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Journal of Technological Prototypes

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Support the international scientific community in its written production Science, Technology and Innovation in the Field of Engineering and Technology, in Subdisciplines of technological development, digitized technology, technological impact, computer aided teaching, computers reliability, heuristics, computing, machine arithmetic instructions, artificial intelligence, algorithmic languages, programming languages.

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The works must be unpublished and refer to topics of technological development, digitized technology, technological impact, computer aided teaching, computers reliability, heuristics, computing, machine arithmetic instructions, artificial intelligence, algorithmic languages, programming languages and other topics related to Engineering and Technology.

Presentation of Content

In the first article we present *Literature review on industry commercialization and transfer of technology 4.0* by VILLAFAÑA-DÍAZ, Luis & LEZAMA-DE LA ROSA, Miguel with adscription in the Universidad Popular Autónoma del Estado de Puebla, in the netx article we present *Adaptive temperature controller for plastic extrusion process* by GUERRERO, Jesús, GONZÁLEZ, Julio and CHIMAL, Martin with adscription in the Universidad Politécnica de Juventino Rosas, in the next article we present *Design y development of a graphical user interface in LabVIEW for acquisition and visualization of climatological data (temperature and relative humidity)* by PEREZ-GARCIA, Víctor, QUINTANILLA-DOMINGUEZ, Joel, YAÑEZ-VARGAS, Israel and AGUILERA-GONZALEZ, José, with adscription in the Universidad Politécnica de Juventino Rosas. In the next article we present *Interface design for monitoring and estimation system for flooding through an image analysis of remote sensing (SAVUI)* by YAÑEZ-VARGAS, Israel, GONZÁLEZ-RAMÍREZ, Andrea, ASTUDILLO-MONTENEGRO, Felipe and FLORES-GARCÍA, Jaqueline, with adscription in the Universidad Politécnica de Juventino Rosas and Instituto Politécnico Nacional.

Content

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Literature review on industry commercialization and transfer of technology 4.0

Revisión de literatura en comercialización y transferencia de tecnología en la industria 4.0

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Abstract

The bonding between searching and technological development strengthens commercial opportunities in 4th industrial revolution. This research analyzed main scientific contributions, published about commercialization and transfer of technology on 4.0 industry environment. The study was applied with 52 articles analyzed, which 30 of them objectively complied the study field from 2015 to 2020, an empiric methodology was applied, which allowed the theoretical construction, being the intellectual property the main commercial armor tool concerning patent management. Inside findings it was discovered a need of new strategies development to strengthen and accelerate the commercialization and transfer processes of technology, due to industry features 4.0, which has accelerated changes in most of the sectors, improving processes and information optimization, generating opportunities in international markets. Because of that the knowledge achieved in technological innovation can boost competitiveness besides income generation for organizations, but it must reach the commercialization and transfer stage, which has been achieved through the patent of the invention. According to the patent office registration, Mexico has one of the lowest levels compared with the main world economies. It is recommended to study more about this topic due to the scarce information in this field of study.

Technological Licensing, Intellectual Property, 4.0 industry

Resumen

La vinculación entre investigación y desarrollo tecnológico fortalecen las oportunidades comerciales en la cuarta revolución industrial. Esta investigación analizó las principales contribuciones científicas, publicadas sobre la comercialización y transferencia de tecnología en el entorno de la industria 4.0. El estudio se realizó con el análisis de 52 artículos los cuales 30 cumplieron objetivamente el campo de estudio en el periodo del año 2015 al 2020, aplicando una metodología empírica la cual permitió la construcción teórica destacando el uso de la propiedad intelectual como principal herramienta de blindaje comercial en la gestión de patentes. Dentro de los hallazgos se encontró la necesidad del desarrollo de nuevas estrategias para fortalecer, así como acelerar los procesos de comercialización y transferencia de tecnología, debido a las características de la industria 4.0, la cual ha acelerado cambios en la mayoría de los sectores, mejorando la optimización de procesos e información, generando oportunidades en los mercados internacionales. Por tal motivo la generación de conocimiento reflejada en innovación tecnológica, puede impulsar la competitividad además de la generación de ingresos para las organizaciones pero debe alcanzar la etapa de la comercialización y transferencia, que se ha logrado a través de patentar la invención.

Licenciamiento tecnológico, Propiedad intelectual, Industria 4.0

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Introduction

There is a gap between technological. development and technology commercialization, due to the product buying purpose is mainly influenced by its perceived value. Success depends on the importance of processes of markets investment, as well as the proportionally commercialization to technological development, since models such as technology life cycle are found, where factors as losing a patent or intellectual property can directly influence on make shorter the life of products and technology.

Considering the global ambit, countries have to take in mind that digital world access opens opportunities for a sustained prosperity, so it must be considered a strategical development that aims in its implementation the unemployment reduction, inequality, and poverty eradication. In this sense, digital economy is quickly impacting to global economy causing big changes and growth, influencing on the commercial exchange of products and services as well as their related activities OCDE (2015).

Digitalization is transforming value chains in different directions allowing the opening of new channels, which make possible adding more value, stretching towards structural changes that will affect directly and indirectly to companies, countries and their workers; impact level will depend on development level, the speed of digital preparation, policy adoption and national implementation, regional and international UNCTAD (2019).

In recent years, the 4.0 industry has caught searchers and businessmen attention, since it contemplates a wide market, spanning production processes, efficiency, data management, relationship with consumers, competitiveness as well as technological scaling and maturation. For Lalanda, Morand and Chollet (2017) 4.0 industry is based on the application of new production techniques, new materials and the wide use of new digital technologies.

The importance of accelerating the selling process of patents and implementing commercialization strategies and technology transfer within 4.0 industry environment, requires having competitive traits due to markets tendencies, where the creation of intelligent processes is characterized for the adaptation capacity and productive resources efficiency. Jasiulewicz, Saniuk & Nowicki (2017).

In the new technological age, the responsibility from universities is not based only on formation anymore, but passing the acquired knowledge through applied searching for industry with economic and social impact. Nowadays the ecosystem is in an evolutionary process of technology boosted by the 4.0 industry, such as Hecklau, Galeitzke, Flachs and Kohl (2016) indicated, which has as a main goal the creation of a diversity of opportunities for industries, by means of automation and digitalization process integration.

Bonding strategies with the triple helix improve the commercialization and transfer of technology process, since public universities as well as investigation centers are financed by government, in order that these form professionals to investigation development in early stages of maturation as well as solutions validation. On the other hand, the private businesses are those ones that acquire technologies by means of licenses and exclusivity contracts to ease the escalation and the introduction of new inventions to the market. The technological performance refers to the absorption and application capacity with success in the organization of the licensed and commercialized technological packages.

The goal of this investigation is to analyze the main scientific contributions, published about the commercialization and transfer of technology topic in the 4.0 industry environment.

Materials and methods

Methods are very important in empirical studies and for theory construction; databases were used such as Ebsco, Conricyt, Thomson Reuters, Science Direct, Scopus and Web of Science.

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52 articles were analyzed, which 30 of them achieved objectively the field of study concerning commercialization and transfer of technology inside 4.0 industry. In the same way for the filtering of relevant data there were applied different Boolean combinations AND, OR and truncation *,? helping to obtain the specific information.

In this same order and direction, the searching was made from 2015 to 2020, with the next key word combination in Spanish: Transferencia de Tecnología, Comercialización Tecnológica, Licenciamiento Tecnológico, Industria 4.0, Comercio Internacional, Patentes de la industria 4.0, Digitalización Tecnológica. In the same way with the next key word combination in English: Technology Tension, Technology Marketing, Technology Licensing, Industry 4.0, International Trade, Industry 4.0 Patents, Technology Digitalization.

Commercialization and transfer of technology

Khadhraoui, Plaisent, Lakhal and Prosper (2016) carried out a research work about the factors that affect the transfer of technology development from university to company.

They mentioned that one of the most relevant factors that improve the processes of innovation is technology transfer from university to company. Nevertheless, the potential barriers in the commercialization process within universities are bureaucracy as well as politics, nonexistence incentives for researchers, applied research funds, low culture concerning protection of intellectual property, high costs related to escalation and verification of technology.

Savescu (2017) proposed the fundamental aspects of intellectual property in the transfer of technology process with the finality of decreasing the level of concentration of falsification, as well as the novelty elements piracy inside the creative processes. In his results it could be observed how companies' competitiveness increases by means of intellectual property management as a tool for technology transfer and economic development inside the European Union.

Hayter and Link (2018) showed how big high technology companies improve their market position through intellectual protection, as well as divulgation of developed knowledge through scientific publications (SP) as commercial armor strategy. The SP are a legal substitute to industrial property invalidity when uncertainty of obtaining the patent title is very high. They identified that in commercialization and transfer of technology process the patents as well as scientific articles are recognized as an important indicator in the early stage commercial activity.

Maresova, Stemberkova and Fadeyi (2019) made a research about management models and transfer of technology in universities, which guarantee the increase on success rate, since these represent a fundamental role in investigation to the development of tradable products. The research results were 22 transfer of technology models, from four approaches, internal strategies, management and investment, politics and business development; where main goals, proceedings, strengths and each one deficiencies are described. The study identified new technology transfer models within emergent economies, where highlights the INNOSPICE model, which nourish software technologies in market.

Industry 4.0

Philbeck and Davis (2018) commented that 4th industrial revolution concept (4IR) has been used as a synonym of 4.0 industry, an initiative born in Germany between 2011 and 2015 which is focused on the digital technology application to manufacturing, despite this terms describe different aspects they are related, being a very important component in the 4IR narrative focused in the relationship between digitalization, transformational organization, and the productivity improvement.

Mikulic and Stefanic (2018) mention that 4.0 industry represents technology development and use that alters industry traditional models.

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They pointed out the traits that marks the globalization, stablishing new challenges with the existent resources generating new concepts such as intelligent factories, cyber-physical systems, stuff Internet, and intelligent products, forcing companies to embrace the new technologies to achieve all consumers demands including high quality and added value. They presented an article identifying advantages, as well as disadvantages of technology implementation considering the human factor impact, identifying the relationship between 4.0 industry and the efficient management, the main idea is to connect all the elements to the value chain process in just one system, to achieve it successfully is necessary the human factor inclusion in all stages from design and technology implementation.

Kodama (2018) mentioned that innovations that 4th industrial revolution requires (4IR) will be characterized by the accumulation of innovations, as well as technology evolution instead of disruptive innovations, besides fusing lines between physical, digital, and biological areas. The Japanese government proposed the term 5.0 to make reference to the combination of social problems solving and the economic progress made by the 4.0 industry.

Magruk (2016) indicated that uncertainty in the 4th industrial revolution give birth to new potential fields of research, in his work he analyses the different opportunities and threats. The author identified that a technological limit exists within the concept used by companies. It was discovered that the actual challenge is technology commercialization, by consequence of the infrastructure that is not adapted to these technologies. The study considers that 4.0 industry has very complex systems that could never be completely understood due to the indetermination of the concept.

Nikolic, Ignjatic, Suzic, Stevanov and Rikalovic (2017) proposed a study about predictive systems for fabrication and commercialization in the 4.0 industry, which found that the pushing of technological predictive systems has a positive consequence in the loss of costs, improvement of production and material resources efficiency.

Industry 4.0 sustainable model through commercialization shows the hidden innovation value as well as competence in the market, proposed by Misyunay, Mayhurova and Zubkov (2018), it made an analysis of business models and the competitiveness level, in the big data, artificial intelligence, cyber systems and stuff Internet, such study work developed the creation of key indicators that affect the competitiveness and the technology commercialization, with financial impacts and market shares growing in the medium term.

Intelligent objects require a minimal human intervention to develop the auto management capacities. In Kauffman and Soares (2018) research, it was described the intellectual property (IP) opportunities as a commercialization strategy in the 4th industrial revolution. According to the study the IP is the intangible active that is fundamental in the 4.0 industry, due to the impact on the value chain in the hardware protection, software and the storage data processes; these could ascend to the 80% of a company value. The study also proposes de industrial secret as the best option to protect the innovations related to the 4.0 industry, due to this decreases the level of unfair competition, likewise in 2017 the success rate improved in 69% the litigation in the United States of America.

Dash, Farooq, Sankar and Sandhyavani, (2019) made an evidenced study about competence development in 4th industrial revolution and the stuff Internet, the authors mentioned that technological advances are marked by the acceleration of innovation and artificial intelligence estimating 30 thousand millions of devices in 2025. Data was obtained through a comparative of regulations, theoretical evidences and challenges in assimilation of new technological tendencies. It was obtained that new innovation politics in India are based on the digital empowerment by the adoption of emergent technologies, becoming the labor force more productive and efficient.

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Commercialization and transfer of technology in the 4.0 industry

The transfer of technology in the 4.0 industry bring closer to the small and medium companies to the efficiency and flexibility, the study made by Wank (2016) showed the opportunity to increase competitiveness from digitalization as well as the interconnection in the fabrication processes, making an analysis from optimization in industry and the value chain, which helped to link companies with the 4.0 industry technologies through new market opportunities.

Dong and Jong (2017) presented a study work about the determinant features in the marketing performance in high technological companies. It was found that these companies use the social capital as a collaboration network and bonding for the innovation growth in the technological performance. The study was crucial to identify the factors that influence the performance and adaptation improvement of technology in the process of commercialization or discharge.

Technology transfer and human capital in the 4.0 industry shows the acceleration in the digital process between the academy, company and government, is the case of the study published by da Silva, Kovaleski and Pagani (2018) in which the changes and perspectives of human processes inside the 4.0 industry are analyzed. The authors mentioned that the pillar of this model is the big data, autonomous robots, simulation, horizontal and vertical systems integration, Internet stuff, cybersecurity, cloud computing, additive manufacturing and augmented reality.

Jun, Park and Jang (2015) developed a technological assessment model based on the European international patent classification (IPC) H01S3/05 from a technology transfer of big data. They identified that usually the transfer of technology is made from universities to companies through licensing; by consequence they built the model from intellectual property protection, data mining, I+D planning, technological segments, as well as future descriptive statistics. It brought a model that strengthens the decision making in the decreasing of financial risk in technological investments.

Gbadegeshin, (2018) proposed a new slender marketing theoretical framework which has as a main objective the reduction of economic risks and the technical uncertainty for the commercialization of new services and products. It was obtained that due to the nature of digital technology the commercialization processes have to be validated fast through the technical analysis of market and influenced by the intellectual property. The digitalization fusion in physical products, digital services as well as biological spheres, improve the commercialization process by means of metadata sourcing, artificial intelligence and automation that make easier the information measurement bringing a competitive advantage. The study helps to the commercialization acceleration of high technologies by means of the minimal investment in technical and commercial validation inside health areas in Finland.

In this way, Hyunji, Sun and Won (2019) presented a study about the technological performance which is based on the I+D performance in patents and selling increasing as well as reduction of costs. Likewise the commercialization performance was measured according to PYMES development capacity, identifying the success factors of high technology industries commercialization. It was obtained that technological development cost has an influence on the technical performance competitiveness, that is, as higher is the I+D cost greater is the commercialization capacity. An opportunity was identified in relation to the pymes performance in the Korean economic industry.

The acceleration in the commercialization and transfer of technology from the opened innovation approach, study proposed by Wahyudi, Rina and Retno (2019) showed a variable measurement in the commercialization of technology models performance developed in universities. The study helped to compare the efficiency in commercialization strategies, discharge and spin offs creation managed by universities.

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Kim, Sawng, & Park, (2019) propose a validation model of the commercialization process of a 3 stage digital innovation, technology, product and market, where technology acceptation depends on the technological market potential as well as the consumer's perspective. The study identified that the most advanced countries focus on increasing the business competitiveness through open innovation, due to the intention on buying a new technology is significantly influenced by its perceived value, this is, the importance on demand of the digital technological market. For increasing the commercialization opportunities, it is wise to evaluate potential client needs and the market size.

In this manner Yeverino and Montoro (2019) made an investigation about the efficiency and the productivity of academic units in charge of technology transfer in Mexico. It was obtained that a strong heterogeneity in the institutions and searching centers between a limited productivity, license revenue, notifications of inventions, intellectual property expenses, as well as the transfer of technology offices experience, highlighting 40 years of retardation in this industry with respect to most competitive countries such as USA.

The interest in the development of searching work with technological basis within higher education institutions in Mexico has become bigger, with the objective of generating new knowledge to compete, as well as improving the national economic growth, Puerta, Marín and López (2017) developed an institutional framework to explain the determinant factors in activities that make easier the transfer of technology, such work identified the necessity of managing the intellectual property of universities by a transfer of technology office, to encourage to researchers and the academic staff, to protect the intellectual property developed, to strengthen linking activities with the business and governmental sector and to spread the technological projects with society. It highlights the importance of maximizing the success chances of technology commercialization through the triple helix model, which is based on the strategical linking between university, company and government.

Gathering OCDE data and indicators inside its database about technology and innovation, Mexico shows the following results about triad patent register, indicator referring to a registered patent in 3 patent offices: USA, Japan and the European Union.

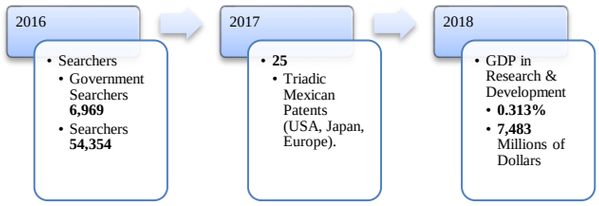
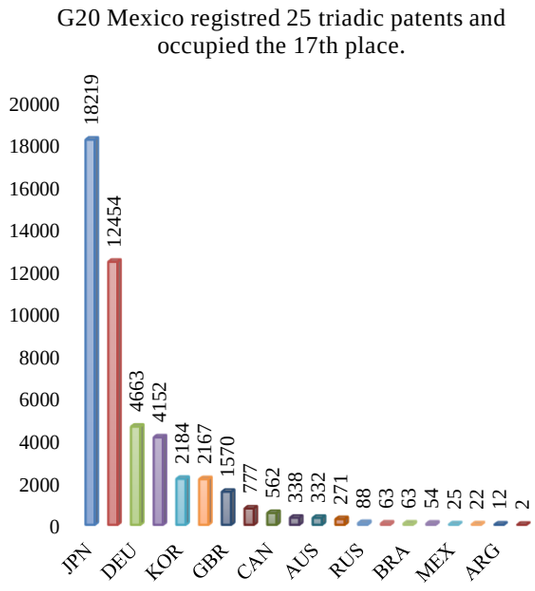


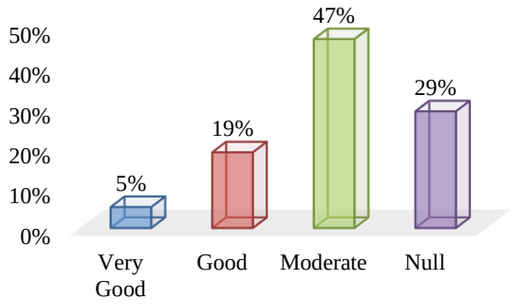
Figure 1 OCDE Mexico Indicators
Source: OCDE Innovation and Technology Indicators, Data 2020

Comparing Mexico with the G20 countries, in 2017 Mexico was in the 17th position with relation to the triadic patent registration as it is showed in the next chart.



Graphic 1 OCDE indicators Triadic Patent Families
Source: OCDE Innovation and Technology Indicators, Data 2020

According to the ENPECYT survey made by INEGI in collaboration with CONACYT, the perception in population over 18, relating to inventions, discovery as well as technological development, shows a knowledge level in population mainly moderate, nevertheless the nullity perception is higher than good and very good perception.



Graphic 2 Level of knowledge in Mexico concerning inventions and discoveries
Source: INEGI, CONACYT, (ENPECYT) 2017

In the next chart it is showed the contribution of all the papers relating to commercialization methodology and technology transfer.

Authors	Study Work	Results	Methodology
Jun S., Park S., and Jang D. (2015)	Technological assessment model through the quantitative analysis of patents: a transfer of technology case study in Big Data Marketing	Transfer of technology is made from universities to companies through licensing	Technological assessment model based on the international classification of European patents IPC H01S3/05
Wank (2016)	To increase competitiveness from digitalization making analysis from industry and chain value optimization	It helped linking companies with industry 4.0 technologies though new market opportunities	Compilation of successful cases: 12 companies and 2 searching centers. 3 modules, Physic Cyber System, 4.0 Business map, 4.0 benefit
Dong and Jong (2017)	Determinant features in the commercialization performance in high technology companies	It identified an opportunity in relation to PYMES performance in the Korean economic industry	Analysis of social capital, technological performance in the high technology absorption and commercialization capacity
Da Silva, Kovaleski and Pagani (2018)	Analysis of changes and perspectives of the human processes inside 4.0 industry	Acceleration in the digital process between the academy, company and government, where all the staff must adapt to the new technologies	Systematic review of 50 articles
Gbadegeshin (2018)	Analysis about technical aspects validation, market and intellectual property, with the main goal of decreasing economic risks and uncertainty	Acceleration of high technology commercialization through minimal investment in technical and commercial validation	New theoretical framework named slim marketing by a crossed study between 16 pharmacist companies in Finland
Hyunji, Sun and Won (2019)	Technological performance which is based in I+D performance in patents and selling growth as well as costs reduction	It identified an opportunity in relation to PYMES performance in the Korean economic industry	42,100 PYMES were surveyed from 2003 to 2014 with a 23% result of companies belonging to high technology industries
Wahyundi, Rina and Retno (2019)	Commercialization and transfer of technology acceleration focused on opened innovation	It helped to compare the efficiency of commercialization strategies, discharge and spin offs creation	4 universities in Indonesia that license and commercialize their technology with performance indicators in commercialization strategies
Kim, Sawng and Park (2019)	Model of commercialization processes validation of digital innovation in 3 stages, technology, product and market	It identified that most advanced countries foment the industrial competitiveness through opened innovation	Application of 350 surveys to potential users of the 3 stages
Yeverino and Montoro (2019)	Investigation of efficiency and productivity of academic units in charge of transfer of technology in Mexico	It found heterogeneity in institutions with limited productivity and income by licenses with a 40 year delay respect to USA	2 analysis models to 21 searching centers and higher education institutions

Table 1 Chart of referents about commercialization and transfer of technology methodology
Source: elaborated with proper information obtained from the cited authors

Conclusions and recommendations

The investigation found the need for the development of new strategies to strengthen an accelerate the commercialization and transfer of technology processes, due to the technological industry features such as the importance of time investment in validation stages, as well as verification that regulatory organisms demand and the incorporation in the market.

The analysis shows that the commercialization and transfer of technology channel has been boosted through the synergy between the triple helix, which is made of universities by means of generating research, the government through targeted innovation policies at tax incentives, as well as companies through investment in escalation and incorporation to the market.

Findings in this research describe the intellectual property importance as an opportunity in the commercial armor process, on the other hand, different models and systemic processes application of technical patent information to detect technological licensing opportunities, taking in mind that 4.0 industry shows a fast growth and it is considered as one of the main international markets. This investigation makes a contribution describing the different systematic tools and processes that are used in companies, governments and institutions in a 5 year period to commercialize and transfer knowledge and maximize the opportunities based on innovation inside 4.0 industry with changing and dynamic features.

Limitations when conducting research are related with the scarce concentrated investigation in the exploration of processes, as well as strategies for commercialization and transfer of technology, specifically in 4.0 industry, by consequence, it was identified an opportunity in this area of knowledge to develop new investigation. Consequently, later it will be developed a multifunctional tool based on strategic planning of a constant monitoring of technologies developed in universities through the technical study in patents to accelerate the commercialization and technological licensing process, which would improve the competitive business success.

Interest conflict

The authors declare that does not exist any interest conflict.

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Adaptive temperature controller for plastic extrusion process

Control de temperatura adaptable para proceso de extrusión de plástico

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Abstract

In this paper, an adaptive temperature controller for the plastic extrusion process is designed. The proposed controller aims to solve the set-point regulation problem and the temperature trajectory tracking of a plastic extrusion process. The controller is an adaptive version of the First Sliding Mode Control which is robust towards parametric uncertainties and external disturbances. Also, the finite time convergence is demonstrated by Lyapunov arguments. Finally, the effectiveness of the proposed controller under several scenarios is demonstrated by computer simulations.

Adaptive controller, Sliding modes control, Extrusion process, Temperature control

Resumen

En este artículo, se diseña un control adaptable para el proceso de extrusión de plástico. El controlador propuesto está enfocado en resolver el problema de regulación, así como también el seguimiento de perfiles de temperature en el proceso de extrusion de plástico. El controlador es una versión adaptable de control por modos deslizantes de primer orden, el cual es robusto ante perturbaciones paramétricas y externas. También, se demuestra la estabilidad del controlador propuesto mediante la teoría de Lyapunov. Finalmente, se demuestra la efectividad del controlador por medio de diferentes escenarios en simulación por computadora.

Control adaptable, Control por modos deslizantes, Proceso de extrusión, Control de temperatura

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Introduction

The extrusion process refers to any transformation operation in which molten material is forced through a nozzle to produce an article with a constant cross-section and definite length. In addition to plastics, many other materials are processed by extrusion, such as metal, ceramics or food, obtaining very varied products such as aluminium window frames, pipes, food, and so on (the reader can be referred to (Hammond (2020), Guzmán (2020), Guerrero et. al. (2020), Urra (2020), and Marquina (2020)). From the point of view of plastics engineering, extrusion is one of the most important transformations processes. The plastic extrusion process is carried out in machines called extruders. Although there are extruders of various types, the most commonly used are the single screw.

In the extrusion process, the polymer is fed solidly into a large barrel and is pushed forward with a constant velocity by the screw. While passing through the barrel, the raw polymer is gradually heated until the fed polymer is melted. Finally, the melted material is pushed out of the machine to be processed (Su and Tsai, (1997)). In order to produce a high quality extrudates, the temperature along the barrel must be appropriately set and precisely controlled (Su and Tsai, (2001)).

In recent years, several temperature control techniques have been proposed. For instance, classical schemes such as PD and PID controllers and their adaptive variations (see Taur et. al, (1995), Petrovčič et al., (2013), Hamane et al., (2010)). However, it is well-known that these controllers lack robustness towards time-varying disturbances. For this reason, non-linear control techniques have been developed (see for example, Yao et al., (2007), Yao et al., (2008), Peng and Wei, (2011a), Peng and Wei (2011b)). One of the most popular robust technique is the Sliding Mode Control (SMC). This method ensures finite time convergence and its robust towards parametric uncertainties and external disturbances as well. However, the main drawback of this technique is the undesirable chattering effect. In the study of Su and Tsai (2001), a discrete first order sliding mode controller for the temperature control is proposed.

To tune the developed algorithm, the authors propose an adaptive law. However, the adaption algorithm is complex and it has several controller gains to tune. Moreover, the method to tune the feedback controller gains is not explicitly given.

In this paper, based on the previous results of Su and Tsai (2001), an adaptive first order sliding mode control for regulation and trajectory tracking of temperature profiles is proposed. The adaptation law is based on the proposed technique by Plestan et al., (2010). In our paper, we modify the adaption scheme in order to develop a control law that does not need information about the system and is robust towards parametric uncertainties and external disturbances. To the best knowledge of the authors, this method has not been applied to control this type of systems yet. Moreover, compared to the work of Su and Tsai, (2001), we address the trajectory tracking problem. Finally, the proof of stability is proven by Lyapunov arguments.

The remainder of this paper is organized as follows: The temperature plastic extrusion mathematical description is reminded in Section 2. In Section 3, an adaptive first order sliding mode controller for regulation and trajectory tracking problem and its stability anlysis is presented. In order to demonstrate the effectiveness of the proposed control scheme, computer simulations are presented in Section 5. Finally, we make a brief conclusion on the paper in Section 6.

Temperature Plastic Extrusion Mathematical Model

The general energy balance equation in a stationary volume control defines that the rate of accumulation energy is equal to the rate of input and output energy difference. Thus, the energy balance equation, can be expressed as follows:

$$\rho c_p \mathrm{V_e} \frac{\mathrm{dT}}{\mathrm{dt}} = \omega - \mathrm{hA}(\mathrm{T} - \mathrm{T}_\infty) \quad (1)$$

where T is the temperature, T_∞ is the environment's temperature. ρ and c_p is the density and the specific heat of the material, respectively. V_e is the filament output velocity, A is the filament area, and h is the heat transfer coefficient.

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Finally, ω is the input energy rate where $\omega > 0$ is for heating and $\omega < 0$ is for cooling. Then, arranging Eq. (1), yields to the following dynamic equation:

$$\frac{\mathrm{dT}}{\mathrm{dt}} = \frac{hA}{\rho c_p V_e}\mathrm{T}_\infty - \frac{hA}{\rho c_p V_e}\mathrm{T} + \frac{\omega}{\rho c_p V_e} \tag{2}$$

Note that the electric heaters and the coolers are considered as the thermal actuators of the term ω. Considering that the actuator's internal dynamics is given by the following equation:

$$\dot{\omega} = \gamma(\omega, \mathrm{u}, \mathrm{t}) = \begin{cases} \gamma^+(\omega, u, t) & if\ u \geq 0 \\ \gamma^-(\omega, u, t) & if\ u < 0 \end{cases} \tag{3}$$

Where the electric heaters are activated when the control signal $u > 0$ and the cooling system is on when the term $u < 0$. It is assumed that the functions $\gamma^+(\cdot)$ and $\gamma^-(\cdot)$ are nonlinear, unknown but bounded. Now, from Eq. (2), if we introduce the following variable:

$$\nu = \frac{hA}{\rho V_e c_p}\mathrm{T}_\infty + \frac{\omega}{\rho c_p V_e} \tag{4}$$

Taking into account (4), the system (2) yields to the following single-channel dynamic system:

$$\begin{aligned} \frac{dT}{dt} &= -\frac{hA}{\rho c_p V_e}\mathrm{T} + \nu \\ \frac{d\nu}{dt} &= \frac{\gamma(\omega,u,t)}{\rho c_p V_e} + \xi_0(t) \end{aligned} \tag{5}$$

Where $\xi_0(t)$ is the unknown dynamics of ν. Moreover, in order to improve the the given model, we introduce lumped disturbances in each channel of the proposed system. Thus, the system (5) can be expressed as follows:

$$\begin{aligned} \frac{dT}{dt} &= -\alpha_1\mathrm{T} + \nu + \xi_0(t) \\ \frac{d\nu}{dt} &= \alpha_2\gamma(\omega,u,t) + \xi_2(t) \end{aligned} \tag{6}$$

Where $\alpha_1 = hA/\rho c_p V_e$ and $\alpha_2 = 1/\rho c_p V_e$. Also, $\xi_2(t)$ contains the term $\xi_0(t)$ and any bounded external disturbance.

In real applications, it is well-known that the partial information about the system parameters is available only. Taking into account this issue, it is assumed that the system parameters α_i are partially known. Thus, the terms α_i are divided into two terms, i.e., $\alpha_i = \hat{\alpha}_i - \tilde{\alpha}_i$, where $\hat{\alpha}_i$ is the nominal parameter and $\tilde{\alpha}_i$ represents the term that contains the unknown model parameter and model uncertainties, and it is defined as $\tilde{\alpha}_i = \hat{\alpha}_i - \alpha_i$. Finally, taking into account the given nomenclature, we can rewrite the system (6) as follows:

$$\begin{aligned} \frac{dT}{dt} &= -\hat{\alpha}_1\mathrm{T} + \nu + \mathrm{d}_1(t) \\ \frac{d\nu}{dt} &= \hat{\alpha}_2\gamma(\omega,u,t) + \mathrm{d}_2(t) \end{aligned} \tag{7}$$

Where $d_i(t)\ \forall\ i = 1{,}2$ are the disturbance terms and contain the lumped external disturbances $\xi_1(t)$ and $\xi_2(t)$, and the parameter uncertainties. Moreover, this term is explicitly defined as

$d_1(t) = \xi_1(t) + \tilde{\alpha}_1 T$ and $d_2(t) = \xi_2(t) - \tilde{\alpha}_2\gamma(\cdot)$.

Remark 1. It is assumed that the disturbance term is bounded as follows:

$$\|d_i(t)\| \leq \delta_\mathrm{i} \tag{8}$$

Where $\delta_i \in \mathbb{R}\ \forall\ i = 1{,}2$ is the positive upper bound of the disturbance but it is not known.

Controller Design

In this section, an adaptive controller based on first order sliding modes theory is designed. First, we introduce the sliding surface, σ, which depends on the error variable as follows:

$$\sigma(t) = \dot{e}(\mathrm{t}) + \lambda\mathrm{e}(\mathrm{t}) \tag{9}$$

Where $e(t) = T(t) - T^d(t)$ is the tracking error, $\dot{e}(t)$ is the time derivative of the error signal, $T(t)$ is the temperature and $T^d(t)$ is the desired temperature value. It is worth to note that $T^d(t)$ is a function in time because the proposed controller addresses the trajectory tracking problem. However, to solve the set-point regulation, the desired value needs to be fixed to a constant value instead a function on time.

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Then, the proposed controller's objective is to drive the error value to zero, this means that $T(t) \rightarrow T^d(t)$ in finite time, in spite of the external disturbances and/or model uncertainties. This condition can be achieved by the following control law:

$$u(t) = \frac{1}{\hat{\alpha}_2}\left[\ddot{T}^d(t) + \hat{\alpha}_1\dot{T}(t) - \lambda\dot{e} - \hat{K}sgn(\sigma)\right] \quad (10)$$

Where $\ddot{T}^d(t)$ is the second time derivative of $T(t)$, $sgn(\cdot)$ is the signum function and $\hat{K}$ is the controller's adaptive gain, which its dynamics are given as follows:

$$\dot{\hat{K}} = \begin{cases} \beta|\sigma|^{\frac{1}{2}}sgn(|\sigma| - \mu) if\ \hat{K} \geq K_{min} \\ \kappa \qquad\qquad\qquad if\ \hat{K} < K_{min} \end{cases} \quad (11)$$

Where β, μ, κ and K_{min} are positive constants. The stability of the proposed controller is given in the main theorem below.

Theorem 1. Let the temperature dynamics of the plastic extrusion process given by the Eq. (5). Taking into account the model uncertainties and the lumped external disturbance, the model (5) can be rewritten as the equivalent system (7). Suppose that the disturbance term $d_i(t)$ satisfies (8). Then for any initial condition $\sigma(0)$ the sliding surface $\sigma = 0$ will be reached in finite time via the adaptive controller (10) with the adaptive gain selected as shown in Eq. (11).

Proof. Injecting the control law (10) into the time derivative of σ given by Eq. (9), yields to:

$$\dot{\sigma} = -\hat{K}sgn(|\sigma| - \mu) + \dot{d}_1(t) + d_2(t) \quad (12)$$

Let us define the following candidate Lyapunov function as:

$$V(\sigma, \hat{K}) = \frac{1}{2}\sigma^2 + \frac{1}{2\eta}\left(\hat{K} - \hat{K}^*\right)^2 \quad (13)$$

Where $\eta > 0$. Also, note that the given function is positive and radially unbounded in almost everywhere except in the origin. Then, taking its time derivative, one can obtain the following expression:

$$\begin{aligned} \dot{V}(\sigma, \hat{K}) &= \sigma\dot{\sigma} + \frac{1}{\lambda}(\hat{K} - \hat{K}^*)\dot{\hat{K}} = \\ &\sigma\left[-\hat{K}sgn(|\sigma| - \mu) + \dot{d}_1(t) + d_2(t)\right] + \\ &+ \frac{1}{\eta}(\hat{K} - \hat{K}^*)(\beta|\sigma|^{\frac{1}{2}}\mathrm{sgn}(|\sigma| - \mu)) \\ &\leq -\hat{K}|\sigma| - \delta_3|\sigma| + \hat{K}^*|\sigma| - \hat{K}^*|\sigma| \\ &+ \frac{1}{2}(\hat{K} - \hat{K}^*)(\beta sgn|\sigma|^{\frac{1}{2}}(|\sigma| - \mu)) \end{aligned} \quad (14)$$

Remark 2. Note that the boundary of the disturbances exists, but is unknown. This is:

$$\left|\dot{d}_1(t) + d_2(t)\right| \leq \delta_1 + \delta_2 = \delta_3 \quad (15)$$

Considering that there exist a $K^* > 0$ such that $\hat{K} - K^* < 0$ for all $t \geq 0$, then, it is possible to rewrite the Eq. (14) as follows:

$$\begin{aligned} &\dot{V}(\cdot) \leq \left(\delta_3 - \hat{K}^*\right)|\sigma| + \varsigma\left|\hat{K} - \hat{K}^*\right| - \varsigma\left|\hat{K} - \hat{K}^*\right| \\ &+(\hat{K} - \hat{K}^*)\left(-|\sigma| + \frac{\beta}{\eta}sgn|\sigma|^{\frac{1}{2}}(|\sigma| - \mu)\right) \\ &= -\left(\hat{K}^* - \delta_3\right)|\sigma| - \varsigma\left|\hat{K} - \hat{K}^*\right| - \\ &-\left|\hat{K} - \hat{K}^*\right|\left(-|\sigma| + \frac{\beta}{\eta}sgn|\sigma|^{\frac{1}{2}}(|\sigma| - \mu) - \varsigma\right) \end{aligned} \quad (16)$$

Let us define $\pi_1 = \hat{K}^* - \delta_3$ and $\pi_2 = \left|\hat{K} - \hat{K}^*\right|(-|\sigma| + \frac{\beta}{\eta}sgn|\sigma|^{\frac{1}{2}}(|\sigma| - \mu) - \varphi)$.

Then, the above equation can be rewritten as:

$$\begin{aligned} &\dot{V}(\sigma, \hat{K}) = -\pi_1|\sigma| - \varsigma\left|\hat{K} - \hat{K}^*\right| - \pi_2 \\ &\dot{V}(\sigma, \hat{K}) = -\pi_1\sqrt{2}\frac{|\sigma|}{\sqrt{2}} - \varsigma\sqrt{2\eta}\frac{|\hat{K} - \hat{K}^*|}{\sqrt{2\eta}} - \pi_2 \\ &\dot{V}(\cdot) \leq -\min\{\pi_1\sqrt{2}, \varsigma\sqrt{2\eta}\}\left(\frac{|\sigma|}{\sqrt{2}} + \frac{|\hat{K} - \hat{K}^*|}{\sqrt{2\eta}}\right) - \pi_2 \\ &\dot{V}(\sigma, \hat{K}) \leq -\chi V^{\frac{1}{2}} - \pi_2 \end{aligned} \quad (17)$$

Where $\chi = \min\{\pi_2\sqrt{2}, \varsigma\sqrt{2\eta}\}$. The analysis of the behavior of the time derivative of V can be addressed by considering two cases only. On the one hand, if we consider that $\sigma > \mu$, this means that π_2 is:

$$\pi_2 = -\mu + \frac{\beta}{\eta}\mu^{\frac{1}{2}} - \varsigma > 0 \quad (18)$$

From Eq. (18), it is easy to see that the following condition holds:

$$\eta = \frac{\beta\mu^{\frac{1}{2}}}{\mu + \varsigma} \quad (19)$$

This condition ensures the negativeness of the function $\dot{V} = (\sigma, \hat{K})$ when the trajectories enter in the region $\hat{K} > K_{min}$.

On the other hand, when $|\sigma| < \mu$, it is not possible to prove the negativeness of the function $\dot{V}$. However, based on the structure of the dynamics of $\dot{\hat{K}}$, when the system trajectories are in this region, the gain will increase as time grows up and, eventually, the value of σ will satisfy $|\sigma| > \mu$ and the function $\dot{V}(x)$ will be negative definite. Finally, the sliding surface $\sigma = 0$ will be reached in finite time in spite of parametric uncertainties and bounded external disturbances. This means that the $T(t)$ will tend to the desired value $T^d(t)$ as time increases.

Remark 3. The main theorem given above ensures the finite time convergence of the system trajectories to the reference signal in spite of parametric uncertainties and external disturbances. However, it is well-known that the main drawback of the first order sliding mode control is the chattering effect. The chattering amplitude is related to the controller gain, this means that if the gain is set to a high value, the amplitude of the chattering effect will be large. Nevertheless, we can consider different approaches in order to reduce the chattering into the control signal. For instance, a sigmoid profile is used instead the signum function, or a Low Pass Filter (LPF) is designed to alleviate the chattering effect. In this work, we design the LPF as follows:

$$\varrho\, \dot{v}(\mathrm{t}) + v(\mathrm{t}) = \mathrm{u}(\mathrm{t}) \qquad (20)$$

Where ϱ is a small positive constant. Note that (20) represents the filter dynamics and the variable v will be the new control signal.

Simulation Results

In this section, the robustness of the proposed controller is demonstrated through computer simulations. The simulations were performed in MATLAB software. The parameters used in the simulations are synthesized in Table I. Also, we consider the temperature profile for the PET material. Finally, the controller parameters are synthesized in Table II.

Parameter	Value
ρ	1380 $[Kg/m^3]$
c_p	1350 [kJ/(kg ∗ K)]
V_e	0.0207$[m/s]$
h	133[W/m^{2}K]
T_∞	25[°C]

Table 1 System Parameters when PET material is considered
Source: own elaboration

Parameter	Value
λ	1
β	0.005
μ	1
κ	0.1
K_{min}	0.01
ϱ	2

Table 2 Control Parameter used in the simulation.
Source: own elaboration

In this study, we consider the simulation for the temperature dynamics into the plastic extruder feed zone only. Note that the proposed methodology can be applied to each heat zone of the extruder. In fact, the robustness of the controller reduces the coupling effect when several controllers are considered.

In order to demonstrate the positive properties of the proposed controller, four scenarios arise as:

– Nominal Scenario: In this case, the set-point regulation is addressed without considering external disturbances or parametric uncertainties.

– Controller's robustness towards parametric uncertainties: In this case, it is assumed that the model parameters are unknown, and therefore they are not considered into the controller design.

– Controller's robustness towards external disturbances: In this scenario, it is considered external disturbances such as environmental temperature changes, sudden changes in the system parameters, actuation failure and so on.

– Trajectory tracking test: The reference signal is a time varying function. In this test, external disturbances and model uncertainties are considered.

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Nominal Case

In this scenario, the full knowledge of the system parameters is considered. Moreover, we do not take into account the lumped external disturbance, i.e., $d_i(t) = 0$. The reference signal is fixed to $T^d(t) = 260\,°C$. Finally, the control law tested is given by Eq. (10).

The set-point regulation results are shown in Fig. 1. From this Figure, we can observe that the temperature profile goes to the reference signal in almost 2500 seconds, which is a reasonable amount of time compared to other studies (see Su and Tsai, (2001)). The error signal plot is shown in the middle of Fig. 1. From this Figure, it can be observed that the tracking error vanishes as time increases. At the right lower part of Fig. 1, we can observe the controller's gain adaption. Finally, the left lower part of Fig. 1 shows the controller's signal evolution. It is possible to observe that the amplitude of the chattering effect was reduced using the LPF.

Controller Robustness Towards Parametric Uncertainties

In this scenario, the model parameters are unknown. For this reason, we modify the control law (10) as follows:

$$\mathrm{u(t)} = \frac{1}{\hat{\alpha}_2}\left[-\lambda \dot{e} - \hat{K} sgn(\sigma)\right] \qquad (21)$$

Note that we have neglected the term $\hat{f}(x) = \ddot{T}^d(t) + \hat{\alpha}_1 \dot{T}(t)$, which is related to the system's parameters.

Figure 2 shows the controller performance when parameter uncertainties are considered. As we can see, the trajectory system tends to the reference value even in presence of model uncertainties. In fact, the behavior is similar to the previous case, and the system converge to the T^d in almost 2500 seconds. The error plot is shown in the middle of Fig. 2. The evolution of the control signal is displayed in the left lower part of Fig. 2. As expected, the chattering amplitude is increased.

Controller's Robustness Towards External Disturbances

In this case, external disturbances are considered. We consider both cases: the constant disturbance, i.e., $d_1(t) = 10$ and a time varying disturbance such as $d_1(t) = 5\sin(2\pi f t)$ where the period was set to $T_f = 50$ seconds, and $f = 1/T_f$ is the frequency signal. The disturbance was introduced from 2500 to 4000 seconds.

The performance of the controller towards the constant disturbance can be seen in Figure 3. In the middle of Fig. 3 shows the convergence of the error to the origin. The evolution of the controller signal is displayed at the bottom of Fig. 3. Finally, the gain evolution is shown in the left lower part of the Fig. 3.

Fig. 4 shows the controller's response when time-varying external disturbance is considered. In the upper part of Fig. 4, we can see that the trajectory system reaches the reference in spite of the external disturbance at a time of 2500 seconds. In this plot, it is possible to observe that the disturbance is not completely suppressed. However, the controller's response is enough to minimize the negative impact of the disturbance. In the middle of Fig. 4, the error plot is depicted. The evolution of the controller signal is displayed in the left lower part of Fig. 4. From this Figure, we can observe that the chattering amplitude is increased because the controller needs to adjust its gain to counteract the disturbance effect, when the gain is increased, the chattering amplitude grows up as well.

Trajectory Tracking test

In this scenario, the time-varying profile trajectory tracking is proposed. The desired profile is defined as $T^d(t) = 260 + 5\cos(2\pi f t)$ where f is the signal frequency with a period of $T_f = 100$ seconds. The reference signal is introduced into the system dynamics from 500 seconds to the end of the simulation. In this case, we have assumed that the temperature of the extrusion process change as different material is introduced into the extrusion machine.

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The trajectory tracking task is shown at the top of Fig. 5, as we can see, the controller converges to the reference in finite time. Also, in the middle of Fig. 5, the error plot is displayed. Finally, the control signal is shown at the bottom of Fig. 5. It can be observed that the controller's effort is large when the desired reference changes. In the right bottom side, we can observe the evolution of the controller's feedback gain.

Conclusion

In this paper, an adaptive first order sliding mode control has been proposed. The adaptive controller is designed to address the trajectory tracking problem but it can be used for the set-point regulation paradigm. The stability analysis for the resulting closed-loop system for trajectory tracking has been addressed. The proposed controller has been tested by computer simulations in MATLAB for several scenarios to prove its robustness towards disturbances. The simulation experiments results demonstrate the effectiveness, and robustness of the proposed scheme to uncertainties on the parameters of the system and to external disturbances, as well. In this manuscript, constant disturbances and time-varying external disturbances were considered. The design of the discrete adaptive SMC is a part of future work.

Annexes

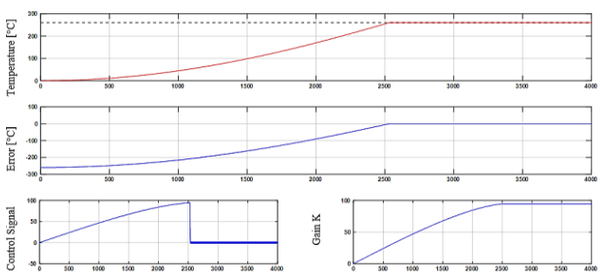

Figure 1 Nominal Case
Source: own work [MatLab]

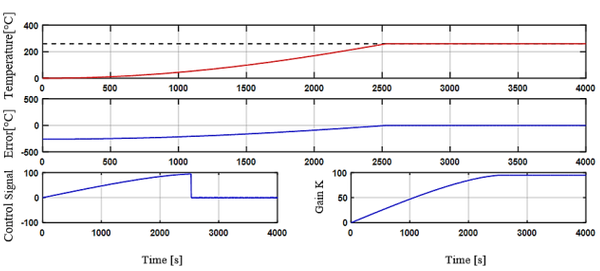

Figure 2 Controller robustness towards parametric uncertainties
Source: own work [MatLab]

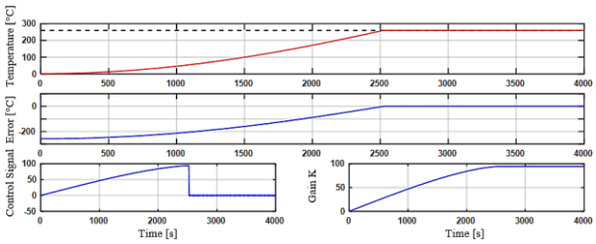

Figure 3 Controller robustness towards constant disturbance
Source: own work [MatLab]

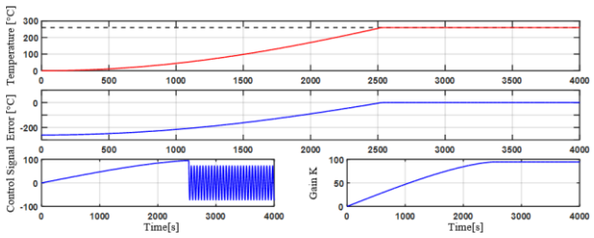

Figure 4 Controller robustness towards time-varying disturbance
Source: own work [MatLab]

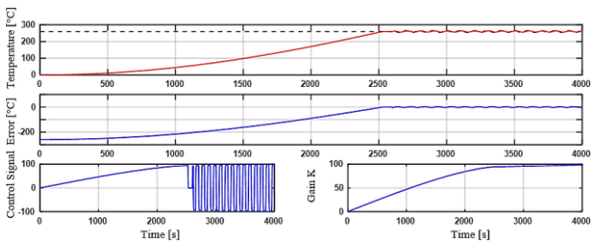

Figure 5 Trajectory tracking test
Source: own work [MatLab]

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Design y development of a graphical user interface in LabVIEW for acquisition and visualization of climatological data (temperature and relative humidity)

Diseño y desarrollo de una interfaz gráfica de usuario en LabVIEW para la adquisición y visualización de datos climatológicos (temperatura y humedad relativa)

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Abstract

This paper describes the design and development of a Graphical User Interface through the virtual instrumentation software NI LabVIEW using the VISA function, to graphically visualize and storage the data of the climatological variables of temperature and relative humidity. The graphical interface offers the option to export the date, time and data of the two variables to text documents with extension ".txt", which acquires the information of the electronic board wireless monitoring and control, which uses a main device PIC16F877A microcontroller. AMT1001 Precision Analog Sensor was used to sense temperature and relative humidity. The PIC16F877A was programmed using a C programming language in the CCS Compiler compiler, to the data acquisition, and send it via RS232 communication to the computer, using the PL2303 module USB to TTL converter. To check the GUI operation, the electronic wireless monitoring and control card was connected to the computer equipment by wire, however, the monitoring of the climate variables can be done wirelessly by XBEE technology. Future work aims to monitor the climate of a horticultural greenhouse with XBBE technology, so that the data is sent wirelessly to a computer that has the GUI, and is also connected to Ethernet or WIFI, which will have the LabVIEW graphical interface explained in this article, and the data will be displayed / analyzed through the internet.

LabVIEW, PIC16F877A, climatological variables

Resumen

El presente artículo describe el diseño y desarrollo de una Interfaz Gráfica de Usuario a través del software de instrumentación virtual NI LabVIEW mediante la función VISA, para visualizar gráficamente y almacenar los datos de las variables climatológicas de temperatura y la humedad relativa. La interfaz gráfica ofrece la opción de exportar la fecha, hora y los datos de las dos variables a documentos de texto con extensión ".txt", la cual adquiere la información de una tarjeta electrónica de monitoreo y control inalámbrico, que utiliza como dispositivo principal un microcontrolador PIC16F877A en la adquisición de datos. Se utilizó el sensor analógico de precisión AMT1001 para sensar la temperatura y humedad relativa. El PIC16F877A se programó utilizando un lenguaje de programación en C en el compilador CCS Compiler, para realización de la adquisición de datos, y enviarlos por comunicación RS232 a la computadora, usando el módulo PL2303 convertidor USB a TTL. En trabajos a futuro se pretende monitorear el clima de un invernadero hortícola con tecnología XBBE, para que los datos sean enviados en forma inalámbrica a una computadora conectada a Ethernet o WIFI, la cual tendrá la interfaz gráfica de LabVIEW explicada en el presente artículo, y los datos sean mostrados/analizados a través de internet**.**

LabVIEW, PIC16F877A, variables climatológicas

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Introduction

Data acquisition is the process of measuring an electrical or physical phenomenon such as voltage, temperature, pressure, among others, with a computer. A Data Acquisition System (SAD) consists of sensors, measurement hardware, and a computer with programmable software (National Instruments, 2020). Figure 1 shows a block diagram of a data acquisition system.

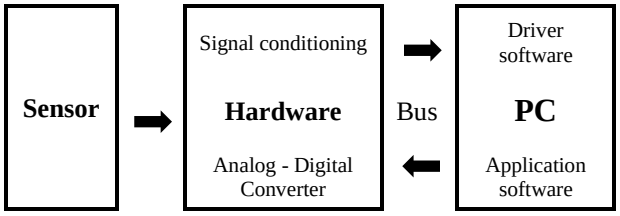

Figure 1 Block diagram of a SAD
Source: self-made

In a SAD the sensor converts a physical variable into an electrical signal that can be measured. The hardware acts as the interface between the computer and the physical variable measured by the sensor, and functions as a device that digitizes analog signals for a computer to interpret. A computer with programmable software is used to process, visualize and store data for the physical variables that have been measured (National Instruments, 2020).

Air temperature, relative humidity (RH), radiation and CO_2 concentration are physical variables that must be measured within a horticultural greenhouse, since they play an important role in product quality, profitability avoiding losses in cultivation and in the use of agrochemical inputs (Martínez & Roca, 2011).

Knowing the development of plant pests and diseases, diagnosing if a good biotic (with bumblebee) or abiotic (forced) pollination is taking place inside the greenhouse, are some of the reasons why horticultural producers monitor with a Graphical Interface User Interface (GUI by its English name, Graphical User Interface) that is interactive and friendly.

A GUI is a fundamental part of any application, to help the user to accomplish tasks quickly, easily and satisfactorily. When the user begins to work with the computer, it interacts with the Interface, either with that of the operating system, that of a particular software or that of any website (Albornoz, Berón, & Montejano, 2017).

LabVIEW is an application software, which facilitates the interaction between the computer and the user, to acquire, analyze and present data of physical variables that have been measured (National Instruments, 2020). Therefore LabVIEW can be used in a SAD and in the design of a custom GUI.

The purpose of this paper is to develop and design a GUI using the VISA functions of LabVIEW, to graphically display and store air temperature and RH data.

The article is organized as follows: The electronic card (hardware) and the analog sensor AMT1001, used in data acquisition, are described in the methodology section. Later in the same section it is mentioned how the data of the electronic card is sent to the port of the computer, for graphic programming in LabVIEW and the design of the GUI. Then, in the tests and results section, the operation of the GUI is presented. Finally, in the last section the conclusions and future works are presented.

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Methodology

Electronic data acquisition card

Figure 2 shows a block diagram of the electronic wireless monitoring and control card that was used as hardware in data acquisition, to interact as an interface between the sensor and the computer.

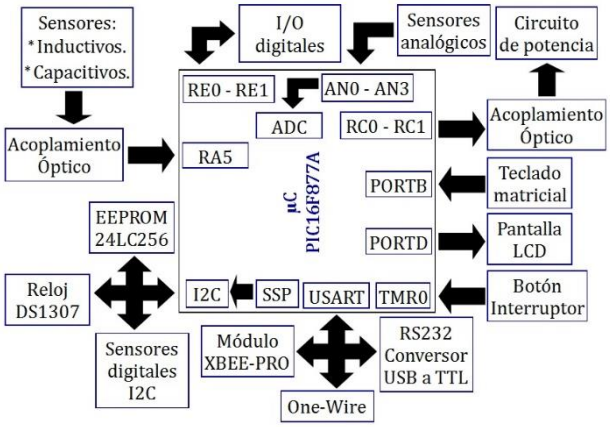

Figure 2 Block diagram of the electronic wireless monitoring and control card
Source: self-made

The electronic wireless monitoring and control card has as its main device a PIC16F877A Microcontroller from Microchip, and female header connectors to connect four analog sensors, an inductive or capacitive digital sensor with 12 Volt output and digital sensors with I2C communication protocol. and One-Wire.

The data obtained during the sampling can be sent to the computer in two ways: wired, using a USB to TTL converter module that connects to two female header connectors on the electronic card, or wirelessly, with an XBBE module integrated in the electronic card. Figure 3 shows an electronic connection diagram of the header connectors and XBEE module to the PIC16F877A.

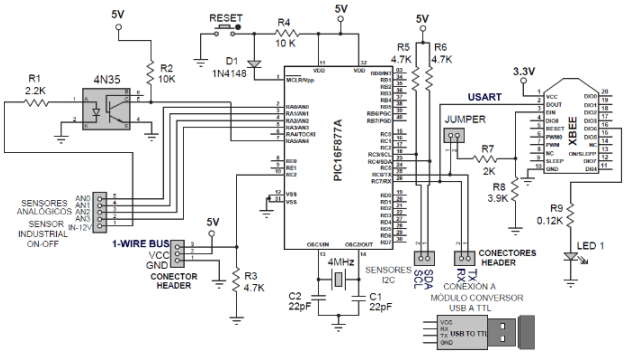

Figure 3 Electronic connection diagram of the XBEE header and module connectors to the PIC16F877A
Source: own elaboration, electronic diagram obtained with the PROTEUS ISIS simulator

Figure 4 shows the physical form of the electronic wireless monitoring and control card, which was used as hardware in data acquisition.

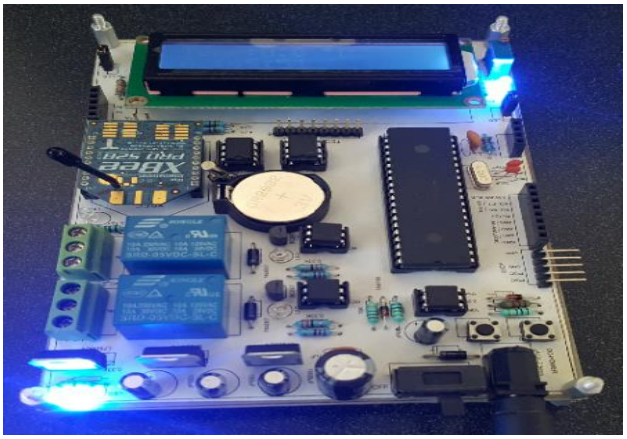

Figure 4 Physical form of the electronic card for wireless monitoring and control
Source: self-made

Temperature and relative humidity measurement

The AMT1001 sensor was used to measure the weather temperature and RH. Figure 5 shows and describes the AMT1001 sensor terminals.

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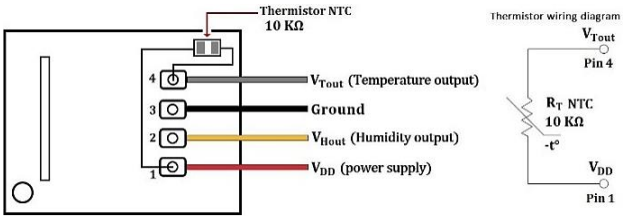

Figure 5 AMT1001 Sensor Terminals Description
Source: self-made

The output voltage V_{Hout} is a linear voltage in the range of 0 to 3 Volts (Temperature and Humidity Module AM1001 / AMT1001 Product Manual, 2020), which was measured with analog channel AN1 of the PIC16F877A Digital Analog Converter (DAC). The relationship between HR and V_{Hout} is shown in equation 1.

$$HR = \frac{V_{Hout}}{0.03} \quad (\%) \tag{1}$$

To measure temperature, the AMT1001 sensor has a 10KΩ NTC negative coefficient thermistor, between terminals 1 and 4. Table 1 shows some parameters of the NTC thermistor.

R_o reference temperature resistance $(298.15\ K)$ $(25\ °C)$	β Thermistor constant	Temperature operating range (°C)
10KΩ	3435	−40~125

Table 1 Some parameters of AMT1001 sensor NTC thermistor
Source: self-made

A precision Trimpot potentiometer set to 10 KΩ was connected between terminal 4 and ground, to obtain the output voltage $V_T$out. The $V_T$out voltage was measured with the analog channel AN0 of the DAC of the PIC16F877A. Figure 6 shows an electrical connection diagram between the NTC thermistor and the Trimpot.

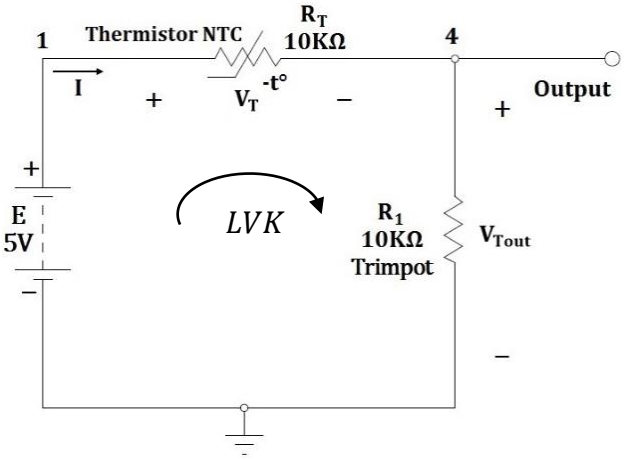

Figure 6 Electrical connection diagram between the NTC thermistor of the AMT1001 sensor and the 10KΩ Trimpot
Source: own elaboration, electronic diagram obtained with the PROTEUS ISIS simulator

A circuit analysis was performed to the electrical diagram of Figure 6, to obtain the relationship between the temperature in degrees centigrade T (° C) and the volatility V_{Tout}. Applying Kirchhoff's Voltage Law (KVL) clockwise to the closed path of the electrical diagram in Figure 6, equation 2 was obtained.

$$-E + V_T + V_{Tout} = 0 \tag{2}$$

By applying Ohm's law in the NTC thermistor to obtain V_T, and by substituting in (2) it was possible to obtain equation 3.

$$-E + IR_T + V_{Tout} = 0 \tag{3}$$

Using Ohm's law in R_1, we obtain equation 4 that calculates the electric current I.

$$I = \frac{V_{Tout}}{R_1} \tag{4}$$

If we substitute (4) in (3) and solve for R_T, we obtain equation 5.

$$R_T = \frac{ER_1}{V_{Tout}} - R_1 \tag{5}$$

Equation 6 relates some NTC thermistor parameters to R_T.

$$R_T = R_0\, e^{\beta\left(\frac{1}{T_K}-\frac{1}{T_0}\right)} \quad (6)$$

Where:

- **T_0**, is the reference temperature 298.15 expressed in degrees Kelvin (25 °C).
- **R_0**, is the resistance of the thermistor at the reference temperature.
- **β**, is a constant of the NTC thermistor.
- **T_K**, is the temperature expressed in degrees Kelvin.

Solving for T_K from (6) and applying the properties of logarithms, equation 7 was obtained.

$$T_K = \frac{1}{\frac{1}{\beta}\ln\frac{R_T}{R_0}+\frac{1}{T_0}} \quad (7)$$

To convert from degrees Kelvin to degrees centigrade, equation 8 is used.

$$T_{°C} = T_K - 273.15 \quad (8)$$

If (7) is substituted in (8) we obtain equation 9 that is used to calculate the temperature in degrees centigrade.

$$T_{°C} = \frac{1}{\frac{1}{\beta}\ln\frac{R_T}{R_0}+\frac{1}{T_0}} - 273.15 \quad (9)$$

Equations (1) and (9) were used to calculate RH and temperature in degrees centigrade respectively. Within the CCS Compiler, these equations were implemented in the C language program code for the PIC16F877A.

Using the description of the AMT1001 sensor terminals in Figure 5, and the electrical diagram in Figure 6, a single-sided Printed Circuit Board (PCB) (Bottom Copper) was made with the ARES tool from PROTEUS. Figure 7 shows the PCB made for the AMT1001 sensor.

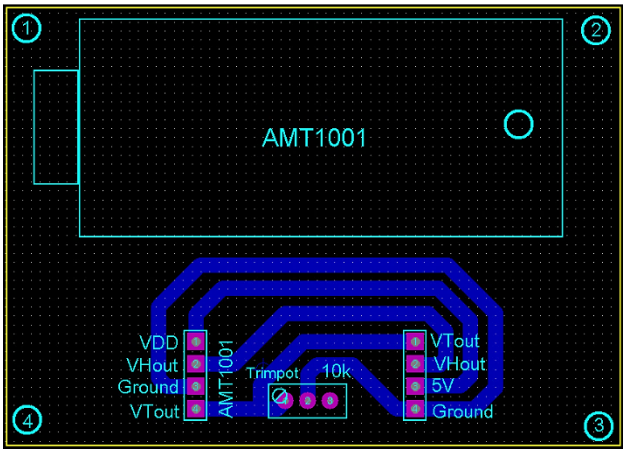

Figure 7 Bottom Copper face of the PCB in ARES
Source: own elaboration, PCB design obtained with the PROTEUS ARES tool

Figure 8 shows in physical form the top view of the PCB made for the AMT1001 sensor.

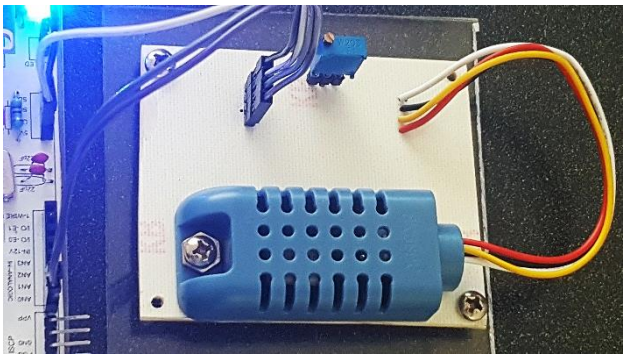

Figure 8 Top view of the PCB made for the AMT1001 sensor
Source: self-made

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Sending the climatological data to the computer by RS232 communication

The PL2303 USB to TTL serial converter module from Prolific was used to communicate the PIC16F877A of the wireless monitoring and control electronic card with the NI LabVIEW virtual instrumentation software, using an asynchronous RS232 serial communication protocol.

In the serial transmission of data to the computer, the PIC16F877A sends the temperature or RH in a seven-byte ASCII character string format. Figure 9 shows the format used to send and identify the value of the climatological variables.

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6
I	**E1**	**E2**	**.**	**D1**	**D2**	**LF**

Figure 9 Format of ASCII characters that are sent to the computer port
Source: self-made

The first ASCII character sent is Byte 0 (I) with the value of '0' or '1', which indicates whether it is the temperature or HR. The characters from Byte 1 to Byte 5 is the reading made by the PIC16F877A of the AMT1001 sensor, in two whole digits and two digits after the decimal point. Finally, Byte 6 (LF) is the newline character (10 in ASCII code) that is sent to the end of the string. An example of the ASCII character format is shown in Figure 10, used to send the HR value to the LabVIEW software.

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6
0	**6**	**5**	**.**	**3**	**0**	**LF**

Figure 10 Example of the format for sending the HR value to the LabVIEW software
Source: self-made

The CCS Compiler has functions to send data through the USART module (Henao & Duque, 2009). Figure 11 shows the functions used in the C language program code to send the HR value to LabVIEW.

```
printf("0"); //Se envia '0'
printf("%0.2f",HR); //Se envía el valor de HR
putc(10); //Se envía carácter de nueva línea, fin del dato
```

Figure 11 Functions used in CCS Compiler to send HR ASCII character format to LabVIEW
Source: self-made

The function *printf ("0")* writes and sends the character '0', indicating that the characters that will be sent after this character correspond to the climatological variable HR. *The printf ("% 0.2f", HR)* function sends the value of the climate variable HR, with two whole digits and two after the decimal point. The *putc (10)* function writes the newline character 'LF' in ASCII code.

An example of the character format is shown in Figure 12, used to send the temperature value to the computer port.

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6
1	**2**	**5**	**.**	**2**	**0**	**LF**

Figure 12 Example of the format for sending the temperature value to LabVIEW
Source: self-made

Figure 13 shows the functions used in the C language program code to send the temperature value to LabVIEW.

```
printf("1"); //Se envia '1'
printf("%0.2f",Tc); //Se envía el valor de Temperatura
putc(10); //Se envía carácter de nueva línea, fin del dato
```

Figure 13 Functions used in CCS Compiler to send the ASCII temperature character format to LabVIEW
Source: self-made

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Graphical Programming in LabVIEW for the Graphical User Interface (GUI)

A virtual instrument (VI) was developed in NI LabVIEW using the NI VISA functions, based on the methodology of (Flores Flores, 2014), to establish RS232 serial communication with the wireless monitoring and control card, read the data that arrives to the serial communication port, visualize, graph and export the data of the weather variables. Figure 14 shows the program code in graphic language (block diagram) of the VI developed for the GUI.

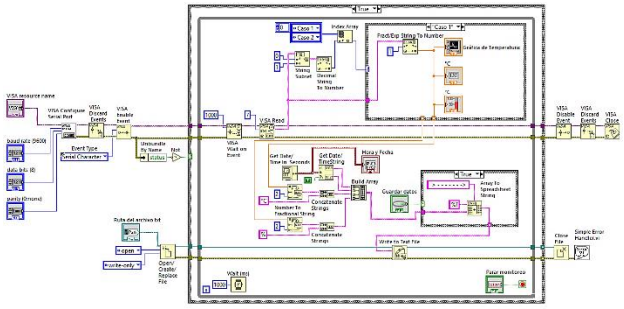

Figure 14 Graphical language program code developed in LabVIEW for the GUI.
Source: own elaboration, block diagram obtained from NI LabVIEW

Figure 15 shows the blocks used to configure and enable asynchronous serial communication and the computer port.

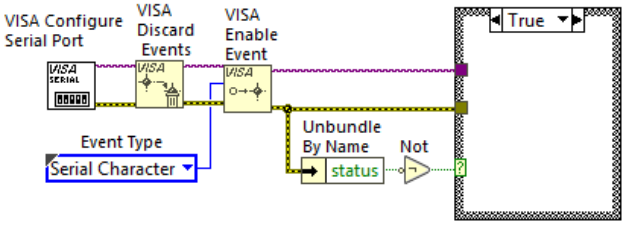

Figure 15 Blocks to configure and enable serial communication and computer port.
Source: own elaboration, obtained from the LabVIEW block diagram

The VISA Configure Serial Port block configures the speed parameters (bits per second), data bits, and parity. The VISA Discard Events block clears the characters that were left in the port from previous events. The VISA Enable Event function enables the serial port to receive a character or byte and place it on hold. Since the wireless control and monitoring card sends ASCII characters to LabVIEW, the Serial Character option is selected in VISA Enable Event. The first case (True) of the Case Structure control structure is used to process the characters that arrive through the port, and the second case (False) is used to rule out errors during serial communication. The Unbundle By Name element was connected with the not operator, to convert the serial port error status to Boolean values.

The VISA Wait on Event and VISA read functions are used to wait and receive respectively an ASCII character (Figure 16).

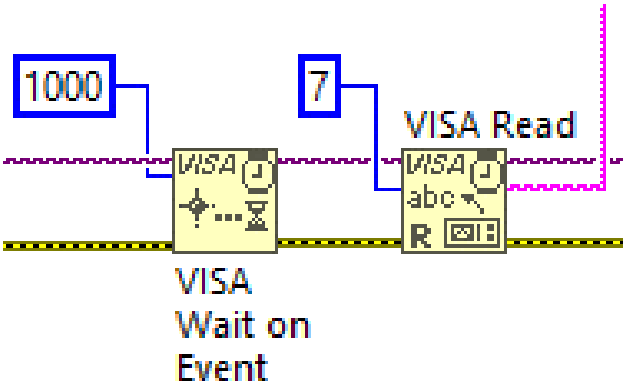

Figure 16 Functions to wait and receive an ASCII character
Source: own elaboration, obtained from the LabVIEW block diagram

The VISA Wait on Event function waits for an ASCII character before 1000 ms, if this does not happen, an error is generated by VISA Discard Events and VISA Enable Event. The VISA read function receives the format of the seven bytes of the temperature or HR before reading them. The VISA read byte count parameter was assigned the value of 7, to indicate the bytes to expect.

Figure 17 shows the functions that were used to convert the seven-byte ASCII character format to a floating point number, and identify whether it is the temperature or HR value.

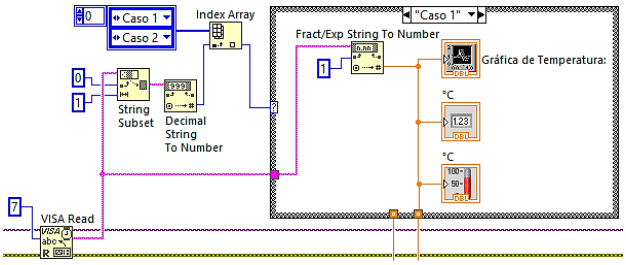

Figure 17 Functions to convert a character string to a floating point number and identify whether it is temperature or HR
Source: own elaboration, obtained from the LabVIEW block diagram

The String Subset block separates byte 0 of the string from the seven bytes that VISA read delivers in the read buffer, and sends it to its output as a substring. The Decimal String To Number block converts the substring (byte 0) to an integer decimal number. To identify if the character string corresponds to temperature or RH, a Case Structure case control structure (case 1 and case 2) was used. The assignment of cases is carried out through the Index Array, which in its row 0 has case 1 and in its row 1 has case 2. The rows of the array must match the output of the Decimal String To Number ('0' or 'one'). The Fract / Exp String To Number block separates byte 0 from the character string that VISA Read sends, and converts the rest of the string to a floating point number.

In case 1 the numerical indicators and graphs of the temperature were placed, and in case 2 the numerical indicators and graphs of HR.

The functions used to export a Table with the date, time and the data of the two climate variables to a text document ".txt", are shown in Figure 18.

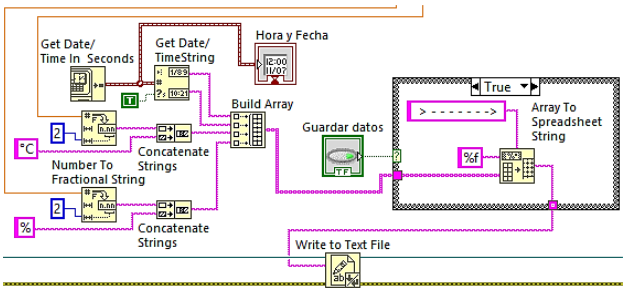

Figure 18 Functions to export a Table with the date, time and the measured variables of the climate to a text document ".txt"
Source: own elaboration, obtained from the LabVIEW block diagram

The functions Get Date / Time in Second and Get Date / Time String obtain the date and time from the computer clock in two strings, one for the date and the other for the time. The Number To Fractional String functions were used to convert temperature and RH to character strings. The Concatenate Strings function was used to concatenate the symbol "° C" with the temperature character string, in the same way, another similar function was used to concatenate the symbol "%" with the HR character string. With the Build Array function, the date, time, temperature and RH strings were concatenated. Within a Case Structure case control structure, the Array To Spreadsheet String function was used to generate a Table with the character strings concatenated by the Build Array function. The case control structure is conditioned by a logical button, when True the Table is generated with the characters. Finally, the function Write Text File prints the Table in the text file ".txt".

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Design of the Graphical User Interface

In the front panel of LabVIEW the GUI was designed mainly to graphically display and store the data of the climatological variables of temperature and RH. Figure 19 shows the GUI designed on the LabVIEW front panel.

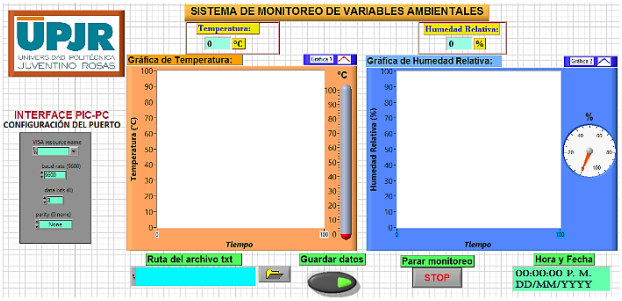

Figure 19 GUI developed on the front panel of LabVIEW
Source: own elaboration, obtained from the LabVIEW control panel

In the port configuration window, select the computer port where the device is connected, the communication speed, the data bits, and the parity. The device connected to the computer port can be any electronic development board that handles the USART asynchronous serial communication protocol.

To visualize the data of the variables as they arrive at the computer port, the GUI has two graphic windows, one to graph temperature and another to graph RH. At the top of each graph, there are numerical indicators where the value of each variable is displayed in a number. A thermometer as a graphical indicator is displayed to the right of the temperature graph, and a hygrometer is displayed to the right of the RH graph.

In the lower left part of the GUI there is an indicator with the time and date. These data are obtained from the computer clock, and it is very important that they are updated, since these will be part of the historical data in the measurements of the climatological variables.

The GUI offers the option of storing the date, time and the data of the weather variables in a text document with the extension ".txt". The user must create the text document, give it a name and save it in some path on the computer's hard drive. In the Path of the txt file window, you must select the path of the text document where the data of the variables will be saved. At the bottom is the Save data button, when pressed it shows an appearance in orange, indicating that the data of the variables will begin to be stored in the text document.

Tests and results

To test the GUI operation, the wireless monitoring and control electronic card was connected to the computer by wire, using the PL2303 USB to TTL converter module (Figure 20).

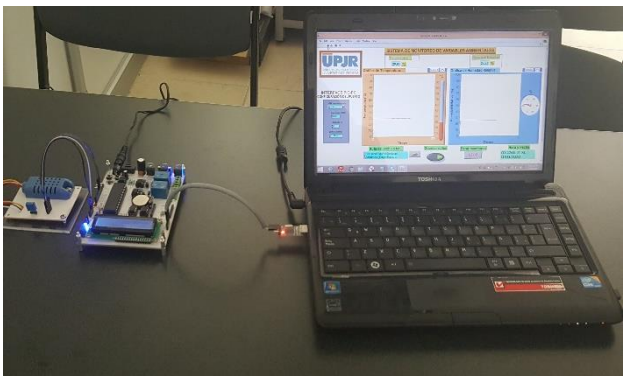

Figure 20 How to connect the wireless monitoring and control electronic card to the computer
Source: self-made

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In the computer equipment where the GUI operation was tested, the PL2303 driver for the USB to TTL converter module was installed, and the NI-VISA driver that allows communication between NI LabVIEW and a device connected to the port. For data acquisition (measurement and reading), the AMT1001 sensor was connected to the electronic wireless monitoring and control card. Figure 21 shows the sensor and electronic card connected in a test performed for the GUI.

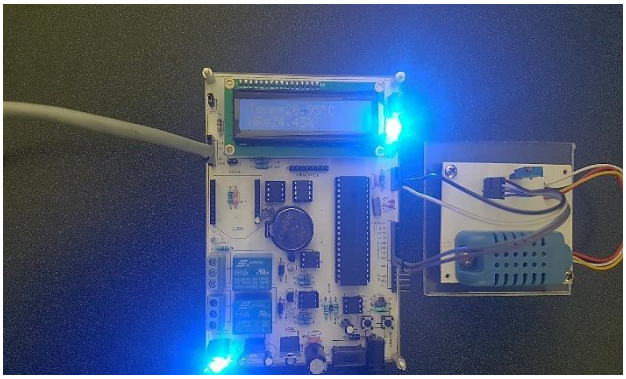

Figure 21 Connection of the AMT1001 sensor and electronic card for data acquisition
Source: self-made

In the design and development of the GUI several performance tests were performed. Figure 22 shows how the GUI worked on the LabVIEW front panel, for a test run performed.

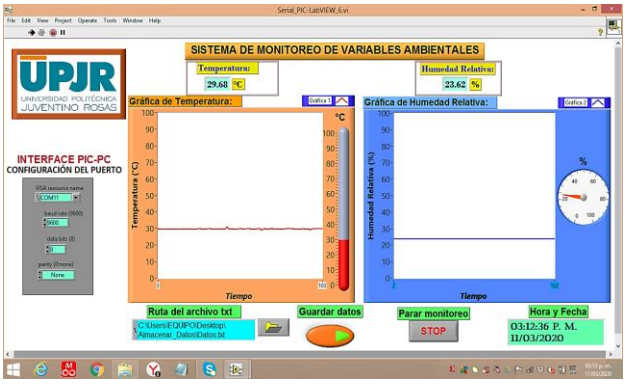

Figure 22 GUI Operation on the LabVIEW Front Panel
Source: own elaboration, obtained from the LabVIEW control panel

Before running the test shown in Figure 22, the document path named Data.txt was selected. The path of this document was a folder named Store_Data (Figure 23).

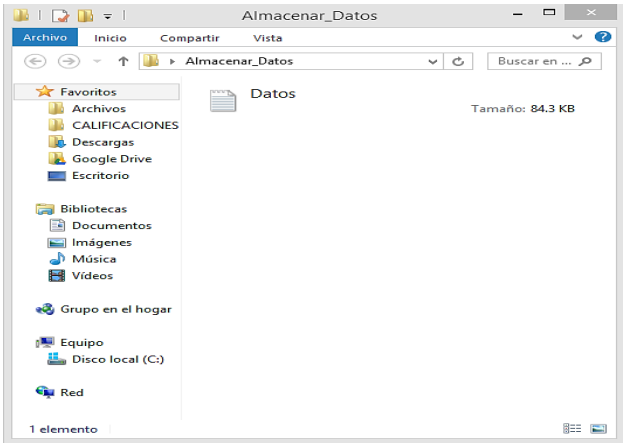

Figure 23 Folder where the document Data.txt was saved
Source: self-made

During the test run, the Save Data button was pressed, only to store some temperature and RH values in the Data.tx document. Figure 24 shows a printed table with the date, time and data of the two climate variables in the document Datos.txt.

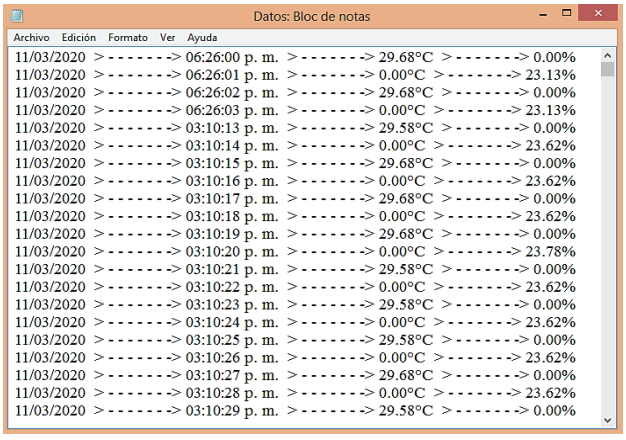

Figure 24 Date, time and temperature and HR data in the document Datos.txt.
Source: self-made

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Conclusions and future work

The purpose of the work was to develop and design a GUI using the LabVIEW VISA functions, to graphically display and store air temperature and HR data. In the functional tests, the GUI worked properly. In future work it is intended to add control buttons to the GUI, to control and activate electric actuators.

Figure 14 shows that the Operation parameter of the Open / Create / Replace File block is set to "open", this causes the data to be overwritten in the text document each time the Save data button is pressed. To generate a new text document each time the Save data button is pressed and the data is not overwritten, the open or create option must be chosen in the Operation parameter.

The GUI stores the temperature and RH data in a single ".txt" text document. If you want to save a variable per text document, in the LabVIEW graphical programming, you will have to add an Open / Create / Replace File, Write to Text File and Close File block for each variable.

The program code for the PIC16F877A and graphical programming in LabVIEW were developed to work with temperatures from 0 to 99 ° C. To perform tests below 0 ° C both codes would have to be modified. In the PIC16F877A an 8-byte character string must be sent, where one byte must be allocated to assign it an ASCII character, indicating whether it is a negative (less than 0 ° C) or positive (greater than 0 ° C) temperature.). In the LabVIEW graphical programming, more blocks must be added, cases in the control structures, and some parameters of the functions must be modified.

The GUI was designed to graphically display and store data for two climatological variables. If you want to add another variable, such as Carbon Dioxide 〖CO〗 _2, the Microcontroller will have to send three strings of ASCII characters instead of two. In the LabVIEW block diagram, more blocks and cases should be added to the control structures.

In this work, the analog sensor AMT1001 was used, however, with the electronic wireless monitoring and control card, digital sensors with I2C and One Wire communication protocol can be used.

To check the operation of the GUI, the electronic wireless monitoring and control card was connected to the computer equipment by wire, however, the monitoring of the climate variables can be done wirelessly by XBEE technology. Future work is intended to monitor the climate of a horticultural greenhouse with XBBE technology, so that the data is sent wirelessly to a computer that has the GUI and is also connected to Ethernet or WIFI.

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Interface design for monitoring and estimation system for flooding through an image analysis of remote sensing (SAVUI)

Diseño de interfaz para el sistema de monitoreo y estimación de inundaciones a través de un análisis de imágenes de percepción remota (SAVUI)

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Abstract

In recent years the floods in Mexico caused economic and human losses, therefore, it is necessary to use the possible tools that can provide help to the government to reduce damage from natural disasters. For this, we decided to develop a graphical user interface, known as GUI in Matlab for the segmentation of SAR, Multispectral and POLSAR images, with the intention of detecting flooding and vulnerable areas to flooding. The designed software compute a rivers segmentation in order to make the comparison between image with flooding and the image without flooding from the same area, and to obtain a visually result where a projection of the vulnerable areas to flooding in the original image this with help of basic segmentation algorithms such as grayscale, binarization, dilation, wavelet, normalization, filtering and edge detection.

SAR image, Matlab GUIDE, Flooding

Resumen

En los últimos años, las inundaciones en México causaron pérdidas económicas y humanas, por lo tanto, es necesario utilizar las posibles herramientas que pueden proporcionar ayuda al gobierno para reducir los daños causados por los desastres naturales. Para esto, decidimos desarrollar una interfaz gráfica de usuario, conocida como GUI en Matlab para la segmentación de imágenes SAR, Multiespectrales y POLSAR, con la intención de detectar inundaciones y áreas vulnerables a las inundaciones. El software diseñado calcula una segmentación de ríos para hacer la comparación entre la imagen con inundación y la imagen sin inundación desde la misma área, y para obtener un resultado visual donde una proyección de las áreas vulnerables a inundación en la imagen original esto con la ayuda de algoritmos de segmentación básicos como escala de grises, binarización, dilatación, wavelet, normalización, filtrado y detección de bordes.

Imágenes SAR, Interfaz de Matlab, Inundaciones

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Introduction

Mexico suffer hundreds of human deceased and economic losses due to the constant rains, river overflows and landslides caused by storms or hurricanes, the most dangerous occurring when rivers are exceeded in their capacity and carries excess water, mud and trash to small villages, crops and cities, causing severe flooding and even death explained in INEGI (2011) and Index Mundi (2015). In recent years and with current technology is possible to prevent dangerous situations and thus increase the probabilities of reducing human and material losses when a natural disaster occurs. Aware that natural events are unavoidable, it is necessary to design a valuable tool in which, using satellite imagery, images from drones and/or air vehicles with synthetic aperture radar (SAR) systems, can be assessed in a more timely and effective way in areas damaged by disasters, with the development of software that will contain as main tools the use of image processing and the design of a friendly interface for the final user, how Popescu, Ichim y Caramihale (2015) develop it.

Satellite or drone information allows not only the planning and management of recovery actions of the post-event areas, but in many cases, can issue early warnings, prior to the event. Floods emit precursor signals that a satellite can detect and that would help prevent dangerous situations. We design a software for identify rivers, flooding zones and flood predictions using image processing tools (image segmentation, a priori information of floods and images without flooding), the software aims to support federal institutions of government in Mexico such as Civil Protection, INEGI (Instituto Nacional de Estadística y Geografía in spanish), SEMAR (Secretaría de Marina in spanish), SEDENA (Secretaría de la Defensa Nacional in spanish), CONAGUA (Comisión Nacional del Agua) and any institution that has access to SAR images, images acquired by drones and/or air vehicles.

For monitoring flooding zones or areas with probability for flooding, it is necessary any tool that helps to analyse the land, population and the environment, especially with new technological advances in the remote sensing (RS) area, such as the use of images from SAR systems, LANDSAT satellites and polarimetric image (POLSAR).

For flooding segmentation and classification areas or zones with water, an analysis of RS images is required for to know the multiple features in areas with water, with the intention to get information that helps to classify, separate/segment the class mentioned above, an example is described in the research paper (Shen, Wang, Mao, Anagnostou & Hong, 2019), where the study reviews theories and algorithms of flood inundation mapping using SAR data, together with a discussion of their strengths and limitations, focusing on the level of automation, robustness, and accuracy.

Avendano & Bayona (2014) and Avendano, Mora, Vera, Torres & Prieto (2015), describes that in order to prevent natural flood disasters is important to identify the flood areas. For this reason, in Colombia, Avendano propose a computational tool in MATLAB, able to detect and classify Colombia's flood zones in SAR images. They used different classifiers, and according to the performance we selected the best. The training database was generated with the results of Fuzzy Clustering, K -means and Region -Growing segmentations on flood zones in SAR imagery. We used two different classifiers: the first one is a Bayes classifier, while the second one is a Support Vector Machine (SVM). The United States Geological Survey (USGS) Flood Inundation Mapping (FIM) (USGS, 2017) program focuses on developing one such product, a flood inundation map library, and helping communities pair that library with USGS real-time stream data and National Weather Service flood forecasts to form a two-dimensional flood warning system. Together, these products can help communities estimate the extent of the flood and identify at-risk areas and resources in advance of the floodwaters arriving, providing a powerful advantage in the effort to keep people and property safe from rising waters. In Mexico, in the University UNAM (Parrot 2013) development the software TLALOC (Three-dimensional Landscape Analysis Local Operating Computation) represents a new and powerful tool for the study of morphometry and geomorphology from the use of Digital Terrain Models (DTM). In fact, DTM describes more accurately the land surface, in such a way that they offer the possibility of studying in detail the various aspects related to the shape of the relief.

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An innovative tool for remote sensing is (QGIS, 2019) (formerly also called Quantum GIS) is a free code Geographic Information System (GIS) for GNU / Linux, Unix, Mac OS, Microsoft Windows and Android platforms, the problem is that the project is for the study of map and mapping, also (ArcGIS, 2019) is general-purpose industry-standard software that not only maps data but provides many means to transform it for other purposes. Its tools can extract related features, provide geostatistical analysis, and generate 3D models and movies of time-dependent changes.

However, all the previous algorithms/softwares fail to locate flooded areas with a large percentage, in addition to not having information from multiple images of remote perception (SAR, LANDSAT and POLSAR), and it is added that they do not have an interface that allows the user Make image changes for later analysis.

For this reason, this research work explains the design of a Matlab's interface for the detection and visualization of flooding in RS images and areas with flooding probability.

Remote Sensing Introduction

In (Ryerson & Henderson, 1998) and (Curlander & McDonough, 1991) Remote Sensing (RS) can be defined as the science and art of obtaining information about an object by analysing the data acquired through a device that is not in physical contact with that object. RS systems, mainly used in satellites, drone and Unmanned Aerial Vehicle (UAV), provide a repetitive and consistent view of the earth that is very important in the short and long-term monitoring of the Earth's surface.

Some specific uses of RS images of the Earth include: Large forest fires can be mapped from space, allowing rangers to see a much larger area than from the ground and tracking clouds to help predict the weather or watch erupting volcanoes, and help watch for dust storms. RS contain multiple sensors or systems but for this research paper we use three imagery RS systems (SAR imagery system, Multispectral imagery system and POLSAR imagery system).

SAR image

SAR is a radar system used in space and air vehicles that uses the relative movement between the antenna and a region of interest in order to obtain a finer spatial resolution than would be obtained if the radar and the region of interest were fixed with respect to each other. (Curlander & McDonough, 1991) and (Moreira et al., 2013). The electromagnetic pulses are sent to the ground in a direction perpendicular to the vehicle's flight and is implemented by an antenna mounted on a mobile platform or airplane from which a scene is repeatedly lit target with pulses of radio waves that can have wavelengths from one meter to millimetres.

The SAR takes advantage of the long-range propagation features of radar signals and the large information processing capacity of current digital computers to provide high-resolution images.

Landsat 5

In 2012, EOS establish that Landsat 5 was a low Earth orbit satellite launched on March 1, 1984 to collect imagery of the surface of Earth. Since 1984, Landsat 5 has gathered more than 700,000 images and observed climate change, agricultural practices, development and urbanization of cities, ecosystem evolution, and increasing demand for natural resources.

Landsat Thematic Mapper (TM) sensor was carried on Landsat 4 and Landsat 5, and created images consisting of six spectral bands with a spatial resolution of 30 meters for Bands 1-5 and 7, and one thermal band (Band 6). The approximate scene size is 170 km north-south and 183 km east-west (106 mi by 114 mi). TM could not resolve individual houses or trees, but it could record areas where houses had been constructed or forests had been cleared.

Multispectral image

Vignesh & Thyagharajan (2017) described that a multispectral image is a collection of several monochrome images of the same scene, each taken with a different sensor. Each image is known as a band. A well-known multispectral (or multiband) image is an RGB colour image, consisting of a red, a green and a blue image, each taken with a sensor sensitive to a different wavelength. In image processing, multispectral images are most used for remote sensing applications. Satellites generally take several images of frequency bands in the visual and non-visual range.

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POLSAR Image

Moreira et al. (2013) and Boerner (2015) depict the Polarimetric SAR is a mode of SAR imagery which transmits and receives signals of multiple polarizations rather than just one polarization.

Polarimetric SAR systems enhance the capabilities of basic radar systems by transmitting and receiving in multiple polarizations. By utilizing different polarizations, it is possible to discern unique and distinct features of targets. Some features can be observed in one polarization and not in another. Target features can be defined more clearly by combining all four polarization modes.

In other words, radar systems can transmit and receive either a Vertical (V) or a Horizontal (H) polarization of a radio wave. Polarimetric SAR can be performed by either transmitting vertical and horizontal polarizations or receiving vertical and horizontal polarizations, or both.

Background Image Processing

In 2008, Gonzalez & Woods and 2015, Russ & Neal establish that an image may be defined as a two-dimensional function, $\mathbf{I}(x, y)$, where x and y are spatial coordinates, and the amplitude of $\mathbf{I}$ at any pair of coordinates (x, y) is called the intensity or gray level of the image at the point. When x, y and the amplitude values of I are all finite, discrete quantities, we call the image a digital image. The field of digital image processing refers to processing the images by means of a digital computer. The next definitions explain the area of image processing and the core of the project:

Grey-Scale image

(Gonzalez & Woods, 2018), (Russ & Neal, 2015) describe that in image processing a greyscale image is one in which the value of each pixel is a single sample representing only an amount of light, that is, it carries only intensity information. Grayscale images, a kind of black-and-white or grey monochrome, are composed exclusively of shades of grey. The contrast ranges from black at the weakest intensity to white at the strongest, Greyscale is represented by the equation 1, where the algorithm converts RGB values to grayscale values by forming a weighted sum of the R, G, and B components:

$$\mathbf{I}_G = 0.2989 * \mathbf{R} + 0.5879 * \mathbf{G} + 0.114 * \mathbf{B} \quad (1)$$

Filtered image

Filtering is a technique used for modifying or enhancing an image like highlights certain features or remove other features, image filtering includes smoothing, sharpening and edge enhancement. It may be applied in either spatial domain or frequency domain.

For the case of the remote sensing image in specific the SAR and POLSAR system the most common noise is the speckle noise that degrading the quality of the image. Therefore, and efficient speckle noise removal technique needs to be sought, the Lee Filter is the most efficient algorithm to reduce the imperfections of the speckle noise according to Moreira et al. (2013) and Yommy, Liu & Wu (2015).

Normalize image

Normalization is a process that changes the range of pixel intensity values. It is sometimes called contrast stretching or histogram stretching. In more general fields of data processing, such as digital signal processing, it is referred to as dynamic range expansion. The normalization is represented by the equation 2:

$$\mathbf{I}_{\mathrm{N}} = (\mathbf{I} - \mathrm{Min}) * \left(\frac{\mathrm{newMax} - \mathrm{newMin}}{\mathrm{Max} - \mathrm{Min}}\right) + \mathrm{newMin} \quad (2)$$

Where $\mathbf{I}_{\mathrm{N}}$ is the normalized pixel, $\mathbf{I}$ is the intensity of the original pixel, Min and Max are the minimum and maximum pixel intensity in the image to be stretched to the new intensity, and newMin and newMax are the new minimum and maximum pixel range for the normalized image (Gonzalez & Woods, 2018), (Russ & Neal, 2015).

Edge detection (sobel)

Edge detection is usually a stage widely used for segmentation tasks or for the search for more complex geometric objects such as lines, ellipses, corners. Edge is understood as the region where there is a strong variation in the intensity level in adjacent pixels. It is main caused by the intersection of several objects, with different levels of reflectance, which when projected on the camera generate intensity discontinuities in the corresponding pixels. However, these discontinuities also appear in an unwanted way due to the presence of noise, the effect of shadows on the objects themselves, or because of uneven lighting within the scene.

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The sobel filter is the most used algorithm for edge detection, it works by calculating the gradient of image intensity at each pixel within the image. It finds the direction of the largest increase from light to dark and the rate of change in that direction. The result shows how abruptly or smoothly the image changes at each pixel, and therefore how likely is that pixel represents and edge (Gonzalez & Woods, 2018), (Russ & Neal, 2015).

Binary image

Gonzalez & Woods (2018), Russ & Neal (2015) define that a binary image is a digital image that has only two possible values for each pixel. Typically, the two colours used for a binary image are black and white, a typical method is the Fixed Thresholding binarization method fixed threshold value is used to assign 0′s and 1′s for all pixel positions in each image. Puneet & Garg (2013) depict that the basic idea for fixed binarization method is described as under, where the $\mathbf{I}_B$ is the Binary image, the **I** is the original image to convert to binary and T shows global threshold value.

$$\mathbf{I}_B = \begin{cases} 1 & if \ \mathbf{I} \geq T \\ 0 & otherwise \end{cases} \quad (3)$$

Dilation image

In (Gonzalez & Woods, 2018), (Russ & Neal, 2015) shown that the mathematical morphology (MM) is a theory and technique for the analysis and processing of geometrical structures, based on set theory, lattice theory, topology, and random functions. MM is most applied to digital images, but it can be employed as well on graphs, surface meshes, solids, and many other spatial structures. The basic morphological operators are erosion, dilation, opening and closing. Dilation usually represented by $\otimes$, originally developed for binary images, it has been expanded first to grayscale images, and then to complete lattices. The dilation operation usually uses a structuring element for probing and expanding the shapes contained in the input image explained in Sghaier, Foucher & Lepage (2017),

$$\mathbf{I} \otimes \mathbf{B} = \bigcup_{b \in \mathbf{B}} \mathbf{I}_b, \quad (4)$$

The equation 4 represent the dilation, where **B** is a structuring element and $\mathbf{I}_b$ is the translation of **I** by b.

Methodology

Figure 1 shown the general flow chart for obtain the segmented flooding area and projected in the original image without flooding.

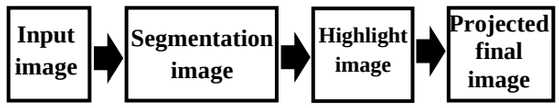

Figure 1 Principal segmentation flow chart
Source: *own work [power point*]

In flow chart the first step corresponds to read the flooding image SAR, Multispectral or POLSAR, depend of the interface that the user selects. The second step is the image segmentation process, the next step is to paint or highlight the segmented image, last step is the final image when the highlight image is projected with the original image (without flooding).

SAVUI Interface and Results

The SAVUI interface project was designed in software Matlab® version 2016 according to the multiple Remote Sensing systems.

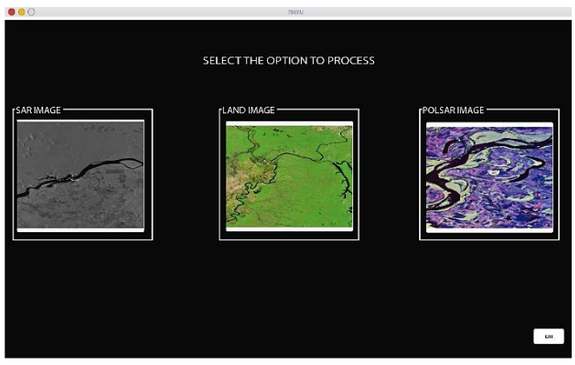

Figure 2 Principal segmentation flow chart
Source: *own work [Matlab*]

Figure 2 is the principal software interface, where contain three different options with multiples process and algorithms, the principal idea is to segment the selected image, specially the water or places with water.

User can select the option according to the different image or images, the options are SAR image, multispectral image (LANDSAT) and POLSAR image.

The first process is when the user selects the option SAR image, where the difference between this process is that the SAR image contains information in greyscale while the other systems (images) works with RGB or multiple polarization information.

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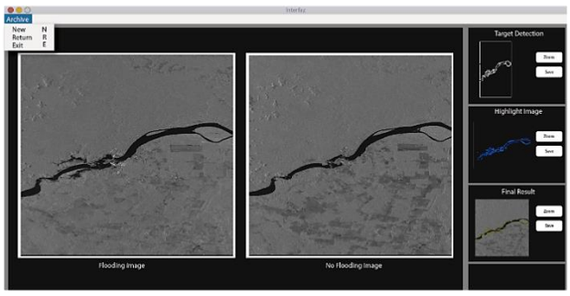

Figure 3 SAR process interface
Source: own work [Matlab]

The figure 3 depicts the SARs interface design image, in top left the user can select multiple operations, the first is to load a new image that will be process with multiple algorithms for segmentation, first space corresponds to the flooding image, after select the image, the software compute different algorithms: (RGB to grey conversion, the use of morphological operators, for this case dilation and convex components with the idea of increase and connect the neighbouring pixels, the next step is the edge detection with the algorithm of sobel and the use of Lee filter to reduce the speckle noise in the image), the second space corresponds to the original SAR image without flooding, after all the process the software shown in the right side three images: final image segmentation, highlight image and the final result.

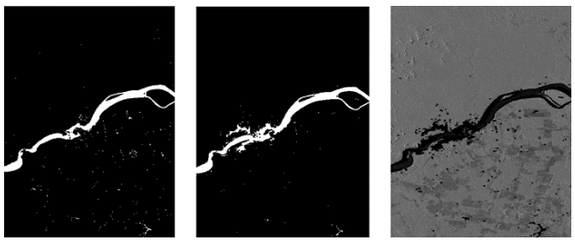

Figure 4 Final SAR segmentation
Source: *Own work [Matlab*]

Also, in figure 4 shown an example with SAR flooding image and original image (without flooding) with the different results, in this part the user can observe that in right side the final result contain the projection of the segmented image and the original image with some areas with flooding, at the same time, the user can apply zoom (image amplification) in each process and observe some extra details, also the user can save in a computer the image in format TIFF.

Figure 5 Example of the toolbar
Source: own work [Matlab]

In figure 3, the final segmentation is with edge information of the river, so it was decided to modify the algorithm to be able to detect the entire river, obtaining the satisfactory result that shown in the figure 4, a) segmentation of the original SAR image, b) temporal image segmentation and c) final result with estimation or vulnerable zones to flooding.

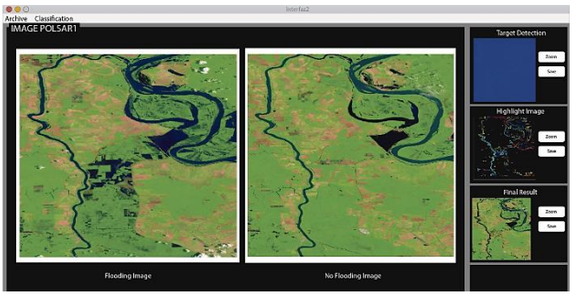

Figure 6 Example of LANDSAT 5 image
Source: own work [Matlab]

In figure 5 depicts the menu of the interface with the main activities described below:

– New: open window to select/load the image to process.

– Return: return to the principal interface.

– Exit: software's exit.

The figure 6 is when the user select the LANDSAT option, in this interface we aggregate an extra example with multispectral image for most specific information the false colour RGB image, the difference between this image with SAR is the bands combination to create and image with false colour, in the final image, we projected the flooding zones segmentation with an original image for represent areas with water with multiple colour (red and blue colour).

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Figure 7 Final Result (Landsat 5)
Source: *own work [Matlab*]

The figure 7 present the amplification of the result in multispectral process, for this case the user can observed areas with flooding highlighted in red colour, this figure is a projection of the segmented flooding image in the original image without flooding.

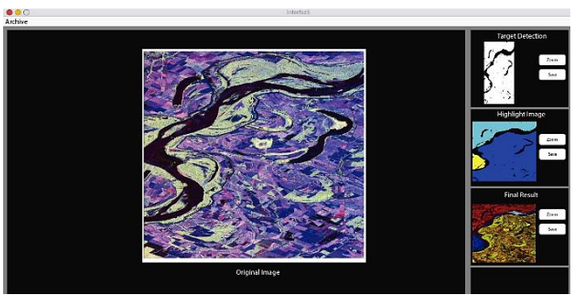

Figure 8 Example of segmentation with POLSAR image
Source: own work [Matlab]

In figure 8, we have the last process when the user select the POLSAR process, in this case the interface is different because is necessary to segment with colours the important areas, the first step is to load the original image, the second step is to segment the image, the third step is to highlight the information (targets) and finally shown the result with classification in colours, this process is for algorithm validation because in this part is not necessary the original image.

The result for the previous process is displayed in figure 9, where the water is segmented in purple colour and the other elements is separated in different colours.

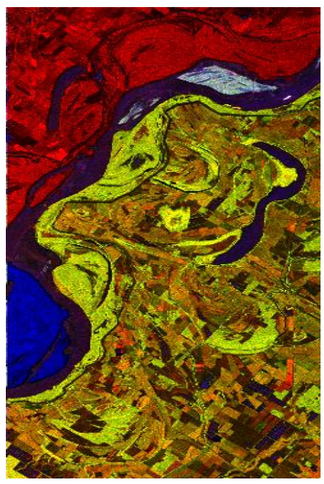

Figure 9 Final Result
Source: *Own work [Matlab*]

Conclusions

In this research project shows a tool that process, segmented and detect flooding in SAR, Multispectral and POLSAR images, as well as the incorporation of an GUI interface in Matlab that will facilitate user-computer communication, this through a set of instructions (algorithms) of images, buttons, bar of tools and texts. The relevant about the GUI-interfaces is that it allows the user to have control of the activities or processes to enhancement, features extraction and segmentation images. It is important to mention that the interfaces are designed to be intuitive so that the user can acquire experience and knowledge in the manipulation of Remote Sensing but specially the analyse the flooding with different sensors.

The differences to this project with a state of the art mentioned previously are the manipulations of multiple images (SAR, Multispectral and POLSAR), the comparative between the normal image and the flooding image for find the zones with more probability of flooding, for this case is necessary to acquire more images from the same scene in different times. This software is the first part of an extended project, for future work, the second part is the use of artificial intelligence for detecting flooding, also the segmentation of water, cities, vegetation and other elements, the third part of the project is to develop a software with all the previous steps in open source and the use of QT for interface design.

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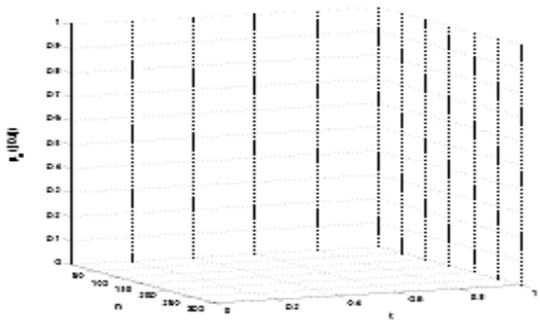

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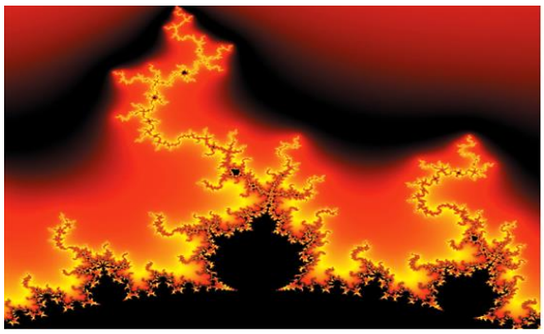

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