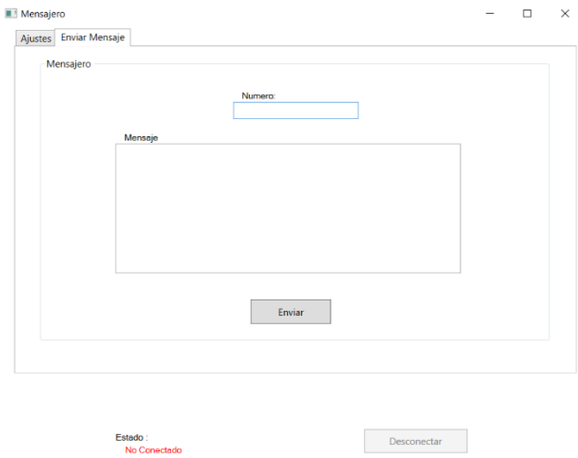

Figure 3 Message sending tab

In the first tab called "Settings" (Figure 1), the user can enter the necessary data for the connection to the GSM modem, such as the COM port to which the GSM modem is connected, bits per second to be handled, data bits, bit stop, parity, and wait in the reading and writing in addition to the connect button that will make the connection to the GSM modem and enable the "Send message" tab when activated.

In the second tab "Send message" (Figure 2), it shows the "Number" fields where the user enters the 10-digit telephone number, which will be the recipient of the message sent by the system, the second field shown called "Message" is where you write the text that will be the body of the message to send to the number entered in the previous field, finally you will find the "Send" button, which when activated prepares the AT commands (2007, March 28) necessary to be interpreted by the GSM modem and this proceeds to send the text messag.

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All the above (design and code) are written in a single form, which has in the lower part a label that shows the GSM port to which it is connected and the right of it the "Disconnect" button for safe release of the modem and lastly in the lower left are the states of the execution of the AT commands of the GSM modem (2015, June 25) as the sending of messages (Appendix A).

Integration

Figure 4 GSM modem used

Figure 5 Modem and System in test equipment

By having the system programmed, the integration with a compatible GSM modem (Figure 5) is carried out in a laptop computer running the Windows 10 operating system.

Components used:

– GUI designed with WPF and written in C #
– Huawei GSM modem model H353
– GSM chip Weex brand
– Dell laptop model Inspiron 15 5567

Tests

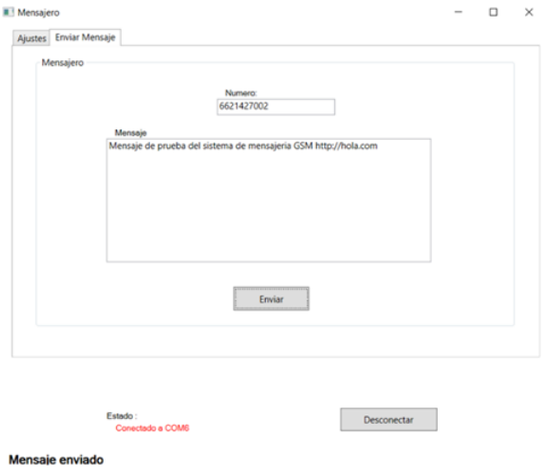

Figure 6 Test message sent

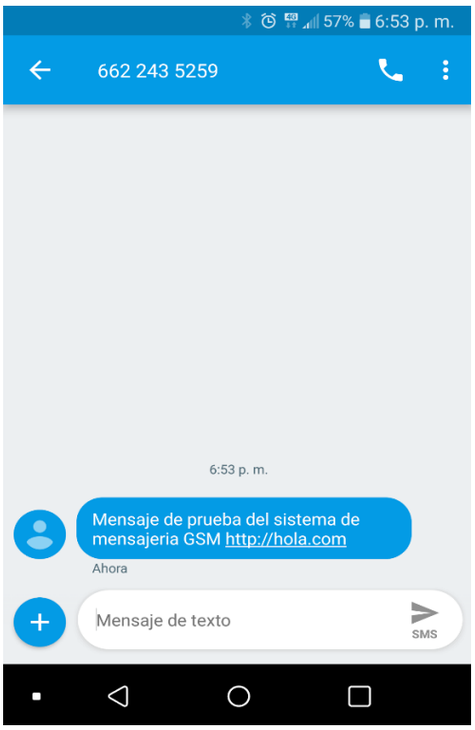

Figure 7 Test message received

By having all the integrated components send a text message with the content "Messaging system test message http://hola.com", and which was received on the client device successfully.

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Conclusions

With the development of this solution it was possible to verify the feasibility of creating a system using the C # programming language and Windows Presentation Foundation for the user interface, implementing the AT commands of the GSM mobile network system together with the use of modems compatible with these, the ability to manage it sent SMS messages without the use of third-party payment software or to make payments to a subscription service for sending bulk messaging to telephone companies, with which the only costs would be the acquisition of the modem GSM, cost of the SIM chip for access to the network and the cost of sending each message consumed to the telephone company.

Appendix A System status messages

Error	Explanation
The port is closed	The Connect button was not clicked after selecting a port in the Settings tab
No COM ports found	There is no compatible device connected to your computer
Invalid port settings	The configuration for the port is incorrect
The COM port is already being used	Another application is using that port
There was no answer	Device problem, if the device persists it is not able to send messages
Incomplete received response	Failure to communicate the device, if it persists reboot the system and the device
No data was received from the device	Failure to communicate the device, if it persists reboot the system and the device
GSM device not connected	The device connected to that port is not GSM
Failed to set the message format	The GSM device does not support sending messages

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A Survey of Performance Models for LTE-WiFi Wireless Heterogeneous Networks

Un estudio de Modelos de Desempeño para Redes Heterogéneas Inalámbricas LTE-WiFi

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Abstract

Nowadays, the network traffic has increased exponentially due to amount of information and number of users which are connected to Heterogeneous Networks (HetNets) in this case we focus on LTE-WiFi technologies. This is an important issue that need to solve for an efficient network communication process end to end. The aim of this article is to present the-state-of-the-art about performance models for LTE-WiFi HetNets and a classification of key performance metrics which help to analyze HetNets behaviour. The article concludes with a methodology that will be applied later for this research problem, as well as opened research questions. We believe, that apply our methodology using accurate and suitable models in HetNets the transmission process will have a fairness traffic when both networks coexist.

Hetergoeneous networks, Performance models, LTE

Resumen

En la actualidad, la creciente demanda de información y la cantidad de usuarios conectados a las redes inalámbricas heterogéneas (en este caso nos enfocamos en LTE-WiFi) está creciendo de forma exponencial. Es muy importante disminuir la congestión de la red generada por esta demanda para tener un eficiente proceso de comunicación fin a fin. EL objetivo principal de este artículo es presentar el estado del arte de modelos de desempeño para redes inalámbricas heterogéneas LTE-WiFi y una clasificación de métricas de desempeño claves para el análisis del comportamiento en estas redes. El articulo concluye con una metodología que será aplicada más adelante para este problema de investigación, así como preguntas de investigación abiertas. Nosotros creemos que al aplicar esta metodología utilizando modelos de desempeño precisos y adecuados en la red heterogénea el proceso de comunicación tendrá un tráfico equitativo cuando ambas redes LTE-WiFi existan y de esta forma se tenga una eficiente comunicación entre los usuarios finales.

Redes Heterogéneas, Modelos de desempeño, LTE

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Introduction

Nowadays, the network traffic has increased exponentially due to number of connected users and amount of information. This is an important issue that need to solve for an efficient network communication process, in other words, the end user can connect anywhere, anytime and any device with a better network quality of service to support user traffic demands.

Therefore, wireless networks are constantly evolving due to different factors that change the network behaviour, such as: (1) amount of users, (2) available bandwidth, (3) employed technology, (4) network load, (5) noise, (6) interference, (7) medium access control (MAC) protocols, etc. Also, the network performance can be affected with these factors. We consider a Heterogeneous Networks (HetNets) such as a set of devices interconnecting with different network protocols. We focus in LTE and WiFi networks which are widely used technologies today.

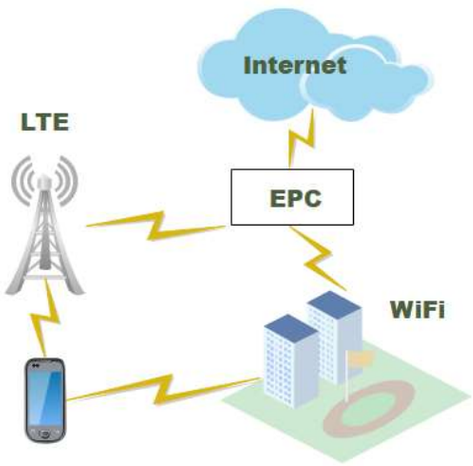

Figure 1 HetNet (LTE-WiFi) Scenario

For example, in Figure 1, we can see an HetNets scenario which components are: a Long Term Evolution (LTE) Network, an User Equipment (UE), a WiFi Network, the Evolved Packet Core (EPC) and Internet. The WiFi Network, in this case is an University Network.

Our motivation is that students can have an efficient connection, when both networks (LTE-WiFi) coexistence, at moment they want to do laboratory practices, school activities, homeworks, research, among others.

We think that performance models, which consider key factors such as: bit error rate (BER), Signal Noise to Ratio (SNR), signal-to-noise-plus-interference ratio (SNIR), packet collision probability, packet retransmission, among others, help to solve this network issue.

Some relevant related work about performance models for LTE and WiFi networks are described below.

The analytical model of Bianchi (2000) is used to estimate the throughput of an IEEE 802.11 network using the Distributed Coordination Function (DCF) under saturated conditions. This assumes: (i) any transmission queue always has packets to be sent, (ii) an ideal channel and (iii) a finite number of stations. The model considers two DCF techniques: basic and request to send/clear to send (RTS/CTS). The approach adopted is to analyze a single station modeled using a Markov Chain. The results demonstrate better performance is achieved when the RTS/CTS mechanism is used.

Duffy, Malone and Leith (2005) present an extension of Bianchi's model. They consider on-saturated network conditions, collisions in the Physical (PHY) layer and no noise present in the medium. The analysis is focused on the throughput, collision probability, delay, total offered load and (the optimal) minimum contention window. They employ three load types: Poisson, conditional and uniform.

Lin and Wong's model (2006) (IEEE 802.11n) addresses a uni-directional and bi-directional RTS/CTS access mechanism in the presence of collisions and channel errors in the system. This model, which is an extension of Bianchi's model, considers BER probability, minimum contention window length and a maximum backoff stage. Their model also includes the Medium Access Control (MAC) Protocol Data Unit Aggregation (A-MPDU) and MAC Service Data Unit Aggregation (A-MSDU) techniques to improve the MAC protocol performance. Simulation and analytical results are presented for throughput and delay. This is done for a different number of aggregations MPDUs and BER conditions.

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Kumar et al. (2017) address load imbalance problem in LTE networks. They propose a novel QoS aware load balance and a centralized software defined LTE RAN framework. The results show a better QoS data rates for more 80% of cells in the networks.

Chaves et al. (2013) present some challenges of WiFi/LTE coexistence, also they consider two mechanisms to enable the WiFi coexistence. These mechanisms are: a) blank subframes and b) uplink power control; both are described by Chaves et al. (2013). The results show a better throughput to use these mechanisms when WiFi coexistence.

Baswade et al. (2018), propose a scheme for WiFi for user fairness and efficient spectrum utilization in the presence of LTE-U. The results improve the performance of WiFi Network in presence of LTE-U.

This paper is structured as follows. First, we present a theoretical background about LTE and WiFi Protocols. Second, some performance metrics in HetNets are discussed. Next, various modelling tools for Networks are reviewed. Latter, we address some future directions and research challenges. Finally, conclusions are drawn up.

LTE and WiFi Protocols theoretical background

LTE protocol

The LTE protocol is developed by 3rd Generation Partnership Project (3GPP), which promises latency reduction, high spectral, frequency and bandwidth flexibility, short round trip time, among others.

The LTE protocol stack has the next layers for eNodeB: Radio Resource Control (RRC), Packet Data Convergence Protocol (PDCP), Radio Link Control (RLC), MAC and PHY; for UE Non-access stratum (NAS), RRC, PDCP, RLC, MAC and PHY. We can see in Figure 2, the LTE protocol stack.

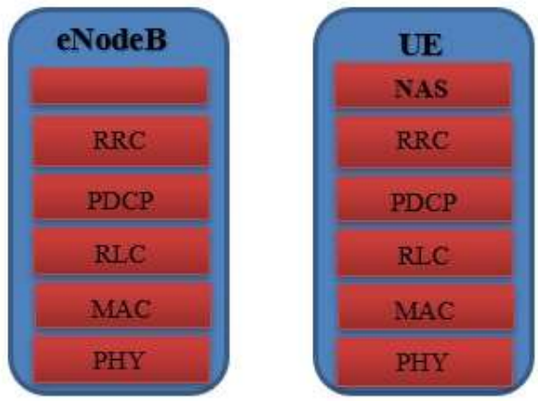

Figure 2 The LTE protocol Stack

MAC Layer

The MAC layer sends logical channels as transport channel and configures PHY layer for the next transport block. Some Mac layer functions are: Logical channel prioritazation, Error correction through hybrid Automatic Repeat Request (ARQ), mapping between transparent and logical channels and priority handling with dinamic scheduling. eNode schedules the uplink and downlink channels.

PHY Layer

This layer is typically full duplex and provides multiple channels simultaneously with different modulation (QPSK, 16QAM, 64QAM). The physical interface is a transport block which has 12 subcarries in one slot. LTE employs Orthogonal Frequency Division Multiplex (OFDM) for downlink data transmission and Single Carrier FDMA (SC-FDMA) for uplink transmission. Peak date rate: 300 Mbps for downlink and 75 Mbps for uplink whilst for LTE-A is 1 Gbps (downlink) and 500 Mbps (uplink).

WiFi protocol

MAC Layer

The DCF is the fundamental mechanism to access the medium based on carrier sense multiple accesses with collision avoidance (CSMA/CA). The DCF employs a binary exponential back-off scheme. When a station wants to transmit a new packet, it monitors the channel activity. If the channel is idle for a period equal to the distributed inter-frame space (DIFS) the station transmits the packet.

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On the other hand, if the channel is busy (either during or immediately after the DIFS), the station continues to monitor the channel until it senses idle for the DIFS. The station generates a random back-off interval before it transmits the packet. After an idle DIFS, a time slot is available and a station can only transmit at the start of each time. The time slot depends on the PHY layer (see Table 1). The back-off time is chosen in the interval 0 to W-1 in each packet transmission. The value W represents the Contention Window (CW) i.e. the amount of time available for the slots (Forouzan, 2013). In the first attempt, the W is equal to CW_{min} (minimum CW); after each unsuccessful transmission the W is doubled subject to a maximum of CW_{maxim}(maximum CW). CW_{maxim}=$2^{max}CW_{min}$, max is the maximum number of attempts or stages. The values of CW_{min} and CW_{maxim} are shown in Table 1. The back-off time counter decreases when the channel is sensed as being idle, but stops when there is a transmission in the channel (Hernandez et al., 2014).

The attempt rate is defined by Duffy, Malone and Leith (2005) as the probability that a station transmits in a randomly chosen slot time.

PHY	Slot Time	CW_{min}	CW_{maxim}
Frequency Hopping Spread Spectrum (FHSS)	50 µs	16	1024
Direct Sequence Spread Spectrum (DSSS)	20 µs	32	1024
Infrared (IR)	8 µs	64	1024

Table 1 Three PHY layers specified by *IEEE 802.11 Standard (2007)*

PHY Layer

We describe the IEEE 802.11g protocol for PHY layer. This protocol was finalized until June 2003; 802.11g is a relative late-comer to the wireless marketplace. Despite the late start, 802.11g is now the de facto standard wireless networking protocol. This standard is used on most laptops and handheld devices. The 802.11g protocol uses the same Industrial, Scientific and Medical (ISM) frequency range as the 802.11b protocol. This physical layer is based on DSSS according to the IEEE 802.11 Standard (2007).

This PHY operates in the 2.4 GHz ISM band and at a maximum raw data rate of 54 Mbit/s (with usable throughput of about 22Mbps). Also, this PHY layer can consider OFDM modulation. This makes it incompatible with 802.11b, and the higher frequency means shorter range compared to 802.11b/g at the same power. The frequency range is 2.400 - 2.495 GHz, which is used by the 802.11b and 802.11g radio standards (corresponding to wavelengths of about 12.5 cm). A single 802.11g link may use 54 Mbps radios, but it will only provide up to 22 Mbps of actual throughput. The remaining bandwidth is the overhead that the radios need in order to coordinate their signals using the 802.11g protocol. Since the 802.11g wireless equipment is half duplex (that is, it only transmits or receives, never both at once) the required throughput must be doubled accordingly, for a total of 10 Mbps. The wireless links must provide that capacity every second**,** or conversations will lag.

Performance Metrics in HetNets

In this subsection, we introduce some performance metrics that affect data transmission quality in HetNets. We focus mainly on: Packet Error Rate (PER), SNR, packet collision probability, bandwidth, throughput and delay. These metrics are described as follows:

1. PER. This metric is determined by the BER. The BER is defined as the number of bit errors divided with the total number of transfer bits in a time interval which is defined by Lin and Wong (2006). The PER is denoted as pe while the BER is P_{BER}. The PER is defined as:

$$pe = 1 - (1 - P_{BER})^{L_a} \quad (1)$$

L_a is the DATA packet length in bits, which includes physical layer header (PHY_H), MAC layer header (MAC_H) and packet load. The payload information is defined as:

$$P_{aload} = \frac{L_a - H_{total}}{\tau^a} \quad (2)$$

where

$$H_{total} = PHY_H + MAC_H \quad (3)$$

Physical layer header and MAC layer header are defined by IEEE 802.11 Standard (2007).

2. SNR. The SNR is a metric which compares the desired signal level to the level noise, and it is defined as:

$$SNR = \frac{P_{signal}}{P_{noise}} \quad (4)$$

P_{signal} is the average power of signal and P_{noise} is the average power of noise.

3. Packet Collision probability. It is the probability that a packet chrashes with other packet during the transmission process and is defined as:

$$Pc = 1 - (1-t)^{n-1} \quad (5)$$

Where t is the stationary probability (presented in Bianchi, 2000) when a station transmits a packet in a random slot time. At least one of $n-1$ stations transmit, in a time slot.

4. Bandwidth. This metric refers to the number of bits per second that can transmit in a channel, in other words, "refers to the speed of bit transmission in a channel" (Forouzan, 2013).

5. Throughput. Fakhri et al. (2006) defined the throughput as: the number of payload bits received with no error per second and kept this quantity as high as possible. They used the equation:

$$T = \sum_{i=1}^{N} \frac{L-C}{L} * R_i * f(\gamma_i) \quad (6)$$

Where L is total packet length (bits), C is a bit Cyclic Redundancy Check (CRC), R_i is the symbol rate assigned to sub-carriers i, $f(\gamma_i)$ is the packet success rate (PSR) defined as the probability to receive a correct packet.

Baswade et al. (2018), calculate the average throughput for non-victim users which are deprived of packets in LTE-U ON period and victim users which receive packets in both LTE-U ON and OFF periods, as follows:

$$\Gamma_{nv}^{new} = (1-\alpha)\Gamma_{nv}^{prev} + \alpha\Gamma_{nv}^{old} \quad (7)$$

$$\Gamma_{v}^{new} = (1-\alpha)\Gamma_{v}^{prev} + \alpha\Gamma_{v}^{old}$$

Where α is a smoothing parameter,"Γ_{nv}^{prev} and Γ_{v}^{prev} are average throughputs in the previous duty cycle period, and Γ_{nv}^{old} and Γ_{v}^{old} are the Γ_{nv}^{new} and Γ_{v}^{new} of the previous duty cycle period, for non-victim and victim user, respectively"(Baswade et al., 2018).

6. Delay. According to Forouzan (2013) the delay is defined as the time that a complete message takes to arrive to its destiny from the moment that first bit is sent through its source. Delay is composed in the following times (equation 8):

- Propagation Time (T_{pg}).
- Transmission Time (T_{tx}).
- Processing Time (T_{ps}).
- Queueing Time (T_Q).

$$Delay = T_{pg} + T_{tx} + T_{ps} + T_Q \quad (8)$$

Where: T_{pg} is Propagation time which is represented such as (equation 9):

$$T_{pg} = \frac{d_x}{S_{pg}} \quad (9)$$

The propagation speed of electromagnetic signals depends of medium and frequency signal. T_{tx} is transmission time (Forouzan, 2013) which is represented such as:

$$T_{tx} = \frac{message\ length}{bandwidth} \quad (10)$$

Abu-Ali et Al. (2014) mention that LTE defines nine categorias for delay 50 ms and 300 ms for the tightest and slackest respectivately.

Modelling for Networks

Queueing Models

One important tool for communication system is queueing analysis. This tool is similar to Markov's chains. Some examples of queues are: the number of customers in a bank line, the number of tasks needed to be processed, the number of messages in a network to be sent to their destiny, the number of patients in a hospital's waiting room, etc. The main purpose of queueing analysis is to predict the system performance.

For instance, the average delay a customer endures before served, the number of customers that are processed per time step and the queue size or waiting room requested (Dattatreya, 2008). The queueing model has the following characteristics (according with Adan and Resing, 2015):

1. Arrival Process of customers. This characteristic assumes that inter-arrival times have a common distribution and thus are independent. In some cases, the customer arrival ratio is based on Poisson Stream such as exponential inter-arrival times. The number of customers can arrive individually or in groups.

2. Behavior of customers. We can observe two kinds of customer´s behavior. Either a customer could have the patience to wait for a short or long period and could be impatient or leave after a short time.

3. Service Times. Adan and Resing (2015) mentioned that these kinds of times are independent and identically distributed and are also considered independent of inter-arrival times.

4. Service Discipline. There are two disciplines for customers: (1) they are served individually or (2) in groups. We present some of the common disciplines: First in – first out, Last in – first out, Priorities (e.g. hierarchical token bucket filter), Random order and Stochastic Fair.

5. Service Capacity. The service capacity is handled by a single server or several servers to provide support to the clients.

6. Waiting Room. Every system has a limited size of customers. Waiting room is less when a buffer size tends to be infinity. This is an important factor to the number customers that can be stored in system.

Process Algrebra

This methodology is defined as: "a mathematical framework in which system behaviour is expressed in the form of algebraic terms, enhancing the available techniques for manipulation" by Fokkink (2007).

Hernández Ochoa, et al. (2014) proposed a HMAN end to end communication process which is represented using process algebra. They presented the next communication processes: transmission process from the source, receiving process at the destination node, for any intermediate node and aggregation process at bridge node. They described a case study between 802.11 and 802.16.

Cross Layer Design

Currently, Cross Layer Design has become a great potential in wireless communication systems according to Aune (2004). Different Cross-Layer proposals are depicted in figure 3. Srivastava and Motani (2005) mentioned that layered architecture could be modified in the following different ways: Creation new interfaces (figs. 3 a-c); Fusion of adjacent layers (fig. 3 d); Design coupling without new interfaces (fig. 3 e); Vertical calibration across layers (fig. 3f).

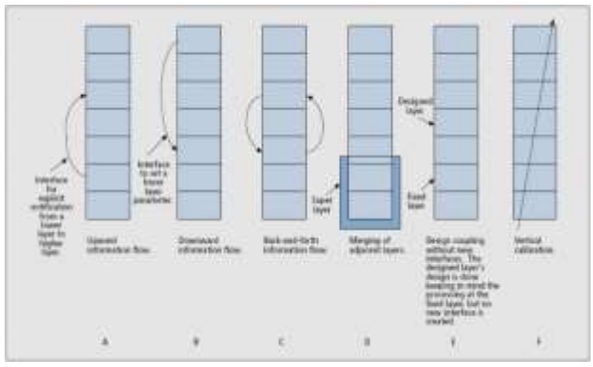

Figure 3 Different Cross-layer proposals by *Srivastava and Motani (2005)*

Performance Modelling

Performance modelling is a real system abstraction of a simplified representation to realize the performance's prediction (Ackerley, 2003). Although there are different working domains to the basic principles of modeling they are the same. However, the people who are working under those domains have to adapt them in accordance to their needs.

The two main domains for telecommunications are: (1) Network performance and (2) IT (Information technology) System Performance.

Performance modelling has the following advantages: inexpensive predictions for future performance, designed to allow objective polls to be made, support to decide for future of existing systems, a clear understanding of characteristics for system performance, a management mechanism for risks and reduction.

Future Directions and Research Challenges

In this survey, we present a review of some LTE-WiFi performance models and key metrics which give us a general vision of our methodology that we will apply in the near future. We can see in Fig. 4, the network performance before congestion (e.g. $t_k, k\epsilon N$), latter the factors can decrease the network performance and affect some Quality of Service (QoS) metrics, such as: delay, throughput, jitter, packet loss ratio, bandwidth, BER, PER, SNR, SNIR, among others. However, it must also be considered scalability, interoperability, and security to achieve a better communication process in the HetNets. Achieving this issue in HetNets at network domains is challenging. Thus, there should be mechanisms join to performance models capable to modify some processes, characteristics or state of the system caused by changes in network.

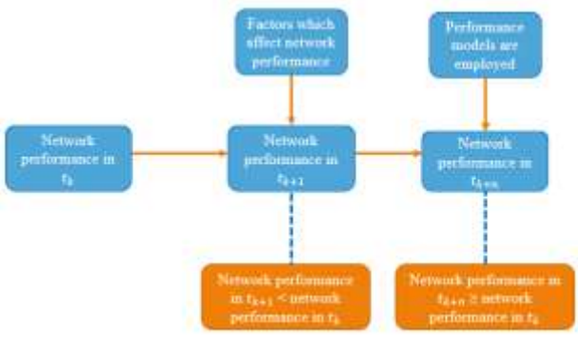

Figure 4 Methodology for HetNet (LTE-WiFi) performance

We believe, that apply a suitable methodology using accurate models that occurs in any network domain, the transmission process will have a fairness traffic when both networks coexist. Once the factors have affected the network behaviour (e.g. t_{k+1}), mechanisms and performance models are employed in a time ahead (e.g. $t_{k+n}, n = 2,3,4, ...$), as a result the network performance is improved.

For example, when university students (that is our study case, see the example of Fig. 1) can use this methodology, they could have a good end to end communication process although LTE and WiFi coexistence. Also, with this methodology, we will find key performance metrics that affect network behaviour. We wonder whether exists a metric that affects more than other metrics in network performance.

Conclusions

The HetNets behaviour problem can be studied considering BER, SNR, SNIR, packet collision probability, packet retransmission, among others. When all of them are analyzed together it becomes an interesting investigation. In this article, we presented a concise review of performance models between WiFi-LTE, a classification of key performance metrics and a methodology for HetNet (WiFi-LTE) performance. We showed that some fundamental challenges are to find accurate and adequate performance models as well as key metrics which it will depend on the context and needs in each HetNet. Hovewer, we still don´t know which key performance metrics will have greatest impact in this investigation. Research results of the main idea from our methodology will be issued in near future.

Annexes

We are grateful with the Secretary of Public Education which give us resources through the NPTC program. UDG-PTC-1435, (Scholar-NPTC)

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Clearly focus each of its features

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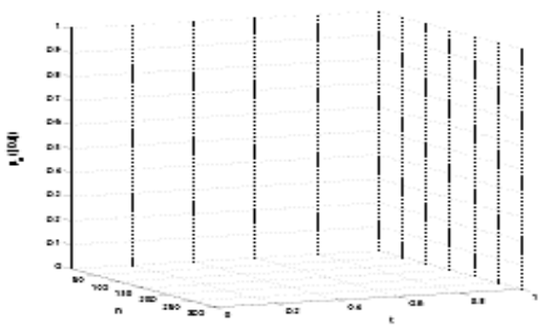

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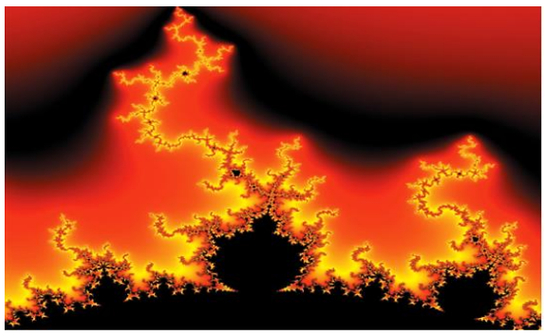

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$$Y_{ij} = \alpha + \sum_{h=1}^{r} \beta_h X_{hij} + u_j + e_{ij} \quad (1)$$

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Annexes

Tables and adequate sources

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Conclusions

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