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Journal of Computational Technologies

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Presentation of the content

In the first article we present, *Development and validation of distributed communication protocol from finite-state machines*, by RODRÍGUEZ-FRANCO, Martín Eduardo, MALDONADO-RUELAS, Víctor Arturo, VILLALOBOS-PIÑA, Francisco Javier and ORTIZ-MEDINA, Raúl Arturo, with adscription in the Universidad Politécnica de Aguascalientes and Instituto Tecnológico de Aguascalientes, in the next article we present, *Multi-agent system integrated to a Smart campus for mobile device detection and lamp management*, by DE LA CRUZ-PONCE, José Fabricio, LINO-RAMÍREZ, Carlos, ZAMUDIO-RODRÍGUEZ, Víctor Manuel and GUTIÉRREZ-HERNANDEZ, David Asael, with adscription in the Tecnológico Nacional de México, Campus León, in the next article we present, *Classification of emotions on images through convolutional neural networks as a method of preventing secondary alexithymia*, by TREJO-FRÍAS, Alejandra, RICO-GARCÍA, Paulina, VILLAFUERTE-LUCIO, Diego Ángel and PADILLA-NAVARRO, Christian, with adscription in the Universidad Politécnica de Juventino Rosas, in the next article we present, *Transfer learning for handgun detection*, by MARTÍNEZ-DÍAZ, Saúl, with adscription in the Instituto Tecnológico de La Paz.

Content

Development and validation of distributed communication protocol from finite-state machines

Desarrollo y validación de protocolo de comunicación distribuida a partir de máquinas de estados finitos

RODRÍGUEZ-FRANCO, Martín Eduardo†*´, MALDONADO-RUELAS, Víctor Arturo´, VILLALOBOS-PIÑA, Francisco Javier´´ and ORTIZ-MEDINA, Raúl Arturo´

´ Universidad Politécnica de Aguascalientes, Research Lab, Postgraduate and Research Direction, Mexico.
´´ Instituto Tecnológico de Aguascalientes, Tecnológico Nacional de México, Postgraduate Studies and Research Division, Mexico.

ID 1st Author: *Martín Eduardo, Rodríguez-Franco* / **ORC ID:** 0000-0002-6804-4777, **Researcher ID Thomson:** T-1539-2018, **CVU CONACYT ID:** 660892

ID 1st Co-author: *Víctor Arturo, Maldonado-Ruelas* / **ORC ID:** 0000-0003-2125-1557, **Researcher ID Thomson:** I-2774-2018, **CVU CONACYT ID:** 209649

ID 2nd Co-author: *Francisco Javier, Villalobos-Piña* / **ORC ID:** 0000-0003-1053-5642

ID 3rd Co-author: *Raúl Arturo, Ortiz-Medina* / **ORC ID:** 0000-0002-3790-3807, **Researcher ID Thomson:** H-9584-2018, **CVU CONACYT ID:** 878025

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Abstract

This work documents the use of communication finite state machines for the representation of interactions in a network of devices. Likewise, a hierarchical structure between elements is adopted, under an organization of master-slave nodes; from which, the implemented communication protocol assumes the particular functions of each device, while ensuring the exchange of information between them. In order to validate the adequate constitution of the proposed protocol, through its respective programming, Arduino and Raspberry free hardware and software are used, as well as a basic interface created from the Thonny development environment, for data entry by the user and the feedback of information to this. The results obtained demonstrate the functionality of the developed protocol, which was implemented from the serial communication standard, supported by the hardware used. However, it is essential to clarify that it is possible to implement this type of application from the use of other standards, as available.

Communication finite-state machines, Communication protocol, Device network

Resumen

Este trabajo documenta la utilización de máquinas de estados finitos de comunicación para la representación de las interacciones en una red de dispositivos. Asimismo, se adopta una estructura jerárquica entre elementos, bajo una organización de nodos maestro-esclavo; a partir de la cual, el protocolo de comunicación implementado asume las funciones particulares de cada dispositivo, al tiempo que asegura el intercambio de información entre éstos. Con el fin de validar la adecuada constitución del protocolo propuesto, a través de su respectiva programación, se emplean hardware y software libre Arduino y Raspberry, así como una interfaz básica creada a partir del entorno de desarrollo Thonny, para el ingreso de datos por parte del usuario y la retroalimentación de información hacia éste. Los resultados obtenidos demuestran la funcionalidad del protocolo desarrollado, mismo que fuera implementado a partir del estándar de comunicación serial, soportado por el hardware empleado. Sin embargo, es indispensable aclarar que es posible implementar este tipo de aplicación a partir del uso de otros estándares, según se disponga.

Máquinas de estados finitos de comunicación, Protocolo de comunicación, Red de dispositivos

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* Correspondence to Author: (E-mail: mc190002@alumnos.upa.edu.mx)
† Researcher contributed as first author.

Introduction

Communication systems are increasingly concurrent and distributed, attributes that are especially distinguishable in Internet of Things (IoT) applications (Duhart, Sauvage, & Bertelle, 2016) (Blanc, Bayo-Montón, Palanca-Barrio, & Arreaga-Alvarado, 2021). Thus, the effective coordination between the different components implies a challenge that must be assumed from the planning (Basu, Bultan, & Ouederni, Deciding choreography realizability, 2012). And, since the contemplated devices must ensure their own executions, while interacting with each other, the term "choreography" is used to distinguish the set of valid sequences for the exchange of messages between them (Basu & Bultan, Automated choreography repair, 2016) (Cruz-Filipe, Montesi, & Peressotti, 2021).

It is worth mentioning that the model proposed by a choreography can be interpreted from finite-state machines (FMS) properly defined. (Barbanera, Lanese, & Tuosto, Choreography automata, 2020) (Orlando, Di Pasquale, Barbanera, Lanese, & Tuosto, 2021). It is a set of states, and another set of transitions; the latter establish an action or conditions that determine a change or achievement between two different states (Ben-Ari & Mondada, 2017). From finite-state machines, it is possible to represent the interaction between elements of an analyzed communication system, through the asynchronous exchange of messages, through one or several channels disposed (Lange, Tuosto, & Yoshida, 2015).

For its part, a communication protocol can be conceived as a set of finite-state machines, which establishes roles, while the messages exchanged are created with a specific vocabulary (Barbanera, de'Liguoro, & Hennicker, Connecting open systems of communicating finite state, 2019). Therefore, the modeling of a communication protocol is formalized, to represent it as a transition of configurations for the transport of information through channels (Fragal, Simao, & Mausavi, 2016). In this way, both a concrete definition of communication processes and its low propensity for deadlocks or mismatches are promoted (Yoshida, Zhou, & Ferreira, 2021); with which, the tests of conformity are automated and speed up the detection and location of faults, once the protocol has been implemented (Yang & Kim, 2019).

Originally, choreographies were used to characterize peer-to-peer communication processes (Muscholl, 2010). However, recently it is possible to represent distributed processes, through master-slave interactions (Popovic, Marinkovic, Djukic, & Popovic, 2021), interest of this work. In such a hierarchical relationship of linked devices, one of these leads the communication process, managing in parallel, the information generated in, or guided towards, one or several alternate devices (Rodríguez Penín, 2012). Moreover, the representation of the relationships established by the communication protocol used must be independent of any programming language that may be used for its implementation (Walkinshaw, Taylor, & Derrick, 2016).

Motivation

The use of formal methods for establishing operation sequences has proven its effectiveness in a large number of technological fields. Important applications have been glimpsed mainly in the industrial environment, through the implementation of highly coordinated processes, involving a large number of physical systems. However, the field of information has not been the exception, constituting complex systems that, through the execution of algorithms, exercise data processing to guide their results to the performance of some task. In both cases, the constant has been the proposal of some methodology whose expression of the required process has gone beyond both the implementation itself, as well as the means used for this.

A way to combine the development of computer applications to ensure proper handling of hardware has been exploited since the proposal of the first cyber-physical systems. Therefore, if the adequate understanding between the real and virtual counterparts is adapted to a mode of operation that ensures functional interaction between them, it is possible to guarantee the fulfillment not only of a specific task, but a set of these, according to the scope of implemented system. Such coordination between the functions of a system, based on the information acquired, processed and issued, is especially enhanced through the use of formal methods, such as finite state-machines.

From the study of finite-state machines, as well as their application to the development of communication systems, promoted by this study, it is intended to establish a model that clearly defines the interactions between several interconnected devices, for data exchange purposes. In this way, data coming from input pins, after being processed and the pertinent decisions taken, will determine specific results, which will be destined to output pins, within a distributed architecture. Through which, not only is a physical organization of devices proposed, but also, from the constituted algorithms, a total adherence to the particular function that each one must perform can be ensured, to guarantee said process.

Device network and communication protocol operation

A hierarchical network of devices is proposed, made up of three classes of elements: end device, router and coordinator, commonly associated with IoT applications (Shrestha & Shakya, 2020). The end device is the means for the acquisition of data from the environment, at the same time that it is capable of generating signals that may affect physical conditions. For its part, the router serves as the communication interface between the end devices and the one used for process management. Finally, the coordinator operation allows interaction with the system user; from the performance of the functions of monitoring and control of the variables acquired, or manipulated, through the final devices. The structure of the proposed interaction is shown in figure 1.

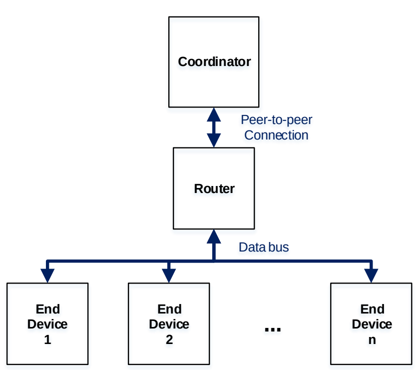

Figure 1 Proposed arrangement for device communication
Source: Own elaboration, 2022

As can be seen in the previous figure, a full-duplex interaction is promoted between the devices that conform the proposed communication network. Likewise, a peer-to-peer connection is adopted between the coordinator and the router, while a data bus is established for communication between the latter and the multiple end devices used. A data bus enables interaction between the router and the end devices by enabling communication channels, through which input or output data associated with each participating device is transported, duly addressed (Tocci, Widmer, & Moss, 2017).

Regarding the communication protocol, a structure based on finite-state machines was developed; which allows the management of certain input and output pins, of the final devices, from a remote interface. It is worth mentioning that there is no direct link, or any physical connection, between end devices and interface; for which, the router is incorporated to associate their functions. In this way, an interaction model is established under the structure of a supervision system, which could be later implemented, without the need to use a particular communication standard.

End device function

Physical input and output pins would be manipulated only in the final devices. The use of analog pins was chosen to provide a variable range of values that the device itself is capable of reading, or can generate. In this way, and if required, the management of physical processes would be facilitated through sensors and actuators that operate under the specifications described. For purposes of this analysis, the mentioned operation is contemplated for each final device incorporated into the suggested communication model. The dynamics of a final device is represented through the finite state machine of figure 2.

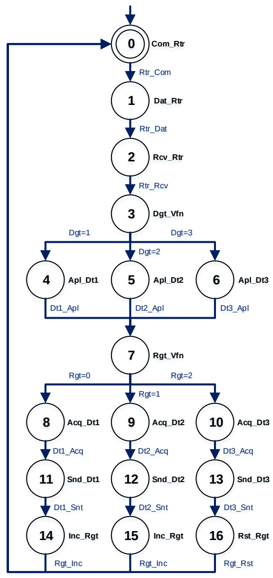

Figure 2 Operation sequence for an end device
Source: Own elaboration, 2022

The performance of the function of an end device would be triggered from the confirmation of communication with the router and the transfer of information from it; seeking immediately, the reception of the transmitted message. Three different types of data to be acquired are established, each one associated with a specific output to be manipulated; therefore, these would be differentiated from the first registered digit. Thus, regardless of the data received, it would be separated from its first digit, and the rest destined for the respective output pin.

Subsequently, the value assigned to a register in the algorithm itself would be evaluated, which would be directly associated with the signal to be acquired, coming from an input pin. Three possible values are proposed in the register, each one corresponding to the reading of a different input pin. It is worth mentioning that, regardless of the source pin, each acquired data would be sent to the router device. Whereas, once the transmission is over, the value of the register would increase by one; except that the previous value was two, in which case it would be reset to zero.

Router function

The information acquired in each end device would arrive at the router, suitably identified, to later be sent to the coordinator. However, such a management device could also send data, in this case, related to the condition of the output pins of the final devices. In this way, the router would receive the information from the coordinator, identify the final destination device and manage the transfer to it. The finite-state machine of figure 3 exposes the interaction performed by the router.

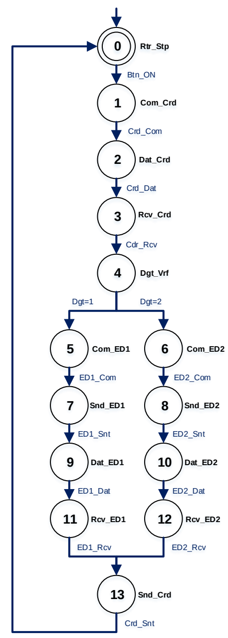

Figure 3 Operation sequence for the router
Source: Own elaboration, 2022

As proposed, the operation of the router would be established from the activation of a start button and inhibited from the activation of a stop button. Therefore, once activated, the router would verify the existence of information coming from the management device. In case of causing the transfer of a message, it would be received; while the contained data would be distinguished in reference to the first digit read. It is worth mentioning that such digit establishes the end device to which the acquired information must be destined.

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However, prior to sending data to any end device, the existence of communication with it would be verified. Therefore, once such a connection is confirmed, the data transfer would proceed, excluding the first number originally registered. Additionally, and according to the end device with which communication has been established, it would be verified if it had sent any data to the router. If the transfer of any data proceeds, it would be identified, registered and sent to the coordinator.

Coordinator function

The proposed communication model would consider the coordinator operation as associated with the system user. In this way, two tasks would be assigned to this device: the registration of the data entered by the user and the presentation of information to this. It is worth mentioning that the data provided by the user would be identified, registered and then conducted, via the concentrator, to the corresponding end device, for the manipulation of one of its output pins. Meanwhile, the information exposed to the user, properly identified, would come from the input pins of each end device contemplated. The coordinator operation is exposed through the finite-state machine of figure 4.

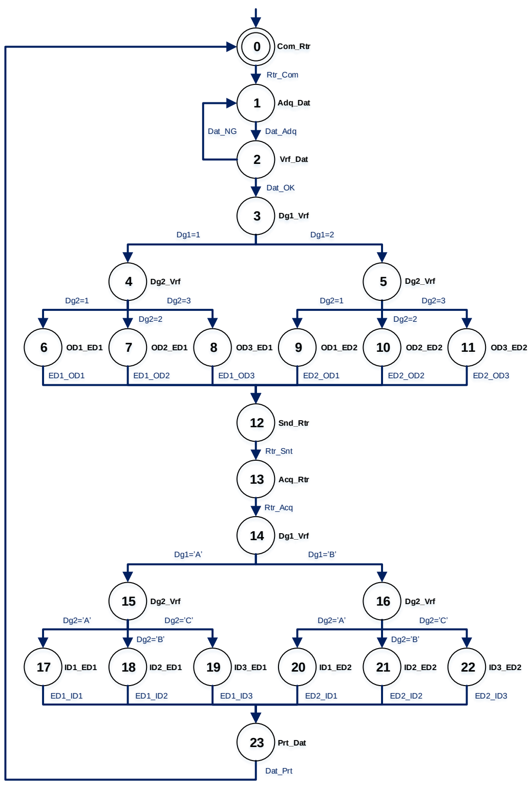


Figure 4 Operation sequence of the coordinator
Source: Own elaboration, 2022

The coordinator function would start by confirming the existence of communication with the router. Subsequently, the entry of some data by the system user would be verified, through the corresponding interface, in order to modify the status of a certain output pin in one of the end devices managed. If there is any data available, and if it complies with the format admissible by the system, it would be registered, according to the final destination device, from the first digit read. At the same time, the physical output pin to be manipulated in the end device at issue would be established, based on the second registered number, and the value assigned to said pin would be identified.

Once the registration of the data entered by the user has been validated, these would be sent to the router, and then be destined for the corresponding end device; at the same time that any data issued in the opposite communication channel would be acquired. In this case, from the identification of the first character in the received message, the final source device would be determined; while, based on the second character read, the physical input pin read would be established. Next, the registered information would be extracted by the input pin itself of the final device at issue; to conclude with the exposure to the user of both types of data processed in the system.

Implementation of the communication system

In order to validate the operation of the proposed communication protocol, the algorithms that would concentrate the functionality of each constituent device were developed. In this way, the abstraction established for each component, represented by the corresponding state machine, would be interpreted through the use of a specific programming language, while the transfer of information would be managed through some communication standard. Physically, the communication system for testing would be made up of a Raspberry Pi 4 computer as coordinator, an Arduino MEGA board as router, and two Arduino UNO boards as end devices, respectively, as shown in figure 5.

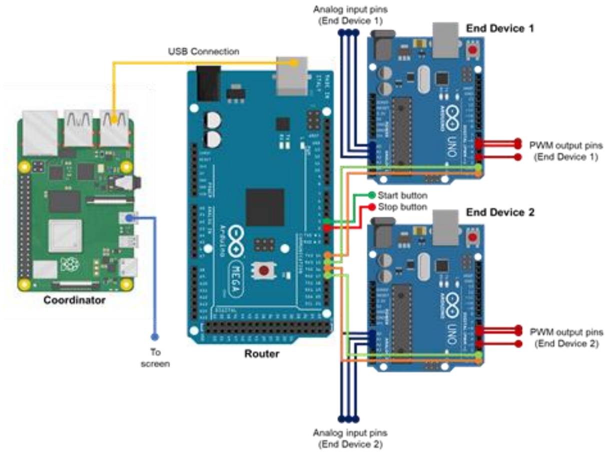


Figure 5 Distribution of devices for the communication system
Source: Own elaboration, 2022

The Python programming language would be used to ensure the operation of the coordinator; while the Arduino language would be associated with the functionality of both the router and the end devices. Likewise, the serial communication standard would be used, powered by the UART (Universal Asynchronous Receiver-Transmitter) device, which is adapted to the selected boards, for the exchange of data between them. Thus, to one of the USB ports of the Raspberry computer would be connected to the Arduino MEGA board, and in turn, to it, the Arduino UNO boards through the integrated serial communication ports.

User interface integration

In order to manage the proper exchange of information between the physical devices described, a user interface would be constituted, whose general structure can be seen in figure 6. To create the required interface, the Thonny integrated development environment was used, incorporated into the Raspberry computer's own operating system. It should be noted that this interface was completely configured in text mode, since it would not be used as a definitive means for entering and presenting information, but rather to validate the effectiveness of the interaction between the devices, based on the communication system implemented.

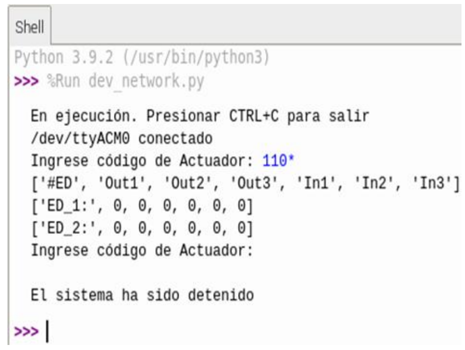


Figure 6 Appearance of the user interface
Source: Own elaboration, 2022

In this way, once the proposed boards have been programmed and duly connected, the user interface will show the confirmation of communication between the coordinator and the router. However, the activation of the respective start button will be necessary for the interface to allow interaction with the user. Subsequent to the issuance of said signal, data entry by the user will be enabled. Therefore, after the user has entered a code, it will be possible to view a table with the respective values for both the status of the output pins of each of the managed end devices, as well as the signals read from of each input pin on these.

Adaptation of exchanged data

Regarding the format used to enter data to the interface, the formation of a text string is contemplated, whose first digit designates the final device with which the session will be established. The second digit of the string will correspond to the specific output channel to which the effective data would be sent. Finally, the remaining numbers in the string refer to the value that will be sent directly to the output channel, in the end device established. It is worth mentioning that the system will ignore any value entered other than those proposed. For output control purposes, data input to the interface was restricted to values between 0 and 255. Such admissible range is determined from the resolution of 8 bits, at which the PWM (Pulse Width Modulation) output channels of the Arduino UNO boards used operate; and it is equivalent to the application of a variable voltage between 0 and 5 volts of direct current. On the other hand, for the representation in the same interface of the data read from the analog input pins used, the printing of values between 0 and 1023 was considered. In this case, the input channels have a resolution of 10 bits to register a variable voltage signal between 0 and 5 volts, also direct current.

System operation results

In order to validate the functioning of the implemented system, the architecture proposed in figure 5 was physically developed, contemplating the connection of potentiometers to the input pins and of LEDs (light-emitting diode) in the output pins, of both Arduino UNO boards used, as shown in figure 7. In this way, it would be possible to characterize, or influence, as the case may be, some variation in the behavior of the final devices. Note that, for purposes of validating the results, some values were previously assigned from the interface to the LEDs connected to the end devices disposed, at the same time, that the position of each of the potentiometers used has been modified and acquired the corresponding data, as reported in figure 8.

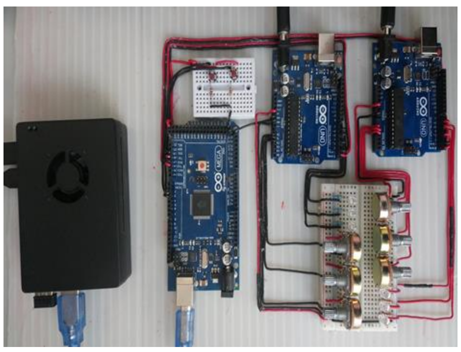
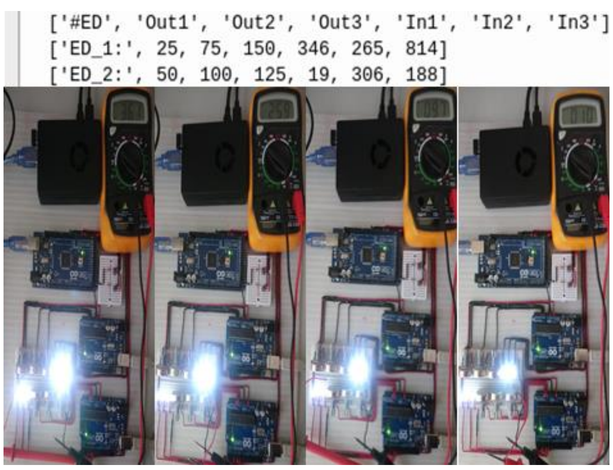


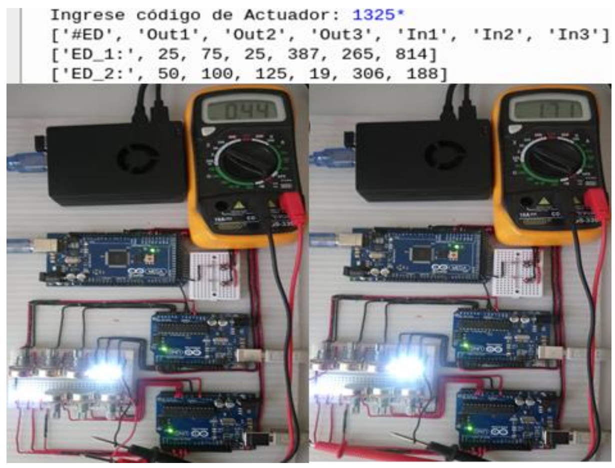
Figure 7 Communication system implemented
Source: Own elaboration, 2022



a) *b)* *c)* *d)*

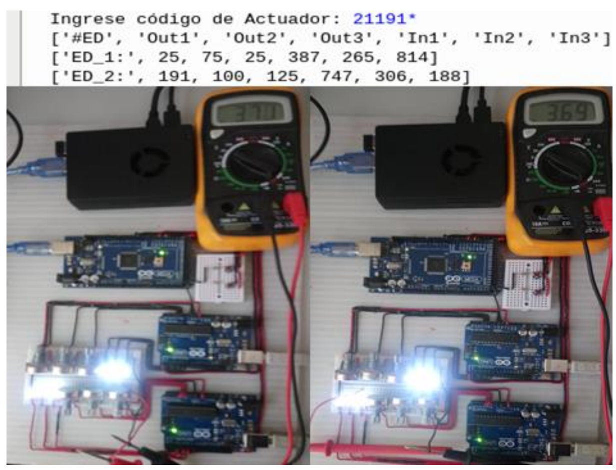
Figure 8 Initial state of the interface and the communication system for tests, and measured values in: *a)* the third output, *b)* the first input, both of the first end device, *c)* the first output and *d)* the first input, both of the second end device.
Source: Own elaboration, 2022

In figures 9 and 10, the designation of 25 and 191 resolution units is observed to the third output pin of the first end device, and to the first pin of the second device, respectively. Being possible to verify the equivalence between both data imposed by the user, from the interface, and those actually adopted, when measured in the corresponding output pin. Also, it is verified that, once the first data has been entered, the interface updates the value read from the first input pin of the same device to 387 units of resolution; while, for the second entered data, the value corresponding to the first input pin of the second device is the one that is updated to 747 units.



a) *b)*

Figure 9 Behavior of the interface and the communication system when: *a)* entering 25 units to the third output of the first end device, and *b)* reading 387 units from its first input
Source: Own elaboration, 2022



a) *b)*

Figure 10 Behavior of the interface and the communication system when: *a)* entering 191 units to the first output of the second end device, and *b)* reading 747 units from its first input
Source: Own elaboration, 2022

From the evidence provided, it is possible to verify that the proposed communication protocol assumes the complete mapping of the functions of each of the devices involved, regardless of the type of hardware used and its configuration. As it was validated, the use of finite-state machines as support for the planning and development of communication systems can be applicable both for peer-to-peer and distributed configurations, constituted under a hierarchical structure. Additionally, from the physical implementation, compliance with the designated operation specifications from the beginning of the development process was assessed.

Conclusions

Finite-state machines are considered powerful tools in the organization of sequential processes. However, a variant of these, used in the management of communication processes, has become very important due to the way in which it is possible to establish an interaction between devices, from abstraction to successful implementation, including planning. Emphasizing the application of finite-state machines for communication with total independence of methodologies, programming languages or established communication standards, without sacrificing the required functionality specifications.

On this occasion, in addition to exploring the adoption of this type of directed graphs in the implementation of peer-to-peer communication, its mostly widespread application, its adaptation between devices whose relationship is hierarchical, such as the master-slave interaction, was also analyzed. Therefore, it is important to highlight that the planning of a hierarchically structured information exchange process requires special care in the development of the necessary algorithms, since it is essential to ensure the proper function of each of the integrating devices, while ensuring the proper interaction between them.

Thus, the constitution of a protocol for the integration and interaction of three devices with different technical specifications is reported. And that, however, from the establishment of the effective relationships between them, by means of finite-state machines, the required exchange of data was successfully achieved.

This protocol could be validated from the use of open-source technology, such as Arduino and Raspberry, and simple electronic devices; in addition to using the serial communication standard, supported by both types of boards, to combine technologies whose potentialities and capabilities are far from each other.

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Multi-agent system integrated to a Smart campus for mobile device detection and lamp management

Sistema multiagente integrado a un Smart campus para la detección de dispositivos móviles y administración de lámparas

DE LA CRUZ-PONCE, José Fabricio†*, LINO-RAMÍREZ, Carlos, ZAMUDIO-RODRÍGUEZ, Víctor Manuel and GUTIÉRREZ-HERNANDEZ, David Asael

Tecnológico Nacional de México, Campus León, Graduate Studies and Research Division, León, Guanajuato, Mexico.

ID 1st Author: *José Fabricio, de la Cruz-Ponce* / **ORC ID:** 0000-0002-3581-9871, **CVU CONACYT ID:** 1031013

ID 1st Co-author: *Carlos, Lino-Ramírez* / **ORC ID:** 0000-0002-6415-8435, **CVU CONACYT ID:** 395781

ID 2nd Co-author: *Víctor Manuel, Zamudio-Rodríguez* / **ORC ID:** 0000-0002-9246-7999, **CVU CONACYT ID:** 70912

ID 3rd Co-author: *David Asael, Gutiérrez-Hernandez* / **ORC ID:** 0000-0002-9374-5110, **CVU CONACYT ID:** 167864

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Abstract

It describes the progress that has been made in the "Smart Campus" project, which is being carried out at the Instituto Tecnológico de León. The objective of this project is to improve the stay of the people who walk through the institution on a daily basis, using intelligent agents, artificial intelligence, the internet of things, software, databases, hardware and platforms that the University already has, using the traditional architecture to its advantage and adding certain elements that allow us to make this proposal a reality. The project aims to census the classrooms to improve the stay of people who walk through the institution every day, obtain environmental data from the classrooms in real time and manipulate the current that can be delivered to a lamp. In this article, we talk in depth about the construction process of the architecture, in which the whole project will be based in a technical way, but at the same time making it as understandable as possible for any type of public.

IoT, Smart campus, Environmental, Agents, Platforms

Resumen

Se describe el avance que se ha tenido en el proyecto “Smart Campus”, el cual se está llevando a cabo en el Instituto Tecnológico de León. Este proyecto tiene como objetivo, mejorar la estancia de las personas que día a día recorren dicha institución, apoyándonos con agentes inteligentes, inteligencia artificial, el internet de las cosas, software, bases de datos, hardware y plataformas con las que ya cuenta la Universidad, usando a favor la arquitectura tradicional y agregando ciertos elementos que nos permiten hacer realidad esta propuesta. El proyecto tiene como objetivo, censar las aulas para mejorar la estancia de las personas que día a día recorren dicha institución, obtener datos ambientales de las aulas en tiempo real y manipular la corriente que se le puede entregar a una lampara. En este artículo, se habla a fondo sobre el proceso de construcción de la arquitectura, en la cual estará cimentado todo el proyecto de manera técnica, pero al mismo tiempo haciéndolo más entendible posible para cualquier tipo de público.

Internet de las cosas, Campus inteligente, Medio ambiente, Agentes, Plataformas

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* Correspondence to Author: (E-mail: m14240570@leon.tecnm.mx)
† Researcher contributed as first author.

Introduction

The word 'Smart' comes from the English language, which we could interpret as 'intelligent', nowadays it is used as a misleading marketing strategy, smart lamps are sold, smart locks, among other things, but we have stopped to think what is smart about them, how can we define that something is smart or not, and then, why this project has that name, maybe we put it because it is fashionable, like the Internet of Things and Industry 4.0.

The Internet of things and intelligent environments are issues that we see closer and closer in our daily lives, because they make use of technologies that years ago were little used in everyday life, such as an internet connection or simply a mobile phone in which the screen time was extremely minor compared to the use that is given to it today, As time goes by, what we saw in films and series such as working from home with video calls where people from all over the world interact and speak different languages or having a humanoid personal assistant, generated feelings of uncertainty and probably excitement, but things that in the last century were big problems, there are probably young people today who never had to know them and now they deal with other types of impediments.

New technologies are of great help and solve many of the problems we have, however, they bring us new problems, imagine the fact of building the nuclear bomb, and ending with an enemy and the problem of radiation that it will leave for years, likewise in this project we propose different ways in which we can help the people who belong to our institution with the use of technologies such as intelligent agents, sensors, databases, to say a few. For us it is important to point out that we use the word intelligent in reference to the fact that at some point we want our technological ecosystem to be able to remember and use these experiences to make decisions and generate recommendations for any individual belonging to the institution.

Intelligent agent

An intelligent agent is considered to be a system that can perform an automated process to achieve a goal, with the condition that the system recognises and acts on an environment, as it can perceive information, communicate or receive data and perform a corresponding action (Serna et al., 2019).

Multi-agent

Each agent is able to understand its situation and adapts to changing environments through self-conFiguration. Situational awareness is achieved through learning and contextual modelling of event data. Once a set of contextual bases is learned from the high-dimensional event data, different scenarios can be represented by the clustered contextual coefficients. Agents can then perceive the situation and locate regions of interest (RoIs) through the identified scenarios. Each agent has a behavioural state machine and a behavioural library; it chooses a certain behaviour according to the target individual and the behaviour of other agents (Sun et al., 2013).

Smart City

The concept of "Smart City" appeared as the application of automatic environmental data collection and processing to achieve efficient management of urban areas and their resources and assets. This approach is supported by the massive application of information and communication technologies (ICTs) and the Internet of Things (IoT) paradigm, in which a large number of distributed devices are connected to transfer the collected data (Fortes et al., 2019).

Smart Campus

A Smart Campus is a smart city-like infrastructure that makes use of Internet of Things (IoT) solutions to connect, monitor, control, optimise and automate a university's systems.

Today, a smart campus represents a challenging scenario for IoT networks, especially in terms of cost, coverage, availability, latency, security, energy consumption and scalability (Fraga-Lamas et al., 2019).

A smart campus must immerse itself into the digital era and improve processes with the help of artificial intelligence (Cesur et al., 2019).

State of the art

In the work of the University of Coruña (UDC) they implement LoRaWAN which is a technology for low-power networks and wide areas. Its objective is to measure the radio frequency intensity in different areas and to propose an architecture for future works such as a mobility pattern detection system, a smart irrigation solution and an implementation of smart traffic monitoring (Fraga-Lamas et al., 2019).

The paper (Smart CEI Moncloa) presents an IoT-based platform for monitoring the flow of people and the environment in a Smart University Campus deployed in the CEI Moncloa campus, with special emphasis on the main technological challenges faced and solutions adopted, as well as the functionality, services and potential offered by the platform (Alvarez-Campana et al., 2017).

In another work it is proposed that a smart room is a way to create a smart campus, using ESP8266 and sensors to control the light in a room (Yuliansyah et al., 2019), in the same way it is possible to use ESP32 to monitor the environment (Babiuch & Postulka, 2021), based on these works a smart room can be considered as a smart classroom.

On the other hand, for the part of mobile device detections they use wifi waves (Gómez R. & Pedraza, 2018).

There are different ways in which a Smart Campus can be built our approach was to put together ideas from different works and create a multi-agent system focused on the Smart Campus, we get to use several technologies for communication such as mobile networks for end users and low-power networks for agents.

Agents

For the construction of each agent, 6 sensors, an actuator, an ESP32 with Arduino and a Raspberry Pi 3 were used, as shown in Figures 1 and 2. An ESP32 is used because the data provided by some sensors are analogue, which cannot be interpreted with a Raspberry Pi 3.

Sensors, actuator and communication

A presence or movement sensor (PIR), a light sensor (BH1750), a noise sensor (KY-037), a temperature and humidity sensor (DHT11), a gas sensor (Sensor MQ-7) and an air quality sensor (MQ-135) were used.

A dimmer module was used that works with a triac whose function is to detect the zero crossing of the alternating current in order to manipulate the light intensity of a lamp.

An ESP32 was used to read the sensors and manipulate the light intensity.

Processing

The ESP32 gets the data from the environment with the sensors and the data is sent to the Raspberry. The Raspberry calculates the required intensity and sends the intensity values to the ESP32 which the ESP32 then sends to the dimmer.

The intensity calculation needs 2 inputs which is the ambient light intensity and the current time. The calculation gives an intensity between 20 and 80, which are values where the lamp works correctly and these same values the ESP32 converts them to milliseconds to send pulses to the dimmer and this in turn turns on the lamp.

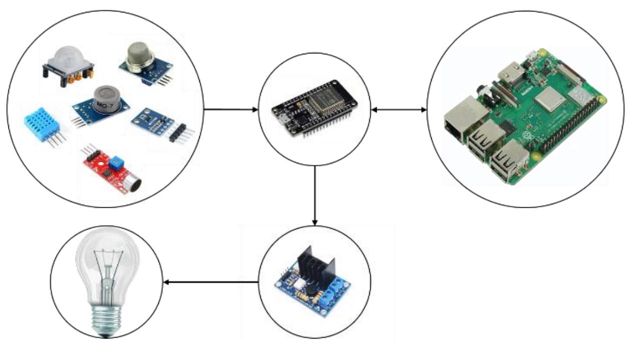

Figure 1 Agent structure
Source: Own elaboration

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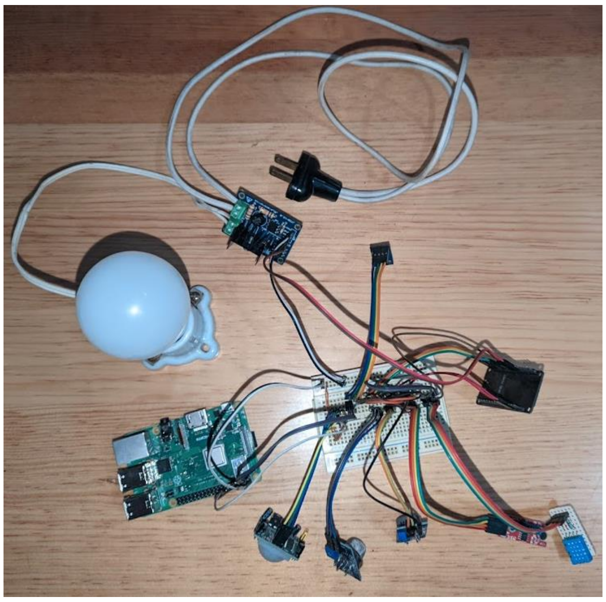


Figure 2 Assembled agent
Source: Own elaboration

Development

The system is based on the architecture proposed in the work "Propuesta de una arquitectura para un Smart Campus Universitario" (CRUZ-PARADA et al., 2020), using sockets, agents, database and end devices, as shown in Figure 3.

Socket

We worked at the same time in the construction of the different actors that we have in the Smart Campus, as shown in Figure 3, we proposed the use of a "Socket" server which will allow us to communicate all our actors within the project, so we will begin by showing its process.

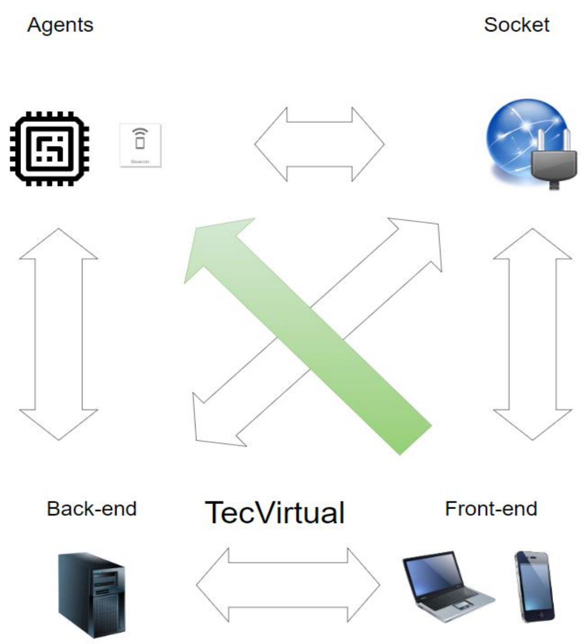


Figure 3 Architecture proposal for the Smart campus
Source: (Cruz-parada et al., 2020)

The first step in the construction was to define which language our socket server would be built on and which library would be used as a base in order to obtain a stable platform that would allow us to have shorter development times using the tools that the repository already has. There are as many alternatives as there are for each language, each one already has specific functions to carry out these tasks. We chose to use the socket.io library, given that it uses the JavaScript programming language and that a large part of the architecture is based on this language.

Once the tool has been defined, we start by making the connection as shown in Figure 4, we define the functions with which we will detect who is connected, differentiating between users and agents, with the possibility of adding more functionality later.

```
io.sockets.on('connection', function (socket) {

    // When human user join to the socket service
    socket.on('join', (user) => {
        removeUser(user.id);
        socket.join(user.type);
        addUser(socket.id, user.id, user.type);
        getAgentsOnlineDB(socket.id);
    });

    // Update the position of the user's match with an agent
    socket.on('here',(macAddressAgent)=> {
        try{
            agentId = getIdFromMac(macAddressAgent);
            user = getUserBySocketId(socket.id);
            updateUserPosition(agentId,user.id);
        } catch (e) {}
    });

    // When agent user join to the socket service
    socket.on('joinAgent', (agentId) => {
        removeAgent(agentId);
        addAgent(socket.id, agentId, 0);
        setAgentOnline(agentId,true);
    });
```

Figure 4 Socket source code
Source: Own elaboration

Mobile application

At the same time we started with the development of the mobile application, which will serve as a link between the user and the Smart Campus, the decision on which development platform we would use was simple, we needed a fast and multiplatform development so we opted for the use of Ionic Cordova, which allows us to develop an application in Angular and reuse the code by compiling it on both the Android and iOS platforms.

We used as a basis the test application with which Ionic shows the full functionality that the platform has, this framework, so it was enough to add our functionality that makes the connection with the backend, which already has the institution, to the views and change some texts, to quickly have a robust application, once we have a functional app we start connecting it with the socket previously described as shown in Figure 5.

```
start() {
    this.socket = io(environment.urlServerSocket);
    this.startScaning()
    console.log('empieza conexión');
    this.socket.on('connect', ()=> {
        this.userData.getUsername().then(username => {
            this.socket.emit('join', {curp:username,sala:1} , (error) => {
                if (error) {} else {}
            });
        });
    });

    this.socket.on('connect_error', async (error) => {
        this.scanning = false;
    });

    this.socket.on('setAgentOnline', (list)=>{
        this.userData.setAgentsOnlineList(list).then(()=>{
            this.scanning = true;
        })
    });
}
```

Figure 5 Source code for connecting application to socket
Source: Own elaboration

Agent

At the same time we worked on the development of the agent, although later we will try to have different types, for the moment we are working on a base agent, which can be used to later add enough code to change the type without losing the structure of the other agents. We will mount our agent on a Raspberry Pi 3 device since it already has the bluetooth connectivity we need for the project and is using a very suitable operating system for this type of task based on Linux. Together with this device we will use the Python programming language and a set of libraries which allow us to create an agent that is constantly listening and at the same time we can add artificial intelligence modules, modules that we will use in future works in order to achieve the objective of the Smart Campus. We start by generating an id with which we can identify our agent and then start listening as shown in Figure 6, once the agent started to run the first thing it does is to establish communication with our socket server as shown in Figure 7, and once the connection to the socket is made, the socket function is called which joins us to the list of agents and at the same time updates the status of the same in the database. As shown in Figure 8, part of the socket code.

```
# Get ID
mac = bluetooth.read_local_bdaddr()
my_id = int(mac[-1].replace(':', ''), 16)

# Turn On Agent
agents_list = list()
agente = Agente(AID(name=str(my_id)))
agents_list.append(agente)

start_loop(agents_list)
```

Figure 6 Obtain identifier to turn on the agent
Source: Own elaboration

```
def on_start(self):
    super(ComportTemporal, self).on_start()

    # Socket
    sio.connect(os.getenv('SOCKET_URI'))
```

Figure 7 Connecting the agent to the socket
Source: Own elaboration

```
// When agent user join to the socket service
socket.on('joinAgent', (agentId) => {
    removeAgent(agentId);
    addAgent(socket.id, agentId, 0);
    setAgentOnline(agentId,true);
});
```

Figure 8 Adding an agent to the connected list of the socket
Source: Own elaboration

Once everything is connected, the socket sends the application a list of identifiers, once the application receives the list, it starts searching for devices using bluetooth as shown in Figure 9, and once it detects a match with an agent it makes the call to update the user's position associated with an agent, which would help for future specialised services, such as automatic roll call, among others.

```
start() {
    this.devices = [];
    this.ble.scan([],20).subscribe(device => {
        this.onDeviceDiscovered(device)
    });
}

onDeviceDiscovered(device){
    this.ngZone.run(()=>{
        this.devices.push(device);
        this.checkAgentList(device)
    });
}

checkAgentList(device) {
    this.userData.getAgentOnlineList().then((list)=>{
        list.forEach((agentId,index)=>{
            if (agentId == device.id) {
                this.socket.here(agentId);
                return;
            }
        })
    })
}
```

Figure 9 Search agents (Application source code)
Source: Own elaboration

Finally, it detects when a user disconnects and updates their status within this ecosystem as shown in Figure 10.

```
// Triggered when a user disconect
socket.on('disconnect', () => {
    let user = getUserBySocketId(socket.id);

    if (user) {
        users.removeUser(user.id);
    } else {
        let agent = getAgentBySocketId(socket.id);

        if(agent) {
            agents.removeUser(agent.id);
            setAgentStatus(agent.id,false);
        }
    }
})
```

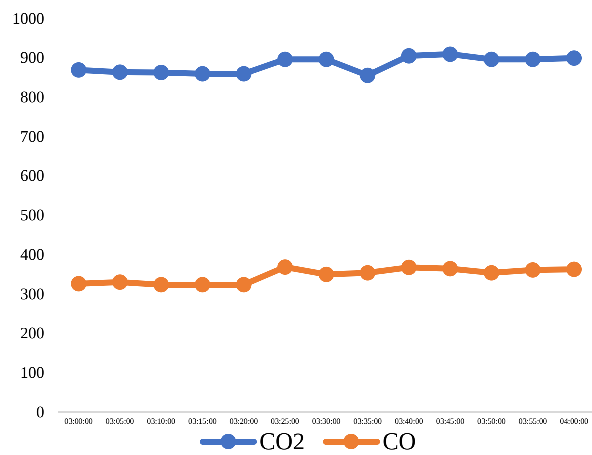
Figure 10 Detecting disconnected agents (Socket source code)
Source: Own elaboration

Results

The results of this stage of the project are in line with what was planned from the beginning, and leave everything ready to start with the next phases of the project, we can see in Figures 11 and 14, we have in real time the status of our agents and they can be consulted at any time, besides being able to generate graphs of environmental data such as air quality as shown in Figure 1, which could be useful in times of COVID.

_id: 242606372691727
status: "online"
build: "Postgrado"
location: "Laboratorio 1"
dates: Array
  0: Object
    date: 2022-02-28T02:55:48.537+00:00
    co2: "869"
    co: "326"
    noise: "59"
    humidity: "21.00"
    temperature_c: "25.50"
    temperature_f: "77.90"
    heat_index_c: "24.65"
    heat_index_f: "76.38"

Figure 11 Real-time agent status
Source: Own elaboration



Graphic 1 Air quality graph for 1 hour on February 28, 2022
Source: Own elaboration

Likewise, as shown in Figure 12, we have the last registered position of the users which is linked to the agent where they were and in Figure 15 we have the position of the users in the application.

_id: ObjectId("621c9c8a2f84b1e21da05a33")
agent: 354653214445
user: "M14240580"
updatedAt: 2022-02-28T09:57:30.531+00:00

_id: ObjectId("621ca5bdad563eed1f632969")
agent: 242606372691727
user: "M14240570"
updatedAt: 2022-02-28T10:36:45.398+00:00

Figure 12 Last location of a user
Source: Own elaboration

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We have a functional application on Android and iOS, which already has a connection with the services that the institute's old platforms already had, such as logging into the system, checking the student's timetable, to mention a couple, thanks to the architecture that was planned based on the strategy of using one or more api, and it is also prepared to add the services that are necessary as the project progresses, as shown in Figures 13, 14 and 15.

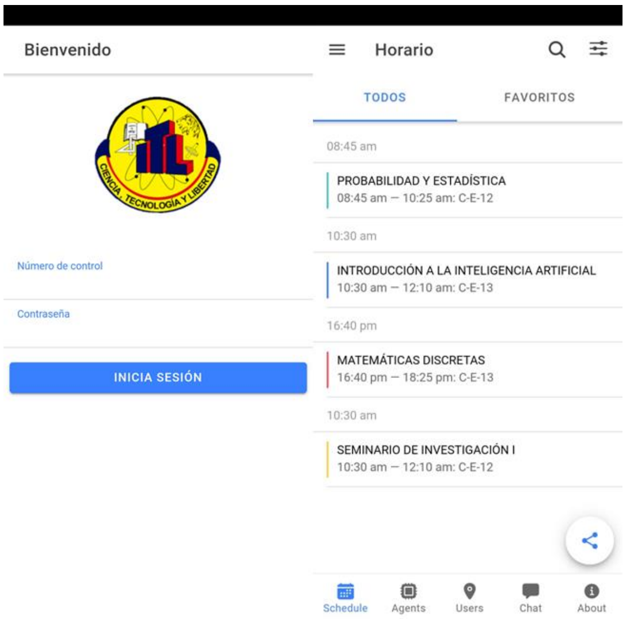

Figure 13 Login application and class schedule on Android
Source: Own elaboration

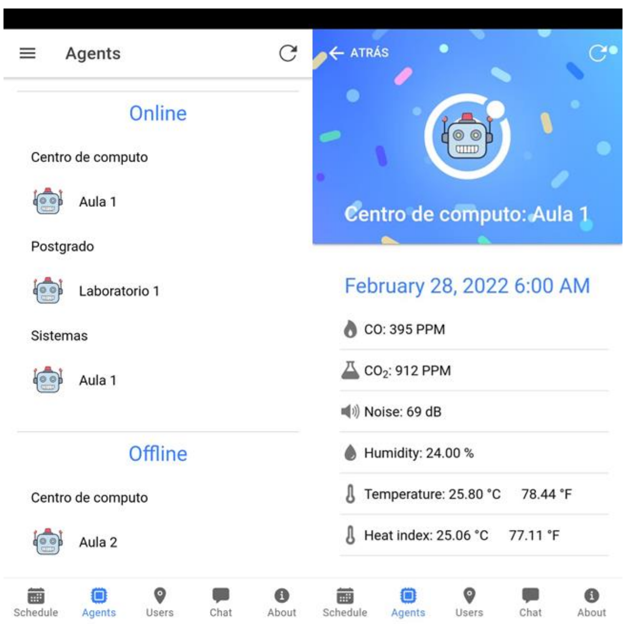

Figure 14 Real-time agent status in Android application
Source: Own elaboration

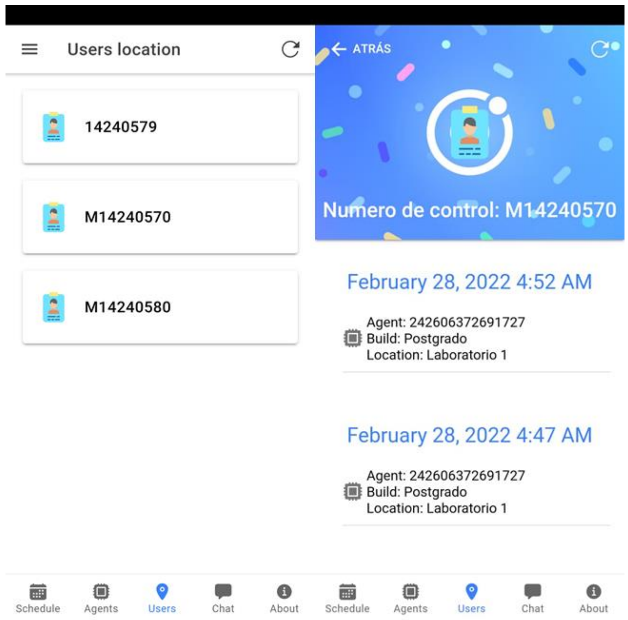

Figure 15 Location of the users application on Android
Source: Own elaboration

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Conclusions

The development of the project described in the document shows how we acted on the need to create an intelligent university campus using agents installed in different areas of the institute, this will allow us in the future to develop modules with artificial intelligence in the agents already installed to improve security, improve welfare, improve academic performance, etc.. And all of this focused on the users of the environment. On the other hand, the location of the devices within the institution may or may not be shared due to privacy issues. Showing the location in the application is provisional and for testing purposes since the location of the users will not be visible to any user.

Some of the future works are the automatic roll call, regulating the temperature of an environment, detecting if a student or teacher is isolated and providing support, making intelligent recommendations according to their subjects, etc.

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Classification of emotions on images through convolutional neural networks as a method of preventing secondary alexithymia

Clasificación de emociones en imágenes mediante redes neuronales convolucionales como método de prevención de la alexitimia secundaria

TREJO-FRÍAS, Alejandra†*, RICO-GARCÍA, Paulina, VILLAFUERTE-LUCIO, Diego Ángel and PADILLA-NAVARRO, Christian

Universidad Politécnica de Juventino Rosas, Department of Network and Telecommunications Engineering, Mexico.

ID 1st Author: *Alejandra, Trejo-Frias* / **ORC ID:** 0000-0003-1582-1971

ID 1st Co-author: *Paulina, Rico-García* / **ORC ID:** 0000-0003-2540-6309

ID 2nd Co-author: *Diego Ángel, Villafuerte-Lucio* / **ORC ID:** 0000-0002-7559-7847

ID 3rd Co-author: *Christian, Padilla-Navarro* / **ORC ID:** 0000-0002-8241-3225, **CVU CONACYT ID:** 427341

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Abstract

Alexithymia can be defined as the inability to verbalize affective states. One of its main causes lies in the lack of learning of emotions during childhood and can prevail until adulthood. Its identification at an early age can solve problems such as depression and cutting that, in severe cases, can lead to suicide. The present investigation shows the implementation of two convolutional neural networks for the classification of emotions through images.

Convolutional neural network, Classification of emotions, Secondary alexithymia

Resumen

La alexitimia puede ser definida como la incapacidad de verbalizar estados afectivos. Una de sus principales causas radica en la falta de aprendizaje de las emociones durante la infancia y puede prevalecer hasta la edad adulta. Su identificación a temprana edad puede solventar problemas como la depresión y el cutting que, en casos severos, pueden llevar al suicidio. La presente investigación muestra la implementación de dos modelos de redes neuronales convolucionales para la clasificación de emociones a través de imágenes.

Red neuronal convolucional, Clasificación de emociones, Alexitimia secundaria

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* Correspondence to Author: (E-mail: atrejof_pa@upjr.edu.mx)
† Researcher contributed as first author.

Introduction

Alexithymia can be defined as the inability to identify, recognize, name or describe one's emotions or feelings, with particular difficulty in finding words to describe them (Alonso-Fernández, 2011). There are two types of alexithymia: primary alexithymia, which occurs due to biological issues; and secondary alexithymia, which is usually attributed to traumatic and psychological factors.

The prevention of secondary alexithymia in early stages can contribute to avoid problems such as: cutting, depression and, in severe degrees, suicide (Alonso-Fernández, 2011).

To achieve the prevention of this emotional communication deficit, it is essential to carry out an adequate detection. For this purpose, there are different tests that involve the classification of emotions through images by the patient. Performing these tests using digital methods is desirable to provide greater confidence to people, in addition to seeking a high degree of efficiency in the process.

The present research implements two convolutional neural network models in order to perform automatic classification of emotions through images as a support tool for prevention of secondary alexithymia.

Literature review

Emotion classification is a research problem that has been worked on constantly for at least two decades; however, it is still relevant because human expressions are complex and variable. Some of the most current contributions to the state of the art are shared below.

In (Jain, 2018), a deep neural network model is presented in a hybrid method of convolutions and recurrent neural networks for facial expression recognition. Such a network is applied to JAFE and MMI databases, which have as emotions: anger, sadness, surprise, joy, disgust, fear and neutral. Its best results are up to 94.91% correct.

Meanwhile, in (Mehendale, 2020), they propose a novel technique called "facial emotion recognition using convolutional neural networks" (FERC). FERC is based on a two-part convolutional neural network (CNN): the first part removes the image background and the second part concentrates on extracting the facial feature vector. The supervised data they used was obtained from the stored database of 10,000 images (154 people). Their results were 96% accuracy.

On the other hand, in (Pranav,2020), they propose a Deep Convolutional Neural Network (DCNN) model that classifies 5 different human facial emotions. The model is trained, tested and validated using the manually collected image dataset. Its results are 78.04% correct.

Similarly, in (Ferreira, 2018), they propose a new end-to-end neural network architecture along with a well-designed loss function based on the strong prior knowledge that facial expressions are the result of movements of some facial muscles and components. As a test dataset they use the CK+ database, which includes 1308 images with different emotions (80% training and 20% test). Their results are 93.64% correct.

On the other hand, in (Saravanan, 2019), classify images of human faces into one of the seven basic emotions. They experimented with several different models, including decision trees and neural networks, before arriving at a final convolutional neural network (CNN) model. As results, they obtained a 60% accuracy rate using the FER-2013 database.

Finally, in (Hung, 2019), a neural network was implemented for basic emotion classification. They used a test set from various databases, including FER-2013. Their best results are 84.59% correct, achieving one of the best classifications in the state of the art when using this database.

Methodology

Two convolutional neural network models were proposed for the development of this research. In both cases, the phases that the methodology went through were: reading the input data, creating the input vector (image and label), normalizing the data, creating the data sets, creating the models, training, and, finally, validation.

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Model 1

The first model of the convolutional neural network (CNN) consists of: a convolutional layer of 32 neurons with linear activation, a LeakyReLU activation function with a parameter of alpha = 0.1, a MaxPooling2D (2x2) function, a Dropout function of 0.5, a Flatten function, a Dense layer of 32 neurons with linear activation, a Dense layer of 32 neurons with linear activation, a LeakyReLU activation function with parameter alpha = 0.1, a Dropout function of 0.5 and finally a Dense layer with Softmax activation..

Model 2

The second model of the convolutional neural network (CNN) consists of: a convolutional layer of 32 neurons with relu activation, a MaxPooling2D function (2x2), a convolutional layer of 64 neurons with relu activation, a MaxPooling2D function (2x2), a convolutional layer of 128 neurons with relu activation, a MaxPooling2D function, a Dropout function of 0.5, a Flatten function, a Dense layer with relu activation, a Dense function with softmax activation

Database

The database used was the "Learn facial expressions from an image", FER-2013, consisting of 48x48 pixel grayscale images of faces. The database is labeled in seven categories: 0=angry, 1=disgust, 2=fear, 3=happy, 4=sad, 5=surprise, 6=neutral. The training set consists of 28,709 examples and the public test set consists of 3,589 examples. An example of this database can be seen in Figure 1.

Figure 1 Sample of the FER-2013 dataset used for emotion classification during this research

Tests and results

For the tests, 10 runs of each proposed model were performed, in all cases for 100 epochs. For the first model, the average accuracy was 60.89%, although the validation of the model obtained 49.98% accuracy. The results of the model can be seen in Figure 2 and Figure 3. For the second model, better results were obtained, with 74.90% accuracy, although the validation of the model obtained 55.42%. The results of the model can be seen in Figure 4 and Figure 5.

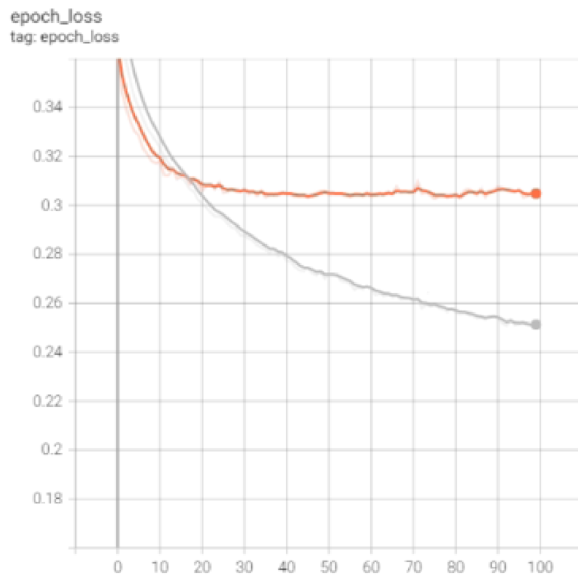

Figure 2 Loss versus number of epochs behavior of the first proposed model for image classification, both validation and hit

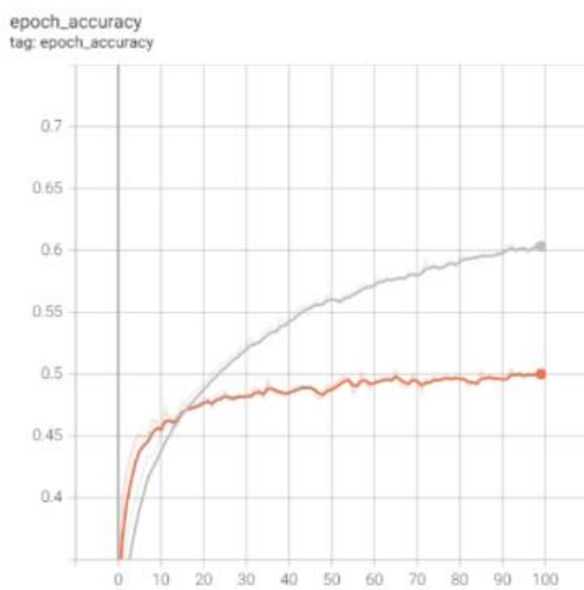

Figure 3 Hit versus number of epochs behavior of the first proposed model for image classification, both validation and hit

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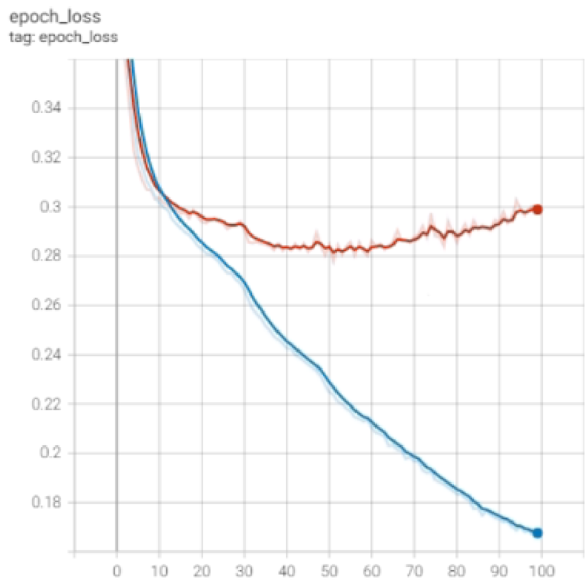

Figure 4 Loss versus number of epochs behavior of the second proposed model for image classification, both validation and hit

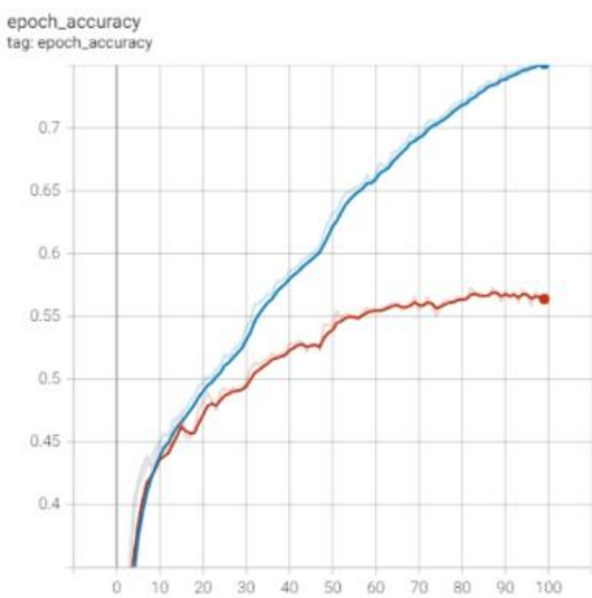

Figure 5 Behavior of hit versus number of epochs of the second proposed model for image classification, both validation and hit

Conclusions

Although we obtained good results compared to what was found in the state of the art by using the FER-2013 database, surpassing research such as that of (Saravanan, 2019), it would be important, as future work, to increase the data of the test set through other more images, since in (Hung, 2019) better results were achieved by implementing this alternative, therefore we conclude with a work that will contribute to the state of the art in this research topic where we will continue working to improve the results and obtain a better tool to be able to meet the objective.

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Transfer learning for handgun detection

Transferencia de aprendizaje para la detección de armas de fuego

MARTÍNEZ-DÍAZ, Saúl†*

Tecnológico Nacional de México/Instituto Tecnológico de La Paz, División de estudios de Posgrado e Investigación, México.

ID 1st Author: *Saúl, Martínez-Díaz* / **ORC ID:** 0000-0003-4962-5995, **Researcher ID Thomson**: Q-7112-2019, **CVU CONACYT ID**: 175255

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Abstract

Insecurity is a growing up problem affecting many cities around the world. Among others, firearm assault is one of the most common crimes committed. Although in some places have been installed video surveillance cameras, human intervention is still required to analyze the captured scenes. To prevent crime, a system that automatically detects dangerous situations is required. However, several problems arise when detecting objects from low-cost video surveillance systems. Some of these problems are poor quality of images, non-homogeneous illumination, background noise, occluded and rotated objects. In this paper, we propose a method to detect handguns by adapting a previously trained Convolutional Neural Network (transfer learning). The system was tested with images obtained from three video sequence captured with a low-cost webcam, under not controlled conditions. The detection errors were 8.3%, 15.7 and 11.7%, respectively. These results are comparable with other state of the art methods tested with higher quality images.

Transfer learning, Crime prevention, Convolutional neural network

Resumen

La inseguridad es un problema creciente que afecta a muchas ciudades del mundo. Entre otros, el asalto con arma de fuego es uno de los delitos que se cometen más comúnmente. Aunque en algunos lugares se han instalado cámaras de videovigilancia, aún se requiere la intervención humana para analizar las escenas captadas. Para prevenir la delincuencia se requiere un sistema que detecte automáticamente las situaciones de peligro. Sin embargo, surgen varios problemas a la hora de detectar objetos con sistemas de videovigilancia de bajo costo. Algunos de estos problemas son la mala calidad de las imágenes, la iluminación no homogénea, el ruido de fondo y objetos girados o parcialmente ocultos. En este artículo, proponemos un método para detectar armas cortas mediante la adaptación de una red neuronal convolucional previamente entrenada (transferencia de aprendizaje). El sistema se probó con imágenes obtenidas a partir de tres secuencias de video capturadas con una cámara web de bajo costo, en condiciones no controladas. Los errores de detección fueron del 8,3%, 15,7 y 11,7%, respectivamente. Estos resultados son comparables con otros métodos de última generación probados con imágenes de mayor calidad.

Transferencia de aprendizaje, Prevención del crimen, Redes neuronales convolucionales

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* Author's Correspondence (E-mail: saul.md@lapaz.tecnm.mx)
† Contributing researcher as first author.

Introduction

In many cities around the world, most crimes are committed by using firearms. This type of crime takes life of many victims annually. For example, in México City, according to the ICESI (Institute of Citizen Insecurity Studies, 2010), firearm assault is the most common crime. Although in some places have been installed video surveillance cameras, most of them require human intervention to analyze videos. Unfortunately, due to the enormous number of images to be analyzed, it is almost impossible for a person to watch simultaneously all scenes, detect suspicious activities and activate a preventive alarm system. Moreover, in many cities, the installed video surveillance systems provide low quality images, making difficult gun identification even for a human. One way to reduce this kind of crimes is early detection, so that the security agents or policemen can prevent violent acts. Therefore, to prevent and reduce crime, automatic detection systems capable of operating in real environments with poor quality images and under not controlled conditions, are required.

To detect suspicious activities, at first, it is necessary to recognize if a gun is present in the analyzed scene. Recognition of objects from video surveillance systems is a challenging problem due to poor quality images, non-homogeneous illumination, background noise distorted (rotated, scaled, blurred, etc.) and occluded objects. Literature offers several methods to classify guns: In (Kasemsan, 2014) proposed a method based on corner detection and template matching is presented; additionally, in (Grega, Matiolanski, Guzik, & Lesczuk, 2016) is proposed a method that uses Principal Component Analysis (PCA) and Artificial Neural Networks (ANN); besides, (Martinez-Diaz, Palacios-Alvarado, & Martinez-Chavelas, 2017) used invariant features and ANN, developed in parallel processing hardware, to detect pistols.

On the other hand, the last few years, Convolutional Neural Network (CNN) have achieved superior results than other classical machine learning methods in image classification, detection, and segmentation, for numerous applications.

For weapon detection, in (Olmos, Tabik, & Herrera, 2018) is introduced a detection system for both, surveillance and control purposes, based on a CNN; also, in (Xu & Hung, 2020) an AI-based system for automatic detection and recognition of weapons in surveillance videos is proposed, reporting precisions of 0.85 and 0.70 at intersection over union values of 0.5 and 0.75, respectively. However, it seems that the problem of guns recognition has not been totally solved yet.

In this paper, we propose a method to detect handguns in a scene. The method is based on deep learning techniques, region proposal CNNs and transfer learning. Transfer learning is very useful to save time and computational resources, due to a pre-trained CNN can be adjusted to recognize other objects. We retrain CNN to recognize rotated and occluded low-quality images. The system was tested with images obtained from three video sequence captured with a low-cost webcam, under not controlled conditions. The detection errors were 8.3%, 15.7 and 11.7%, respectively. The paper is organized as follows: in section 2 we review some basic concepts; in section 3 we introduce the proposed method; in section 4 we provide and discuss computer simulations; finally, in section 5 we summarize our conclusions.

Basic concepts

Convolutional neural networks

Unlike traditional machine learning methods for classification, in which features must be chosen manually and extracted with specialized algorithms, deep learning networks automatically discover relevant features from data. CNNs are composed with an input layer, an output layer, and many hidden layers in between (LeCun, Bengio, & Hinton, 2015). Each hidden layer can be one of the following types:

Convolutional layer. Units in a convolutional layer are organized in feature maps. Within them, each unit is connected to local patches in the feature maps of the previous layer through a set of weights, called a filter bank. Each filter activates certain features from the images. For two-dimensional discrete functions $f(x, y)$ and $g(x, y)$, convolution is defined as:

$$\sum_{i=-\infty}^{\infty} \sum_{j=-\infty}^{\infty} f(i,j) g(x+i, y+j) \quad (1)$$

Pooling layer. This layer is used to merge semantically similar features into one, to simplify the output, by performing nonlinear down sampling, which reduces the number of parameters that the network needs to learn. The pooling layer takes a pool size as a hyperparameter, usually 2 by 2. Processing of the input image is as follows: divide the image in a grid of 2 by 2 areas and take from each four-pixel a representative value (normally the maximum value is used).

Rectified linear unit (ReLU). The result of the convolution is then passed through a non-linearity, usually rectifying the input signal by mapping negative values to zero and maintaining positive values This rectification allows a faster and more effective training.

These three operations are repeated over tens or hundreds of layers, with each layer learning to detect different features. After feature detection, the architecture of a CNN shifts to classification. The next-to-last layer is a fully connected layer that outputs a vector of K dimensions, where K is the number of classes that the network will be able to predict. This vector contains the probabilities for each class of any image being classified. The final layer of the CNN architecture uses a softmax function, to provide the classification output.

Region-based CNN (R-CNN)

Contrasting with classification, detection requires the accurate localization of objects (probably many) into images. Compared to image classification, object detection is a more challenging task that requires more complex methods to be solved. Complexity arises because detection requires the accurate localization and refinement of many objects. Several algorithms have been proposed for training R-CNN´s, some methods use multi-stage pipelines, but they are slow. Other methods use a sliding window technique to generate region proposals.

For this task, region-based methods have shown better performance than other methods. In this case, the first step is proposing several candidate object localizations; then, proposals must be refined to achieve precise localization. Each region must be evaluated and its membership to any class of object vs. background is scored. From the latter, the most popular algorithms are regions with CNN (R-CNN) (Girshick, Donahue, Darrell, & Malik, 2014), Fast Region-based Convolutional Network (Fast R-CNN) (Girshick, Fast R-CNN, 2015) and Faster Region-based Convolutional Network (Faster R-CNN) (Ren, He, Girshick, & Sun, 2015).

Transfer learning

The success of CNNs depends on the number of images used to train them. Usually, thousands or millions of images are required to achieve good results. Training a CNN from scratch may require weeks of computation in a high-performance computer. Besides, preparing manually images for training is a very high time-consuming task. A better option is using a pre-trained network, which is fine-tuned with a few images, to make it work in the new desired task. This method is called transfer learning.

Transfer learning refers to the situation where what has been learned in one setting is exploited to improve generalization in another setting (Goodfellow, Bengio, & Courville, 2016). For example, one CNN trained to recognize one set of visual categories, such as cars, then is fine-tuned to learn about a different set of visual categories, such as trucks. Here, a key point about image data is that the extracted features from a data set are highly reusable across other data sources. Usually, only the deeper layers are fine-tuned, and the weights of the early layers are fixed. The reason for training only the deeper layers, while keeping the early layers fixed, is that the earlier layers capture only primitive features like edges, whereas the deeper layers capture more complex features. The primitive features do not change too much with the application at hand, whereas the deeper features might be sensitive to the application at hand. Some popular pre-trained CNNs, available for transfer learning are AlexNet (Krizhevsky, Sutskever, & Hinton, 2017), ResNet (He, Zhang, Ren, & Sun, 2016) and GoogLeNet (Szegedy, et al., 2016).

Proposed Method

Pre-trained network

For our implementation we selected AlexNet. This network was the winner of the 2012 ILSVRC competition. Figure 1 shows AlexNet architecture. As can be seen, the net contains eight layers with weights; the first five are convolutional and the remaining three are fully connected. The output of the last fully connected layer is fed to a 1000-way softmax which produces a distribution over the 1000 class labels. The kernels of the second, fourth, and fifth convolutional layers are connected only to those kernel maps in the previous layer, which reside on the same graphics processing unit (GPU). The kernels of the third convolutional layer are connected to all kernel maps in the second layer.

Training algorithm

For training, we tested three algorithms: R-CNN, Fast R-CNN and Faster R-CNN. The best results were achieved with Fast R-CNN algorithm. Fig. 2 illustrates the Fast R-CNN operation. The network takes as input an entire image and a set of object proposals. Then, the whole image with several convolutional and max pooling layers is processed to produce a map feature. Then, for each object proposed a pooling layer extracts a fixed-length feature vector from the map. Each feature vector is fed into a sequence of fully connected layers that end in two output layers: one that produces softmax probability estimates over all object classes and a background.

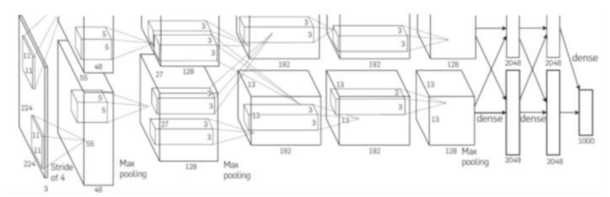

Figure 1 AlexNet architecture
Source: Figure taken from Goodfellow, Bengio & Courville, 2016

All weights of the network are adjusted using backpropagation algorithm. The loss function (L) used is:

$$L(p,u,t^u,v) = L_{cls}(p,u) + \lambda[u \geq 1]L_{loc}(t^u,v) \qquad (2)$$

Where p is a discrete probability distribution, computed by a softmax function; t^u are offsets for each of the K classes; $L_{cls}(p, u) = -\log p_u$ is the log loss for the true class u; L_{loc} is defined over a tuple of true bounding-box regression targets for class u, $v = (v_x; v_y; v_w; v_h)$, and a predicted tuple tu = $(t^u{}_x ; t^u{}_y ; t^u{}_w; t^u{}_h)$, again for class u. $[u \geq 1]$ evaluates to 1 when $u \geq 1$ and 0 otherwise. By convention the background class is $u = 0$.

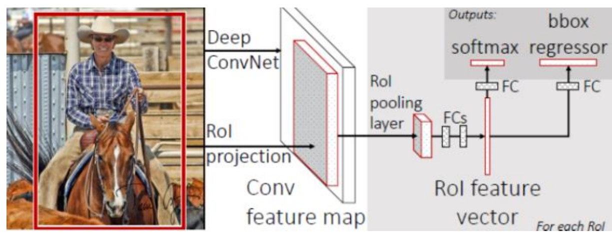

Figure 2 Fast R-CNN operation
Source: Figure taken from Girshick, 2015

Modified network

AlexNet has been trained on over a million images and can classify images into 1000 object categories. The network has learned rich feature representations for a wide range of images. It takes an image as input and outputs the probabilities for each of the object categories. The first layer (input layer) requires input images of size 227-by-227-by-3, where 3 is the number of color channels; then, each input image must be resized to such size. The last three layers of the pretrained network net are configured for 1000 classes. These three layers must be fine-tuned for the new classification problem. To retrain the selected net, we replaced the last three layers of the network. The new added layers were a fully connected layer, a softmax Layer and a classification layer. The final fully connected layer was set to have the same size as the number of classes in the new data set (one class: handgun). To learn faster in the new layers than in the transferred layers, we increased the learning rate factors of the fully connected layer.

Results

CNN

In this section, we illustrate the performance of the proposed technique. We tested the system with images obtained from a low-cost web camera.

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Due to federal regulations, it is difficult to obtain firearms in the country; in consequence, we use a Walther Airsoft pistol, which meets color, size, and shape specifications of a real handgun. The video was captured indoor, under non-controlled conditions. The artificial illumination was produced by a non-homogeneous source of light. All images were 640x480x3 pixels. Figure 3 shows an example of an input image.

Figure 3 Example of training image

To train the network, we used 105 images containing a handgun. Each handgun was manually enclosed into a box, and coordinates of each box were used as ground truth, 60% of the images were used for training and 40% for testing. The network was trained in a low-performance GPU (GeForce GTX 960M). The main parameters selected for training were gradient method L2-norm, epochs 50, minibatch size 8, momentum 0.9000 and initial learning rate 1.0000e-03.

Figure 4 shows the confusion matrix of results, where class one is for the handguns and class zero is for the background. As can be seen, the system misclassifies only 2.3% of images (one false positive). Moreover, figure 5 illustrates the detection of a handgun with 0.99 of confidence, in an image where the handgun is blurred.

Figure 4 Confusion matrix

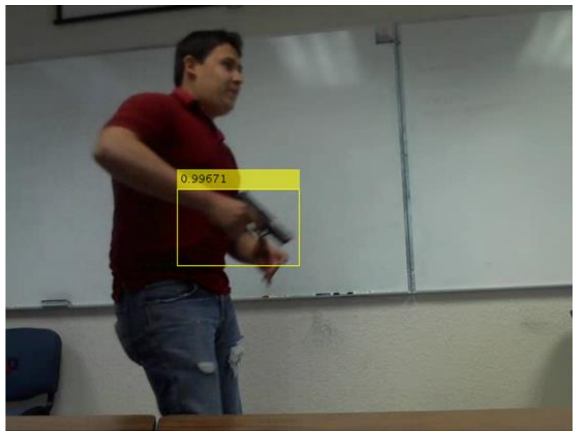

Figure 5 Example of handgun detection

Conclusions

In this paper, we proposed a method to detect handguns in real scenes. The proposed method uses convolutional neural networks to perform handgun detection. With this technique is not required to choose manually the relevant features of objects nor preprocessing of images in the detection stage. Besides, by using transfer learning, we can take advantage of a pre-trained net and adjust it to our application. Results shown a good performance of system, even when it was trained with just a few images, a reduced number of epochs and was tested with poor quality video sequence. This is a first step toward reduce crime in big cities. Future work includes recognition of other kind of weapons, tracking of detected objects and a system to analyze scenes and quantify the risk for people near such scene.

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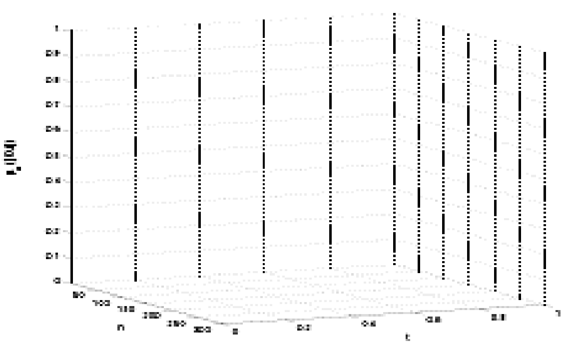

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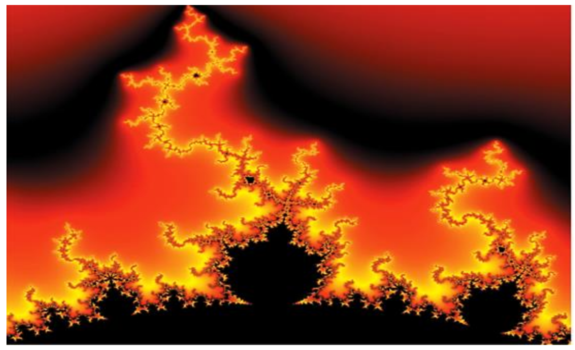

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