JCC-BD & ET 2024

Short Papers

of the

12th Conference on Cloud Computing, Big Data & Emerging Topics

HTTPS://JCC.INFO.UNLP.EDU.AR

@CONF_CC_BD_ET

JCC@LIDI.INFO.UNLP.EDU.AR

POSTGRADO
FACULTAD DE INFORMÁTICA

III-LIDI
INSTITUTO DE INVESTIGACIÓN EN INFORMÁTICA - LIDI

Short Papers of the 12th Conference on Cloud Computing Conference, Big Data & Emerging Topics (JCC-BD&ET 2024)

La Plata, Buenos Aires, Argentina.

June 25−27, 2024

Instituto de Investigación en Informática LIDI

Short papers of the 12th Conference on Cloud Computing Conference, Big Data & Emerging Topics / Editado por Armando De Giusti ... [et al.]. - 1a ed - La Plata: Universidad Nacional de La Plata. Facultad de Informática, 2024.

Libro digital, PDF

Archivo Digital: descarga y online ISBN 978-950-34-2413-1

1. Actas de Congresos. 2. Computación. 3. Conferencias. I. De Giusti, Armando, ed. II. Título.

CDD 004.0711

ISBN 978-950-34-2413-1

Emerging Topics: JCC-BD&ET 2024 / editado por Armando De Giusti,

La Plata: Universidad Nacional de La Plata. Facultad de Informática, 2024.

Preface

Welcome to the short paper proceedings of the 12th Conference on Cloud Computing, Big Data & Emerging Topics (JCC-BD&ET 2024), held in a hybrid modality (both on-site and live online settings were allowed). JCC-BD&ET 2024 was organized by the III-LIDI and the Postgraduate Office, both from School of Computer Science of the National University of La Plata.

Since 2013, this event has been an annual meeting where ideas, projects, scientific results and applications in the cloud computing, big data and other related areas are exchanged and disseminated. The conference focuses on the topics that allow interaction between academia, industry, and other interested parties.

JCC-BD&ET 2024 covered the following topics: high-performance, edge and fog computing; internet of things; modelling and simulation; big and open data; machine and deep learning; smart cities; e-government; human-computer interaction; visualization; and special topics related to emerging technologies. In addition, special activities were also carried out, including 2 plenary lecture and 3 discussion panel.

In this edition, 8 short papers were accepted after the peer-review process. These short papers correspond to initial research with preliminary results, ongoing R+D projects, or postgraduate thesis proposals. The authors of these submissions came from the following 4 countries: Argentina, Ecuador, Cuba and Spain. We hope readers will find these contributions useful and inspiring for their future research.

Special thanks to all the people who contributed to the conference's success: program and organizing committees, authors, reviewers, speakers, and all conference attendees.

June 2024

Armando De Giusti
Marcelo Naiouf
Franco Chichizola
Laura De Giusti
Leandro Libutti

Organization

General Chair

Marcelo Naiouf	Universidad Nacional de La Plata, Argentina.

Associate Chairs

Armando De Giusti	Universidad Nacional de La Plata and CONICET, Argentina.
Franco Chichizola	Universidad Nacional de La Plata, Argentina.
Laura De Giusti	Universidad Nacional de La Plata and CIC, Argentina.
Leandro Libutti	Universidad Nacional de La Plata, Argentina.

Program Committee

María José Abásolo	Universidad Nacional de La Plata and CIC, Argentina
José Aguilar	Universidad de Los Andes, Venezuela
Jorge Ardenghi	Universidad Nacional del Sur, Argentina
Javier Balladini	Universidad Nacional del Comahue, Argentina
Oscar Bria	Universidad Nacional de La Plata and INVAP, Argentina
Silvia Castro	Universidad Nacional del Sur, Argentina
Mónica Denham	Universidad Nacional de Río Negro and CONICET, Argentina
Javier Diaz	Universidad Nacional de La Plata, Argentina
Ramón Doallo	Universidade da Coruña, Spain
Marcelo Errecalde	Universidad Nacional de San Luis, Argentina
Elsa Estevez	Universidad Nacional del Sur and CONICET, Argentina
Pablo Ezzatti	Universidad de la República, Uruguay
Aurelio Fernandez Bariviera	Universitat Rovira i Virgili, Spain
Fernando Emmanuel Frati	Universidad Nacional de Chilecito, Argentina
Carlos Garcia Garino	Universidad Nacional de Cuyo, Argentina
Carlos García Sánchez	Universidad Complutense de Madrid, Spain
Adriana Angélica Gaudiani	Universidad Nacional de General Sarmiento, Argentina

Graciela Verónica Gil Costa	Universidad Nacional de San Luis and CONICET, Argentina
Roberto Guerrero	Universidad Nacional de San Luis, Argentina
Waldo Hasperué	Universidad Nacional de La Plata and CIC, Argentina
Francisco Daniel Igual Peña	Universidad Complutense de Madrid, Spain
Tomasz Janowski	Gdansk University of Technolgy, Poland
Laura Lanzarini	Universidad Nacional de La Plata, Argentina
Guillermo Leguizamón	Universidad Nacional de San Luis, Argentina
Edimara Luciano	Pontificia Universidade Católica do Rio Grande do Sul, Brazil
Emilio Luque Fadón	Universidad Autónoma de Barcelona, Spain
Mauricio Marín	Universidad de Santiago de Chile, Chile
Luis Marrone	Universidad Nacional de La Plata, Argentina
Katzalin Olcoz Herrero	Universidad Complutense de Madrid, Spain
José Angel Olivas Varela	Universidad de Castilla-La Mancha, Spain
Xoan Pardo	Universidade da Coruña, Spain
Patricia Pesado	Universidad Nacional de La Plata, Argentina
Mario Piattini	Universidad de Castilla-La Mancha, Spain
María Fabiana Piccoli	Universidad Nacional de San Luis, Argentina
Luis Piñuel	Universidad Complutense de Madrid, Spain
Adrian Pousa	Universidad Nacional de La Plata, Argentina
Marcela Printista	Universidad Nacional de San Luis, Argentina
Dolores Isabel Rexachs del Rosario	Universidad Autónoma de Barcelona, Spain
Nelson Rodríguez	Universidad Nacional de San Juan, Argentina
Enzo Rucci	Universidad Nacional de La Plata and CIC, Argentina
Juan Carlos Saez Alcaide	Universidad Complutense de Madrid, Spain
Aurora Sánchez	Universidad Católica del Norte, Chile
Victoria Sanz	Universidad Nacional de La Plata, Argentina
Remo Suppi	Universidad Autónoma de Barcelona, Spain
Francisco Tirado Fernández	Universidad Complutense de Madrid, Spain
Juan Touriño Dominguez	Universidade da Coruña, Spain
Gabriela Viale Pereira	Danube University Krems, Austria
Alvaro Wong	Universidad Autónoma de Barcelona, Spain
Gonzalo Zarza	Globant, Argentina

Sponsors

Table of Contents

Modernizing MDD Diagnosis using Deep Learning from EEG Data*

Milena Lebedinsky$^{1[0009-0002-0037-6852]}$, Rocío Leguizamón$^{1[0009-0002-7639-4693]}$, Pytel, P$^{1[0000-0002-3920-1710]}$, Chatterjee, P$^{1[0000-0001-6760-4704]}$, and Pollo-Cattaneo, Maria$^{1[0000-0003-41973880]}$

GEMIS - GEMISba - Universidad Tecnológica Nacional. Buenos Aires. Argentina.

Abstract. Major depressive disorder (MDD) is a widespread illness significantly impacting individuals' quality of life. Its diagnosis through Electroencephalogram (EEG) has long been studied in mental health research. Recent advancements in deep learning present a promising pathway for enhancing MDD diagnosis through EEGs. This study integrates state-of-the-art deep learning techniques, including ConvNext and Transformers architectures, into MDD prediction models. Results demonstrate ConvNext models' robustness and efficiency, in terms of precision and specificity, while Transformer models exhibit high recall and sensitivity for diagnosing MDD from incomplete studies.

Keywords: Major Depression Disorder · Electroencephalogram · Deep Learning.

1 Introduction

Depression is a common yet serious illness that interferes with daily life, affecting the ability to work, sleep, study, eat, and enjoy life in general. [1]. The potential of Electroencephalogram (EEG) studies in diagnosing Major Depressive Disorder (MDD) has been a subject of considerable interest in the psychiatric and neuroscientific community [2]. These studies offer a non-invasive window into the neural patterns that may be indicative of MDD. Recent advancements in deep learning have opened new avenues for extracting meaningful patterns from EEG data [3] [4]. The rapid progression of deep learning technologies for sequence analysis presents a significant opportunity to enhance the accuracy and reliability of EEG-based diagnostic models. Transformer models have recently emerged as powerful tools for sequence and image analysis. Their ability to capture long-range dependencies and intricate patterns in data sets them apart from conventional convolutional neural networks (CNNs, or ConvNets). ConvNext models were proposed, demonstrating a predictive capability comparable to that of transformer models, with the advantage of having a smaller number of parameters, demonstrating the capability of modernizing the existing ConvNet models [6]. This study aims to integrate these recent advancements, into existing

* Supported by GEMIS, Universidad Tecnológica Nacional, Buenos Aires, Argentina

models, particularly for the classification of EEG studies used as a biomarker for diagnosing MDD.

2 Methods and proposed architectures

In this study, three principal architectures were explored: Convolutional Neural Networks (CNNs), architectures based on ConvNext layers, and Transformers, each subjected to multiple topology variations. Initially, the methodology involved incrementally modifying individual layers within a base model to ascertain the configuration that exhibited the most promising metrics. Then, for the best performant models found, 7-fold cross-validation was used to collect training statistics. This performance evaluation was made using a publicly available dataset [7], containing 181 EEG studies, split into 86 studies for the control group and 95 MDD-diagnosed studies, which correspond to 64 different patients. The dataset includes eyes-closed (EC), eyes-open (EO), and task-based (TASK) EEG recordings. The mean performance metrics were computed using 26 test studies, corresponding to 5 patients, that were isolated to validate each fold with unseen data. This methodology provided results that reflect the models' stability and generalizability across different data partitions.

The data was preprocessed by selecting the common channels across all studies and normalizing the study durations to the shortest study length. The short-time Fourier transform (STFT) was computed, to use the absolute value of the resulting matrices as the network input. Building on the foundation laid by previous research [8], indicating a higher accuracy can be achieved through artificially enlarging the dataset, an additional preprocessing stage was tested on the Transformer models. Ten different time windows were cut from each study as a data augmentation technique. Hence, the Transformer model differentiated itself from the other architectures in its ability to predict the diagnosis from shorter or potentially incomplete studies and was trained with ten times more data. The impact of specific layer configurations on the diagnosis prediction accuracy was evaluated. Variations included the selective application of L2 kernel regularizers, introducing spatial dropout layers to mitigate overfitting, and incorporating different pooling strategies, such as global average pooling and global max pooling, to refine feature extraction.

3 Results

The individual training of different architectures revealed that the architecture of a Convolutional model should include a normalization layer before and after the first convolutional, followed by a second convolutional layer. The convolutional block training was the most stable when followed by one MaxPooling2D layer, and finally, a Flatten, one Dense, and one Droput layer, before the single-neuron predictive Dense layer.

The ConvNext model architectures used four ConvNext blocks, as the ones described in the foundational paper [6]. Each ConvNext block was preceded by a SpartialDropout2D layer and for every two of these blocks, a MaxPooling2D layer was inserted.

The same ConvNext (untrained) layers were used as an encoder for the Transformer architecture, followed by the Transformer block, with no positional encoder. After the transformer block, a Dropout layer and a GlobalAveragePooling1D layer followed, before the final Dense layer used for prediction.

Table 1. Trainable parameters of each model.

Transformer	Convolutional	ConvNext
89,137,877	59,850,537	898,025

The three described architectures' number of trainable parameters are shown in the table 1.

Table 2. Average training validation metrics for each model for each fold (the best epochs metric, in terms of training validation loss and training validation accuracy, were stored).

Metrics	Convolutional	ConvNext	Transformer
Best validation loss	0.5810	0.2716	0.3730
Accuracy at best validation loss	0.9193	0.7256	0.7411
Best validation loss epoch	21.2857	12.4286	11.4286
Best validation accuracy	0.9477	0.9088	0.8358
Loss at Best Validation Accuracy	0.6655	0.5146	0.4844
Best validation accuracy epoch	13.0000	10.2857	11.0000

Table 3. Average test metrics for each model across the 7 folds

Metrics	Convolutional	ConvNext	Transformer
Testing loss	0.6115	0.1760	0.4225
Testing accuracy	0.9490	0.9541	0.7804
Presicion	0.9643	1.0000	0.7725
Recall	0.88571	0.8393	0.9409
F1 Score	0.9058	0.8956	0.8332
Sensitivity	0.8571	0.8393	0.9409
Specificity	0.9857	1.0000	0.6032
Gmean	0.9187	0.9070	0.6272

Training validation statistics were captured to exhibit each model's behavior, and are displayed in table 2. Then, metrics calculated with the test data were calculated, and are shown in table 3. The average confusion matrix for each model is displayed in Figure 1, also calculated from the testing set.

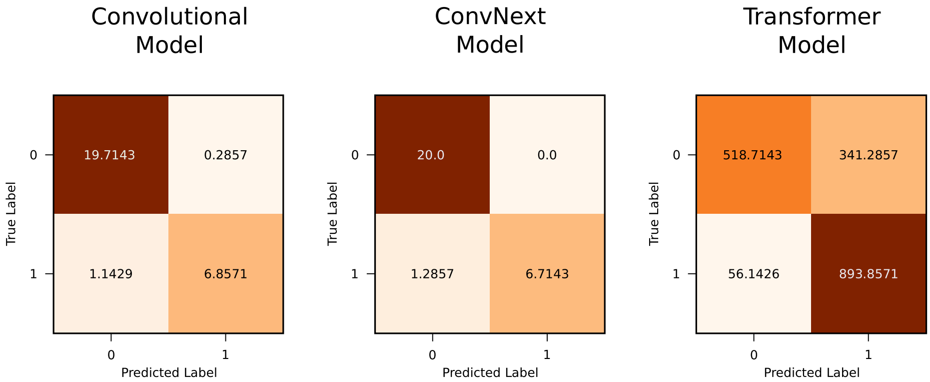

Fig. 1. Average confusion matrix for each model across the seven folds

4 Discussions

The convolutional model reached the highest average F1-score and Gmean, making it the most balanced model in terms of precision and recall, as well as specificity against recall. However, the final architecture resulted in a complex model with a high number of parameters. Presenting the highest loss could be particularly disadvantageous for the specific case of predicting a mood disorder, as it leads to less reliability.

The ConvNext architecture was the one that, while sacrificing some sensitivity and recall, achieved perfect specificity and precision, making no false negative predictions within the testing examples. The loss and accuracy converged at early epochs, showing a great learning capacity in this model which, moreover, is significantly lighter in parameters than the others.

Although the performance of the transformer model yielded lower scores in most of the metrics, it showed the highest recall and sensitivity, parameters that may be of interest when considering a tool for diagnosis assistance. On the other hand, it should be highlighted that the results are not as directly comparable with those of the other models, since both, training and prediction, were made from short snippets taken from the studies in this case. Being this a work in progress, it is worthwhile to continue studying this predictive capacity from incomplete studies.

The relevance of each metric will depend on the model's clinical use and applicability to specific diagnostic scenarios. However, these preliminary results can highlight the ability to obtain better outcomes by tuning the architecture of traditional ConvNets. The results obtained are, to some extent, proof of the success of the ConvNext architecture's underlying hypothesis [6]. In this case, the ConvNext model reached better results with the test data than the best epoch validation results when comparing the averages, meaning it's more robust given the amount of data used for training and testing.

Our future work proposals aim to achieve more robust results. Training the same models with more numerous EEG depression samples will ensure that the performance variations found between the different architectures are consistent. This will also answer to what degree these techniques are subject to overfitting. To make a more robust comparison between the presented architectures, the same preprocessing and data augmentation techniques should be used in the Convolutional and ConvNext models. Also, it's worthwhile to compare the Transformer prediction ability from complete studies. Finally, a hyperparameter exploration must be conducted for each network.

For the transformer models in particular, a pre-trained encoder-decoder that predicts how a study should follow could be used to replace the encoder part. Including the STFT transformation of the data as a layer, so that the parameters of this calculation can be explored as hyperparameters, and the addition of a positional encoder are included in our future work proposals.

References

1. Pan American Health Organization, https://www.paho.org/en/topics/depression. Last accessed 3 March 2024
2. de Aguiar Neto FS, Rosa JLG.: Depression biomarkers using non-invasive EEG: A review. Neurosci Biobehav Rev. 2019 Oct;105:83-93. https://doi.org/10.1016/j.neubiorev.2019.07.021 Epub 2019 Aug 7. PMID: 31400570.
3. Loh, Huiwen, Ooi, Chui, Aydemir, Emrah, Tuncer, Turker, Dogan, Sengul, Acharya, U Rajendra. (2021). Decision support system for major depression detection using spectrogram and convolution neural network with EEG signals. Expert Systems. 39. e12773. 10.1111/exsy.12773.
4. Zhang, J., Xu, B., Yin, H. Depression screening using hybrid neural network. Multimed Tools Appl 82, 26955–26970 (2023). https://doi.org/10.1007/s11042-023-14860-w
5. A. Rafiei, R. Zahedifar, C. Sitaula and F. Marzbanrad, "Automated Detection of Major Depressive Disorder With EEG Signals: A Time Series Classification Using Deep Learning," in IEEE Access, vol. 10, pp. 73804-73817, 2022, doi: 10.1109/ACCESS.2022.3190502,
6. Zhuang Liu and Hanzi Mao and Chao-Yuan Wu and Christoph Feichtenhofer and Trevor Darrell and Saining Xie: A ConvNet for the 2020s. 2022, eprint: 2201.03545, archivePrefix=arXiv, primaryClass=cs.CV
7. Mumtaz, Wajid (2016). MDD Patients and Healthy Controls EEG Data (New). figshare. Dataset. https://doi.org/10.6084/m9.figshare.4244171.v2
8. George O, Smith R, Madiraju P, Yahyasoltani N, Ahamed SI. Data augmentation strategies for EEG-based motor imagery decoding. Heliyon. 2022 Aug 17;8(8):e10240. doi: 10.1016/j.heliyon.2022.e10240. PMID: 36060998; PMCID: PMC9433610.

Fuzzy logic intelligent decision support system for safety of maritime navigation based on COLREG.

José Ignacio Valles[1], José A. Olivas[2] [000-0003-4172-4729] and José A. González Prieto[3]

[1] University of Castilla-La Mancha, 13071 Ciudad Real, Spain
[2] Department of Information Technologies and Systems, University of Castilla-La Mancha, 13071 Ciudad Real, Spain
[2] Defense University Center - Spanish Naval Academy, 36920 Marin, Pontevedra, Spain

Abstract. The main objective of this work is the development of an intelligent decision support system based on soft computing and fuzzy logic that incorporates considerations from the Regulations for Preventing Collisions at Sea (COLREG) and navigation experts knowledge, able to face demanding and complex situations in an evolutive maritime environment, building a comprehensive understanding of the situation and providing explainable and interpretable recommendations to ships' watchkeeping officers or performing actions if integrated in autonomous ships navigation systems.

Keywords: Soft Computing, Fuzzy Logic, Computing with words, COLREG, Safety of Navigation.

1 Introduction

According to the Annual Overview of Marine Casualties and Incidents for the year 2023 prepared by the European Maritime Safety Agency [1], there have been an average of 2,646 casualties and incidents per year, mainly in areas close to the coast and having as one of the main causes the 'Collision' between ships, together with the 'Loss of control - Loss of propulsion power', highlighting the human factor as one of the main factors contributing to marine casualties and incidents.

The Convention of the International Regulations for Preventing Collisions at Sea held in London in 1972 (COLREGs) [2] and its subsequent amendments, set the rules to be applied by ships in order to prevent the risk of collisions at sea.

In this regard, an intelligent decision support system for ships' bridge officers in navigation could be a good tool to contribute to mitigate the human factor present in most maritime casualties and incidents or to be implemented in autonomous ship navigation systems.

Among the different approaches to the problem from the Artificial Intelligence (AI) point of view, we can highlight the use of Deep Learning techniques being applied on neural networks architectures and with the application of different types of algorithms and solutions [3][4], such us Reinforcement Learning [5] or intelligent systems based on rules generated from existing knowledge [6], such as Fuzzy Inference Systems [7][8][9].

2 The problem to navigate through.

Generally, a ship in navigation follows a planned trajectory that optimizes the ship's transit and ensures its safety in navigation with respect to static hazards present in the environment such as shallow areas, offshore structures, islands, the coastline, etc.

During its transit the vessel is subject to interaction with the other vessels navigating in the environment, with the physical characteristics of the environment and with the weather and environmental conditions.

Regarding interactions with other ships, it is vital to determine the risk of collision early enough to be able to take the required actions. Therefore, one of the first steps is the detection of the risk of collision with other ships based on input data gathered from the environment. This data can come from sensors and traditional navigation aid systems such as RADAR, Automatic Identification System (AIS), electronic chart systems, global positioning systems, depth and speed measurement devices, anemometers, etc., or from AI-enabled systems such as systems with artificial vision that can identify beacons, vessel types and their appearance, obstacles, etc.

Once the risk of collision has been determined, it is necessary to identify the situation in which the ships interact among those typified in the COLREG, both in conditions of good visibility and reduced visibility, in order to define the most appropriate actions that must be accomplished to avoid a dangerous situation.

Other key aspects to identify to be able to assess the situation, since they will determine which ship should be kept clear of another, are:

- The kind of vessel approaching the ship, such as mechanically propelled, sailboats, fishing vessels, vessels with restricted maneuverability, without steering capacity, anchored, aground, etc.
- The characteristics of the environment, i.e. whether the vessel navigates in open water, restricted water, narrow channels, traffic separation schemes, etc.
- Proximity to navigational hazards such as low sounding areas or obstacles.
- The evolutionary and acceleration/deceleration characteristics of the vessel, considering relative speeds and trajectories with the surrounding elements.
- The safe distance of passage to be kept with respect to other vessels depending on their characteristics and circumstances, such as size, appearance, etc.

To identify the risk of collision with other ships, the calculated distance of the Closest Point of approach (CPA) with each of them and the time in which it will occur (TCPA) will be considered.

In view of the situation identified, it will be necessary to define the actions to be taken by the vessel, such as varying speed, changing course, etc., while trying not to stray too far from the planned optimized and safe trajectory.

Due to the nature of the problem, in which an adequate expert knowledge base is available and considering the complexity and variability of the maritime environment, an intelligent decision support system based on fuzzy logic will be used to represent the complexity of the problem, to model the available knowledge and to deal with all different kinds of situations at sea, providing also an adequate level of explainability and interpretability.

3 The course to steer.

The first step is to model and develop a realistic 2D simulation environment that emulates the peculiarities of the maritime environment and allows testing the rule base and the inference system in complex and changing environments of multiple ships interactions.

The second step is to translate that simulated environment in the form of the data delivered by existing ship navigation aid systems that will serve as input data to the intelligent decision support system.

The third step is to define the linguistic term sets that will model the input data to the system, as well as the linguistic rule sets and the inference system for the determination of collision risk, excessive proximity to navigational hazards and general prioritization of threats to ship safety.

The fourth step is to model the knowledge contained in COLREG for the creation of the set of linguistic rules necessary for the inference of the recommendation, adding as many input linguistic sets as necessary to cover all the possibilities contemplated in COLREG and those existing in a real maritime environment. In addition, and because COLREG does not detail all possible situations, such as situations of interaction with multiple vessels simultaneously, it will be necessary to model the necessary rules to cover complex situations (see Fig. 1), taking as a starting point the general information contained in COLREG and prioritizing actions according to the risk of collision with other vessels and the elements of the environment. During this process it is necessary to add considerations such as the size and physical and evolutionary characteristics of the ships, incorporate them into the fuzzy inference system and take them into account when recommending actions (see example in Fig. 2).

In addition, it is necessary to define and model a set of actions and their characteristics that will represent the output of the intelligent decision support system. These proposed actions must be presented in a natural and interpretable form by the ships' watchkeeping officers and accompanied by an explanation and motivation. On the other hand, in case of being integrated in autonomous ships navigation systems, the autonomous actions taken based on the intelligent system outputs, could be logged along with their explanation and motivation.

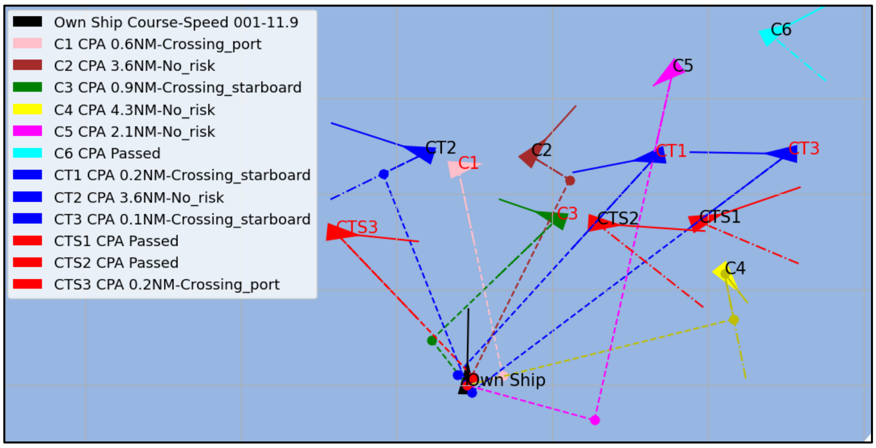

Fig. 1. Complex maritime environment with ship´s relative trajectories (12 Ships).

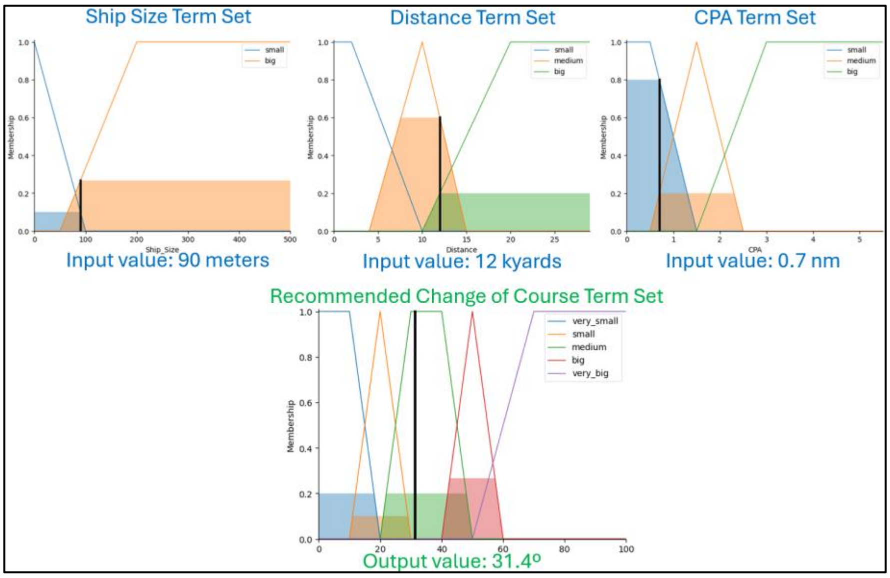

Fig. 2. Example of term sets and inference process used to determine the required change of course in an overtaking situation.

4 Conclusions.

The outcome of this thesis is the development of an intelligent decision support system based on fuzzy logic and approximate reasoning capable of receiving the processed input data coming from the ship's sensors and navigation aid systems, obtaining a comprehensive knowledge of the environment, assessing the situation, determining the risk of collision and excessive approach to navigational hazards and recommending a suitably motivated action to maintain the safety of the ship while navigating along a predefined trajectory.

The main effort will consist of the proper modeling of the simulation environment, as well as the fuzzy sets and linguistic rules needed to capture the complexity of the environment and the available expert knowledge and the design of an inference system that will yield appropriate and interpretable recommendations by the officers on watch on the ship's bridges or autonomously perform actions if integrated in autonomous ships navigation systems.

Acknowledgements.

This work has been partially supported by FEDER and the State Research Agency (AEI) of the Spanish Ministry of Economy and Competition under grant SAFER: PID2019-104735RB-C42 (AEI/FEDER, UE).

References

1. European Maritime Safety Agency: Annual Overview of Marine Casualties and Incidents (2023).
2. International Maritime Organization (IMO): Convention on the International Regulations for Preventing Collisions at Sea, (COLREGs) (1972).
3. Liang, H., Huosheng, H., Wasif, N., Zidong, W.: A review on COLREGs-compliant navigation of autonomous surface vehicles: From traditional to learning-based approaches. Journal of Automation and Intelligence 1(1), (2022).
4. Mohamed-Seghir, M., Kula, K., Kouzou, A.: Artificial Intelligence-Based Methods for Decision Support to Avoid Collisions at Sea. Electronics 10(19), 2360 (2021)
5. Heiberg, A., Larsen, T.N., Meyer, E., Adiel, R., San, O., Varagnolo, D.: Risk-based implementation of COLREGs for autonomous surface vehicles using deep reinforcement learning. Neural Networks 152, 17-33 (2022).
6. Constapel, M., Koch, P., Burmeister, H-C.: On the implementation of a rule-based system to perform assessment of COLREGs onboard maritime autonomous surface ships. Journal of Physics: Conference Series. 2311. (2022).
7. Sang-Min, L., Kyung-Yub, K., Joongseon, J.: A Fuzzy Logic for Autonomous Navigation of Marine Vehicles Satisfying COLREG Guidelines. International Journal of Control Automation and Systems 2(2). (2004).
8. Bakdi, A., Vanem, E.: Fullest COLREGs evaluation using fuzzy logic for collaborative decision-making analysis of autonomous ships in complex situations. IEEE Transactions on Intelligent Transportation Systems 23(10), 1-13(2022)
9. Perera, L-P., Carvalho, J.P., Guedes, Soares C.: Autonomous guidance and navigation based on the COLREGs rules and regulations of collision avoidance. Advanced Ship Design for Pollution Prevention. 205-216 (2009)

Habanadigital - A smart city project adapted to Cuban conditions

Habanadigital - Un proyecto de ciudad inteligente adaptado a las condiciones cubanas

Joaquín-Danilo Pina-Amargós[1] and Raisa Socorro-Llanes[1]

[1] *Universidad Tecnológica de La Habana, Cuba*
{jpina, raisa}@ceis.cujae.edu.cu

Abstract

One of the sustainable development goals established by the United Nations in the 2030 Agenda is to make cities and human settlements inclusive, safe, resilient and sustainable. The Smart City concept is aimed in this direction and one of the requirements considered by most current solutions is the intensive use of modern technologies to increase efficiency in order to better use available resources. However, in countries with technological limitations due to their underdevelopment or because they are under sanctions from foreign powers, this requirement cannot be achieved in the short term. This paper presents a novel solution through a local development project that involves civil organizations, the different economic actors, the government and the community so that in an orderly way it manages to solve the existing problems at the local level and the best solutions are generalized in the rest of the province. The proposal is made in the context of the province of Havana Cuba but can be adapted for extension to other provinces of the country and even in other geographical areas that have the stated limitations.

Keywords: digital transformation, smart city, sustainable development.

Resumen

Uno de los objetivos de desarrollo sostenible establecidos por la Organización de las Naciones Unidas en la Agenda 2030 es lograr que las ciudades y los asentamientos humanos sean inclusivos, seguros, resilientes y sostenibles. El concepto de Ciudad Inteligente va encaminado en este sentido y uno de los requisitos considerados por la mayoría de las soluciones actuales es el uso intensivo de tecnologías modernas para aumentar la eficiencia con el fin de utilizar mejor los recursos disponibles. Sin embargo, en países con limitaciones tecnológicas debido a su subdesarrollo o por encontrarse bajo sanciones de potencias extranjeras, este requisito no es posible lograrlo a corto plazo. En este trabajo se presenta una solución novedosa a través de un proyecto de desarrollo local que involucra a las organizaciones civiles, los diferentes actores económicos, al gobierno y a la comunidad para que de manera ordenada logre resolver los problemas existentes a nivel local y se logren generalizar las mejores soluciones en el resto de la provincia. La propuesta se realiza en el contexto de la provincia La Habana de Cuba pero podrá ser adaptado para su extensión a otras provincias del país e incluso en otras zonas geográficas que tengas las limitaciones planteadas.

Palabras claves: transformación digital, ciudad inteligente, desarrollo sostenible.

1 Introduction

The rapid development of science and technology during recent decades has had a significant impact on all areas of human and community development, with a consequent change in the paradigm of knowledge and a cultural transformation of society. From the simple use of a mobile phone to the most advanced artificial intelligence applications, technologies mark the daily lives of citizens around the world and constitute, in many cases, the most efficient instrument to respond to certain daily problems. The digital transformation and the democratization of the use of technologies and social networks have represented a challenge and, at the same time, an opportunity for the dynamization of societies, the management of public spaces (whether physical or virtual), the growth economic, productive innovation, and the incorporation of citizens into local, regional and national processes [1]. These processes are reflected in the so-called *Smart City*, the concept of which refers to a local environment in which information and communication technologies (ICT) are used to improve its inhabitants' quality of life and optimise the management of its resources [2].

In Cuba, at the national level there is a commitment to computerize the different structures of Cuban society in a safe and sustainable way, as reflected in the Decree-Law "On the Informatization of Society in Cuba" [3] and the Guidelines of Economic and Social Policy [4]. Specifically, Guideline No. 108 establishes as a priority for the country "to gradually advance, as economic possibilities allow, in the process of computerization of society, the development of telecommunications infrastructure and the computer applications and services industry".

However, this process is slowed down by the sanctions imposed by foreign powers as described in [5] and despite being presented and approved every year since 1992 by the vast majority of countries at the United Nations General Assembly [6]. All spheres of daily life are affected because it is not possible to accelerate the improvement of the telecommunications infrastructure necessary to achieve such a transformation.

Despite this, the main opportunities presented in the current context include the development of a technological infrastructure that has been strengthened in recent years, and a variety of institutions linked to the Information and Communication Technologies sector with the capacity to promote these processes. Precisely one of these civil organizations is the Union of Cuban Computer Scientists of the Havana province that through the proposal indicated in this work aims to materialize the premises and objectives proposed in the strategic document.

2 Previous works

Despite the limitations set out above, as part of the process of computerization of society promoted by the Cuban government, in the case of the capital of the country, the Strategy for the Digital Transformation of Havana (2022-2026) was designed. This document, approved unanimously in the Ordinary Provincial Council and reflected in this way in the Agreement No. 17/2022, Act No. 2 of February 22, 2022, has as areas of action:

1. Governance and coordination, focused on the creation of capacities and infrastructure for governance; citizen participation in interaction with the government; the scalability and sustainability of the developments achieved.

2. Development of institutional and service innovations, which are linked to the strategic dimensions of Governance as a platform, and Data-driven governance.

3. Citizen competences, which respond to the dimensions: Management of digital competences in citizens; Creation of governance capacities on digital competencies; Innovation of services that promote the training of digital competences; and Implementation of a program for the development, attraction and retention of digital talent.

In addition to the boost provided by the existence of this Provincial Strategy, the Cuban capital has excellent starting conditions to promote and implement comprehensive digital transformation projects, which guarantee greater well-being of its citizens and more efficient management of the city. The following list relates the infrastructure developed in Havana until July 2022:

- Asymmetric digital subscriber line (ADSL) named "Nauta Hogar": 51 353 users, present in all municipalities and 98 % (103) people's councils.

- Mobile telephony users: 1,76 million with a penetration of 82,77 %.

- Fixed telephony users: 456 980 with a penetration of 21,43 %.

The Union of Computer Science Professionals of Cuba (UIC) is, according to its Statutes [7], a "voluntary, inclusive and selective, self-financed and non-profit social organization of natural and legal persons, professionals in Information and Communication Technologies, Electronics, Automation and other related specialties, with a scientific-technical profile."

Since its foundation, the UIC has supported, as an agglutinating reference, the digital transformation processes promoted in the country, whether in physical and virtual spaces. To this end, it has promoted the analysis and debate of the areas of its competences; as well as the exchange and connection between the members, the government, the company, the academy, the scientific community, the non-state sector, the different associative forms recognized by the law and the citizenship. Other of its main functions and objectives are:

- To foster and promote a creative climate related to Information and Communication Technologies (ICT), Electronics, Automation and other related specialties, which pays tribute to national programs and entities, to local development and to raising the well-being of citizens.

- Contribute to the management of advisory and consulting projects approved by the governing bodies.

- Coordinate and participate in science, technology and innovation projects, enabling projects, export of computer services and local development, as well as international cooperation, as part of the contribution to the digital transformation of society.

- Establish alliances with the government, economic actors, academia, the scientific community, and the different associative forms recognized by law for the insertion of members in development projects related to the technological sector, both in the country and abroad, in accordance with current legislation.

3 Proposed solution

In a coherent way with these purposes and taking into account the experience of the entity, the UIC Provincial Council in Havana proposes the creation of the Local Development Project (LDP) called Habanadigital, a specialized professional structure with the capacity to advise the Government and materialize the Strategy for Digital Transformation. In this way, the opportunities for institutionalization that have been generated as part of the process of updating the economic-social model of our country and the consequent recognition and diversification of forms of ownership and management are also taken advantage of, contributing to the economic sustainability of the UIC itself.

As part of its functions, the LDP Habanadigital will offer services focused on the areas of action established in the Provincial Strategy for Digital Transformation and will support the functions of the IT belonging to the provincial Government.

To promote digital governance and the development of innovative proposals, the project will work on the creation and management of a *Repository of Problems and Solutions*. This platform will allow the identification and implementation of actions to specific challenges of the territory, based on the priorities of the government, and in accordance with the policies, conceptual bases, methodologies and regulatory framework that govern the economic and social development of the city.

This *Repository of Problems and Solutions* represents a strategic tool to connect and involve the dissimilar actors of the territorial ecosystem, characterized by the model of the four helices: the government, the economic actors, the Academy and the citizenship (resident and visitor). In this case, it is based on an open, participatory and inclusive approach, which puts all possible actors in contact, either to present problems of everyday life, or to offer solutions and services that respond to social needs.

Once these solutions have been defined and the actors that must intervene to carry them out, the LDP will also support, from interoperability and scalability approaches, the implementation of the initiatives and the identification of possibilities to replicate them in other localities or sectors. Among the solutions that could be carried out are the creation of a digital platform for the commercialization of local products and services, the development of mobile applications to facilitate access to information and public services, and the implementation of information and communication technologies in sectors such as food, transport, education, health, tourism and cultural heritage.

On the other hand, the project will accompany the process of transformation and cultural change of our society towards a paradigm that places research, innovation and co-creation as centers of development [8]. It is necessary to strengthen the institutional capacities of the different actors of the province, in order to have public officials properly prepared to face this challenge linked to the use of technologies (see Figure 1).

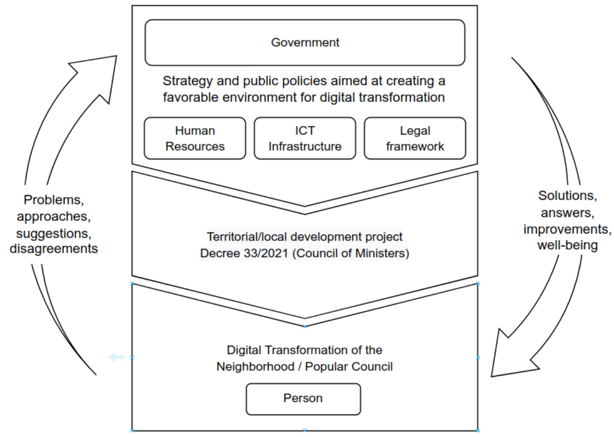

Figure 1: Infographic that shows the relations between the government and the people to know and solve the existing problems in the community.

In addition, actions are coordinated and developed for the empowerment of the local population (including children, adolescents, older adults and people with disabilities) in the areas of access to technologies, in order to reduce the digital divide and promote an inclusive and sustainable transformation.

These trainings allow to develop logical-mathematical thinking and promote knowledge of technical areas. Likewise, training on the responsible use of technologies will be included, which is essential because all citizens are prone to accessing inappropriate content, which involves violence, sociopathic patterns of behavior, pornography, risk of isolation, contact with strangers, harassment or loss of privacy, identity theft, among others. In this way behavioral alterations, confusion between the intimate, private and public, loss in the notion of time, tendency to consumerism, decrease in school and professional performance, aggressiveness in the family environment, suffering harassment and addiction to social networks and cyber games are avoided.

The awareness-raising and training actions will be developed based on advice and consultancies contracted to the LDP by the entities and people interested in its services. In addition, the initiative will henceforth support the annual coordination of national and international events, such as: Girls in ICTs, Seniors in ICTs, ICTs Boulevard, Hackathons, Internet Governance Forum and Safe Internet.

All the described actions will be carried out in correspondence and to respond to the Sustainable Development Goals and the 2030 Agenda established by the United Nations Organization [9]. Specifically, in the "Goal 11 Sustainable Cities and communities" where the need "to make cities and human settlements inclusive, safe, resilient and sustainable" is established.

Through the LDP, sources of financing will be managed for the realization of these events and the coordination of logistics, visibility, communications, rental of rooms or equipment, or other necessary expenses. At the LDP headquarters, and other locations agreed with the Government, co-creation spaces will be created in which all UIC members can come together to debate and exchange ideas, establish alliances and undertake innovative projects for the good of the population. Some results achieved by Habanadigital in the first years of its operation are shown bellow.

4 Results analysis

An example that allows to illustrate this work is the *Tetoca* initiative, designed by the UIC to implement in the province of Havana, with possibilities of replicability throughout the country. This system has the antecedent in Cola.cu that was developed and implemented in all the municipalities of Havana during the COVID-19 pandemic [10]. The action consisted in the creation and management of an automatic warning computer system to organize the equitable distribution of goods in the territory's stores. From the sending of alarms by SMS messages or social networks to each family nucleus, information will be provided about the time, place and goods that may be acquired, in order to minimize waiting time and uncertainty. The intensification of the United States blockade against Cuba added to the global crisis due to the COVID-19 pandemic have caused the shortage of basic necessities for the Cuban people. This situation is taken advantage of by some unscrupulous people who dial in various queues, sell the shifts, sneak to other people and manage to hoard the products and then resell them at speculative prices to the needy population. (see Figure 2).

Figure 2: Photograph that illustrates the existing situation before the implementation of the solution.

The foreign and Cuban softwares that allow queue management, none allow the management of multiple queues with the possibilities of specifying the products that are offered and alerting the queue organizer if a customer has recently registered in some other queue according to the number of days declared by the local government. These two functionalities are the main novelties of the new software proposed and developed by the Union of Cuban Computer Scientists together with private and state economic actors and government and community factors to achieve distributed queue management in a certain region. This system has been widespread in Havana since September 1, 2020 and worked uninterrupted daily with more than 1,6 million different people registered and more than 500 thousand people who have been able to buy thanks to the detection of recent buyers. This system has enabled the shared management of the queues in Havana to avoid unscrupulous people, and it has been especially useful in these times of shortage of products because it allows the distribution of the same to the population in a more equitable way (see Figure 3).

Figure 3: Photograph that illustrates the existing situation after the implementation of the solution.

Another example of actions in the community environment are registered in actions aimed at improving the digital skills of the population. These actions are coordinated with the authorities of the people's councils and the population. Some results of these actions in primary schools for the Girls in ICT Day are illustrated below (see Figure 4).

Figure 4: Photograph that illustrates the exhibition of a girl who programmed the mood of a robot doll.

Other community actions have been aimed at more vulnerable groups such as the elderly and their necessary inclusion with the incorporation of digital competences to make the reservation and payment for various services (see Figure 5).

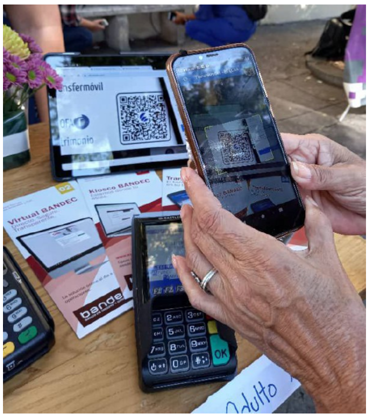

Figure 5: Photograph that illustrates the use of technology by older adults based on promotion at a popular fair.

5 Conclusions

The study of the background showed that there is a declared interest on the part of the country's authorities and Havana in particular to promote the digital transformation of the different spheres of daily life. On the other hand, there is a potential that, since it is not organized, does not accelerate the generalization of the results. The Local Development Project named Habanadigital serves to group and coordinate the community according to the priorities defined by the Government of Havana. The initial results show the feasibility of the Project adapted to the specific conditions of a country blocked by a foreign and developing power.

Competing interests

The authors have declared that no competing interests exist.

Authors' contribution

JDPA conceived the idea, conducted the experiments and wrote the manuscript; RSLL analyzed the results and wrote the manuscript; All authors read, revised and approved the final manuscript.

Acknowledgements

This research has been supported by the Pérez-Guerrero Trust Fund for South-South Cooperation (PGTF) of the United Nations Development Program (UNDP) project INT/24/K12.

References

[1] A. Ruiz Jhones, T. Delgado Fernández, A. Febles Estrada, and S. Estévez Velarde, "Habilitando la Transformación Digital. Tomo I," 2022.

[2] C. of Practice of UCLG Digital Cities, *International study on cities as innovation ecosystems that contribute to the achievement of the SDGs*. Bilbao City Council, 5 ed., 2023.

[3] Consejo de Estado de la República de Cuba, "Decreto-Ley No. 370/2018 "Sobre la informatización de la sociedad en Cuba"," July 2019.

[4] Partido Comunista de Cuba, *Lineamientos de la política económica y social del Partido y la Revolución*. Partido Comunista de Cuba, 2011.

[5] W. Whitney *et al.*, "For the 28th consecutive year, cuba prepares to indict us blockade at united nations," *Guardian (Sydney)*, no. 1888, p. 12, 2019.

[6] General Assembly of the United Nations, "Resolution a/78/l.5 necessity of ending the economic, commercial and financial embargo imposed by the united states of america against cuba," Nov. 2023.

[7] Unión de Informáticos de Cuba, "Estatutos y código de ética de la organización," 2019.

[8] M. Cai, E. Kassens-Noor, Z. Zhao, and D. Colbry, "Are smart cities more sustainable? an exploratory study of 103 u.s. cities," *Journal of Cleaner Production*, vol. 416, p. 137986, 2023.

[9] G. Assembly, "Sustainable development goals," *SDGs Transform Our World*, vol. 2030, pp. 6–28, 2015.

[10] J.-D. Pina-Amargós, J.-J. Granda-Colom, J.-A. Pina-Socorro, R. Socorro-Llanes, D. Martınez-Buznego, F. Rivas-Sotomayor, and S. Hernández-Viera, "New software for queue distributed management at the cuban scope," in *Simposio Internacional Informática desde la comunidad, 18th International Convention and Fair - Informática 2022*, 2022.

Hybrid Intelligent System for Leveraging Georeferenced Data and Knowledge*

D. Carrasco[1], Jose A. Olivas[1[0000-0003-4172-4729]] and Pablo L. Higueras[2[0000-0002-3662-7302]]

[1] Department of Information Technologies and Systems, University of Castilla-La Mancha, 13071 Ciudad Real, Spain
[2] Institute of Applied Geology (IGeA), University of Castilla-La Mancha, 13071 Ciudad Real, Spain

Abstract. This work presents a process for developing an intelligent hybrid system designed to effectively leverage georeferenced data and expert knowledge. The effectiveness of this approach is demonstrated in this work through a specific case study, using the proposed system to achieve a powerful tool for mineral prospectivity. The system consists of three main phases: knowledge and valuable data acquisition, modeling, and results representation using prospectivity heat maps. In the initial step, the recovery and representation of expert knowledge for the case of study was conducted. This system design was tested in the Almadén Mercury Mining District, it involved interviewing expert geologists with ages of experience in the area. Afterwards, the gathering of georeferenced data was carried out to enrich the dataset. Following this phase, the modelling was done, first, using unsupervised techniques to unveil the underlying structure and patterns of the information. Later, employing supervised learning and knowledge representation techniques to enhance the results. In the final step, prospectivity maps were created to represent the achieved results to help in decision making.

Keywords: Hybrid intelligent systems, Mineral Exploration, Artificial intelligence.

1 Introduction

In today's world, with the proliferation of smartphones, GPS-enabled devices and various sensors, georeferenced data is growing at an incredible pace. From optimizing traffic in cities to finding best areas for crops in agriculture, the potential behind this data is beyond imagination, industries like transportation, environmental monitoring, agriculture, or mining rely heavily on it to make well informed decisions.

There are a multitude of existing approaches to analyze this data, ranging from traditional commonly used methods to sophisticated advanced artificial intelligence (AI) techniques that employ complex models to extract well-hidden information within the data. Despite the undeniable importance of this data, its full potential remains underexploited, and more efforts are required to fully leverage its capabilities. In addition to advancing in analytical methods, efforts should also be focused on visualization methods, given that humans comprehend visual representation more effectively than numerical data alone. Heatmaps are powerful techniques to intuitively show the outcomes of georeferenced information studies.

2 Motivation

The development of a system that combines both knowledge and georeferenced data offers numerous benefits, including enhanced generalizability, handling of uncertainty and better interpretability of outcomes. While most works employ either data-driven or knowledge-driven approaches, there are some authors that use data and knowledge integrations at the same time obtaining promising results [5].
In this thesis, an intelligent hybrid system is proposed to leverage georeferenced data using state-of-the-art AI techniques. This method takes advantage of the best of each approach: the scalability of data driven techniques and the domain expertise in knowledge-driven based methods. This multidisciplinary procedure not only enhances the quality of results but also facilitates a deeper understanding of complex geospatial information.

3 Case study: Mineral prospectivity in the Almadén Mining District

The decrease in the number of discovered mineral deposits, caused by the nonstop exploitation of mineral resources for more than three centuries, is a reality. Some authors even argue that valuable minerals like antimony, molybdenum and zinc may be exhausted within a few decades if the extraction continues at the same speed [2].
The scarce resources, combined with the unprecedented increase in demand for minerals in recent years, is leading geologists to seek more efficient methods in the exploration of new mineral deposits. Fortunately, new techniques are emerging in the field of AI to minimize both economic and human efforts in mineral exploration, when finding deposits that would not be found with other methods.
Although mercury has been extracted in numerous locations throughout the Earth's crust, one deposit stands out; this is, without a doubt, the mining deposit of Almadén. It has been estimated that, in this small district southwest of Ciudad Real, 270.000 tons of this metal have been extracted, representing approximately one-third of the total mercury consumed by humanity throughout its history.
There is a lot of known deposit in this area, as well as experts in the area that can guide hybrid intelligent systems and analyze the results.
In literature, the most common approach in this case consists of statistical models, using unsupervised or supervised machine learning (ML) techniques, but in this case, a robust system was created to leverage expert knowledge, as well as georeferenced data of known deposits of the area. This case of study offered a perfect opportunity to test the designed hybrid intelligent system, to discover its capabilities, weaknesses, and limitation. In the following lines, the proposed apprach is explained. The limits of this system

go beyond mineral prospectivity, as it was designed to be capable of leveraging any kind of georeferenced data.

3.1 Methodology

The proposed approach aims to be a method designed to be used for integrating knowledge and data, constructing a robust hybrid intelligent system that can be useful for georeferenced data leveraging. Helping in decision making in several fields like agriculture, mineral prospectivity, archaeology or fire prevention. The proposed system steps are the following ones:

1. Understanding of the case of study: To deeply understand the case study, an initial interview with experts must be conducted. The purpose of the interview is to identify needs, comprehend the field of study, assess available possibilities, and determine relevant variables.
2. Knowledge acquisition and data gathering: Interviews, surveys or any other knowledge acquisition tool must be used to integrate the maximum amount of valuable information.
3. Knowledge and data integration: To incorporate georeferenced information of different typologies, the area of study must be subdivided into smaller regions of regular shape. A regular grid is often the best option. The granularity of the grid is important for achieving best results, this corresponds to the level of detail to be used, which is something that must be chosen with the aid of experts on the field.
4. Knowledge and data leveraging: When knowledge and data are integrated, several AI techniques can be used to extract its full potential. The proposed ones in this work are the following ones:
   4.1. Study of constructions: This analysis explores the characteristics of the elements to achieve a better understanding of the structure of knowledge. The use of grid systems is inspired by the human cognition model developed by the psychologist George Kelly "Personal Construct Theory" [3].
   4.2. Observations analysis: Dendrograms generated from the results of hierarchical clustering algorithms are highly valuable as they provide visual representations of the proximity between observations, revealing groups of similar elements.
   4.3. Cells clustering using partition-based algorithms to distinguish regions with specific properties, for example, high probability of hosting mineral deposits.
   4.4. Supervised Learning and knowledge representation techniques to predict specific targets, like for example areas with high probability of hosting mineral deposits, or susceptible to fire outbreaks.
5. Prospective Mapping using the outcomes of the previous steps. To help in decision making, prospectivity maps are drawn employing the outputs of the models. The use of colour gradients in heat maps enables the identification of areas with high or low levels of potential, with warmer colours typically indicating higher levels of prospectivity and cooler colours representing lower potential. The prospectivity map generated using the outcomes of MinerIA hybrid intelligent system, is presented below (see Fig. 1).

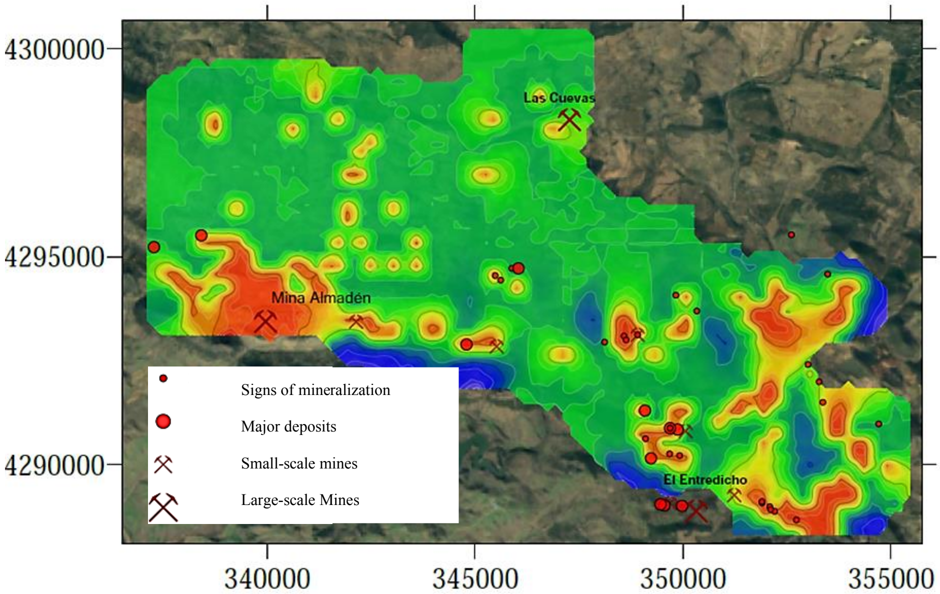

Fig. 1. The final prospectivity heat map, generated using MinerIA proposed system for mineral prospecting in the Almadén Mining districted, is depicted above.

In this map, areas with warmer colours indicate zones identified by MinerIA as having higher prospectivity potential. The map highlights the three largest known deposits in the mining district, with Mina Almadén being the world's largest mercury mineralization. Additionally, smaller deposits and signs of mineralization are represented as dots, with the dot size reflecting the magnitude of the mineralization. It is worth mentioning that the system has successfully categorized the majority of the mineralized zones as having significant potential, while assigning green or blue colours to zones with lower potential that may be discarded in the search for mercury in the area. This confirms its potential as a powerful and promising tool in advanced mineral prospecting. Moreover, the map highlights areas with high potential that lack known deposits, suggesting the possibility of discovering new mineral-rich mercury deposits in these regions.

4 Conclusions

The implementation of this hybrid intelligence system achieved promising results in mineral exploration. By integrating machine learning algorithms with expert knowledge, it has been demonstrated than more accurate results can be achieved.
The generation of prospectivity maps to visualize the results, in the form of heat maps, has been essential for understanding the results of the system. Overlaying georeferenced data on a geographic map with the predictions of the models as a gradient of

colours, offers the expert a powerful tool for decision making. In the case of mineral prospectivity, targeting specific areas with higher probability of hosting mineral deposits can lower the economic costs of a mineral exploration campaigns substantially. Furthermore, the capabilities of the proposed system may extend beyond mineral exploration. It holds promise as a versatile tool in diverse study cases, including archaeological prospection, identifying optimal locations for crops in agriculture, predicting areas with high risk of fire, and many other fields relying heavily in georeferenced data. Its ability to combine the power of machine learning with human expertise offers a handful of new opportunities to fully exploit the potential of georeferenced information.

5 Future work

Some of the future lines of work that will be studied in the near future include:

- Expanding the variety of case studies to demonstrate the generalizability and adaptability of the proposed method to different fields.
- Incorporating techniques such as soft computing [4] to handle uncertainty, like the work of Zhang, where fuzzy logic is used in mineral prospectivity [6].
- Investigating the utilization of tabular Generative Artificial Neural Networks (GANs), like recently discussed in literature [1], to create synthetic data to balance heavily unbalanced datasets.
- Incorporating additional sources of georeferenced data, such as satellite images.

Acknowledgments

This work has been partially supported by FEDER and the State Research Agency (AEI) of the Spanish Ministry of Economy and Competition under grant SAFER: PID2019-104735RB-C42 (AEI/FEDER, UE).

References

1. Bourou, S., El Saer, A., Velivassaki, T. H., Voulkidis, A., & Zahariadis, T.: A Review of Tabular Data Synthesis Using GANs on an IDS Dataset. Information, 12(9), 375. (2021).
2. Henckens, M. L., van Ierland, E. C., Driessen, P. P., & Worrell, E.: Mineral resources: Geological scarcity, market price trends and future generations. Resources Policy, 49, 102-111 (2016).
3. Kelly, G.: Personal construct psychology. Norton, New York (1955).
4. Wilhelm, Y., Reimann, P., Gauchel, W., & Mitschang, B.: Overview on hybrid approaches to fault detection and diagnosis: Combining data-driven, physics-based and knowledge-based models. Procedia Cirp, 99, 278–283 (2021).
5. Zadeh, L.A.: Fuzzy logic. Computer, 21(4), 83-93. (1988).
6. Zhang N.: Mineral prospectivity mapping with weights of evidence and fuzzy logic methods. Journal of Intelligent & Fuzzy Systems, 29(6), 2639-2651 (2015).

Self-sovereign Identity Model in a Higher Education Institution

Facundo N. Montero[1], Hugo Ramon[2] [0000-0003-1577-3092], Adrián Pousa[3] [0000-0001-8072-6626],

[1] Prosecretaria TIC (PRO TIC), Universidad Nacional del Noroeste de la Provincia de Buenos Aires (UNNOBA)
facundomontero@unnoba.edu.ar

[2] Instituto de Investigación y Transferencia en Tecnología (ITT), Comisión de Investigaciones Científicas (CIC), Escuela de Tecnología (ET), Universidad Nacional del Noroeste de la Provincia de Buenos Aires (UNNOBA)
hugo.ramon@itt.unnoba.edu.ar

[3] Instituto de Investigación en Informática-LIDI (III-LIDI), Comisión de Investigaciones Científicas (CIC), Escuela de Tecnología (ET), Universidad Nacional de la Plata (UNLP)
apousa@lidi.info.unlp.edu.ar

Abstract. Self-Sovereign Identity (SSI) arises as a response to the need of users to have control and autonomy over their identity in the digital environment. In this new paradigm, users manage and safeguard their credentials in personal repositories, eliminating dependence on centralized databases of service providers.

The development of IAS-based solutions is growing. It is seen as a key technology to unify personal identity control promoting security, privacy, and transparency by allowing individuals to decide how and when to share their personal information in a decentralized environment.

The proposed work will address the technological and non-technological requirements to implement effective SSI solutions. The state of the art will be analyzed, highlighting government initiatives.

In addition, specific tools such as Hyperledger Indy and Aries will be explored and used to develop a prototype IAS solution in a controlled environment. This prototype will serve as an initial experience using IAS within academia, with the expectation of fostering future Research, Development, and Innovation (R&D&I) projects.

Keywords: Self-Sovereign Identity, Decentralized Identifiers, blockchain., HEI

1 Introduction

Initially, the Internet was designed without a universal user identification system, which led each website to solve this problem independently. Today, there are multiple identification solutions, each with advantages and disadvantages. With the growth of the Internet, individuals must manage numerous credentials to access different services, which can include multiple credentials with different levels of access.

In response to these challenges, the concept of Self-Sovereign Identity emerges, an innovation that seeks to empower individuals by giving them direct control over their digital identity and associated data. This paradigm promises to mitigate the risks of centralization and offer a more secure and transparent solution for identity management in digital environments.

The development of this paper sought to investigate the current status of technologies and projects in the field of Self-Sovereign Identity, as well as to present an initial prototype within the scope of a Higher Education Institution (HEI). This work not only sought to evaluate the technical feasibility of these solutions but also to anticipate future directions in research, development, and innovation in this emerging and crucial field for online security and privacy.

The rest of the paper is organized as follows: Section 2 defines Self-Sovereign Identity. Section 3 describes the experimental work. Finally, Sections 4 and 5 present conclusions and future work, respectively.

2 Self-Sovereign Identity

Self-Sovereign Identity (SSI) is a revolutionary concept for building the Internet that focuses on users' privacy and control over their data. It proposes a new paradigm of decentralized identity where users can manage their identities autonomously. This is achieved through the development of open standards and protocols such as DIDComm [1], and by making use of blockchain technology [2] to store validation records in a secure and immutable way.

SSI allows users to request and receive credentials from entities such as governments, educational institutions or companies, store them securely and share only the necessary information without revealing sensitive data. Christopher Allen defines it as:

> *…the next step beyond user-centric identity and that means it begins at the same place: the user must be central to the administration of identity. That requires not just the interoperability of a user's identity across multiple locations, with the user's consent, but also true user control of that digital identity, creating user autonomy. To accomplish this, a self-sovereign identity must be transportable; it can't be locked down to one site or locale [3].*

In technical terms, the development of SSI requires new standards and communication protocols that extend the OSI model, creating an independent layer for digital identity management. Some key developments include immutable data structures such as blockchain, Decentralised Identifiers (DIDs) [4] that are not controlled by a central authority, and Verifiable Credentials backed by cryptographic validations on blockchain chains.

In addition, SSI leverages technologies such as smartphones and virtual wallets to securely store and manage Verifiable Credentials, empowering individuals with full control over their digital identity in a decentralized and secure environment.

For the adoption of SSI, not only are technological advances necessary, but also regulations and guidelines for governments to adopt and legislate based on them. Highlights the efforts of the European Commission which published the European electronic IDentification, Authentication and Trust Services (eIDAS) regulation [5], compatible with the Self-Sovereign Identity paradigm, in search of facilitating secure cross-border transactions by establishing a framework for digital identity and authentication, offering trust in electronic interactions and promoting seamless digital services within the European Union, and the European Digital Identity (EUDI) regulation [6] that allows the creation of a universal, reliable and secure European digital identity wallet.

3 Experimental Work

As an experimental work, we worked on the implementation of an initial prototype of Self-Sovereign Identity within the Prosecretaría TICs of the Universidad Nacional del Noroeste de la Provincia de Buenos Aires (UNNOBA), this is framed in a use case in which the university issues credentials containing academic and identification data to its students and a test in which they must perform a presentation containing partial information of their credentials. In addition, a zero-knowledge test evaluates whether a given attribute of the credential fulfills an arithmetic condition, allowing the credential holder to validate his or her identity without revealing unnecessary information. For this, it was necessary to deploy a credential issuing agent for the university and develop a controller for simple management of the same, designed for administrative users with a non-technical profile, in addition to publishing in a blockchain the scheme and definition of credentials to be used on which to base the generation of credentials.

The tools used for this development were:

- Hyperledger Indy [7], a blockchain implementation project specifically designed for decentralized for identity solutions, is maintained by the Linux Foundation. Notably, the Verifiable Organizations Network (VON) implementation by the government of the Canadian province of British Columbia worked on its test blockchain running in the https://test.bcovrin.vonx.io/ domain.

- Hyperledger Aries [8], another Linux Foundation project, for the deployment of the agent used by the university to issue Verifiable Credentials. Aries offers a set of tools and libraries that allow the development of agents in different programming languages with support for multiple blockchains, credential types, and protocols. In particular, in this work, we used the one developed in Python, called Aries Cloud Agent Python, known as ACA-Py [9]. In addition, a web driver was developed to interact with the agent, oriented to the use case, allowing the management of credential issuance by non-technical users.

Fig.1 - Controller developed to communicate with the agent

- Lissi ID-Wallet [10], an application of the German company Lissi GmbH, for the use of a digital wallet to store Verifiable Credentials. It is also characterized as an EUDI-Wallet as it complies with the requirements of the European eIDAS regulation.

Once the resources with which to work had been deployed, the credential scheme was defined based on the use case, the generation of Verifiable Credentials, and the creation of Verifiable Presentations. During these steps, particular characteristics and limitations found in the tools used were detailed.

4 Conclusions

It analyzes the state of the art of various public and private initiatives that promote the use of this technology to address and provide solutions to different social problems.

The key technological components for its implementation are detailed, such as distributed log technologies (DLT), in particular blockchain, distributed identifier standards, verifiable credentials, digital wallets, and agents. These components are currently under continuous development and standardization.

Experimental work was carried out using tools such as Indy and Aries from the Hyperledger project to make an initial prototype at UNNOBA, where a credential issuing agent was deployed, a controller was developed, credentials were issued to virtual wallets, and validated against the information in the blockchain. During all these steps we tried to show the degree of maturity of the tools used for its deployment, most of which are considered still in the early stages as they are not in stable versions, we detailed problems and limitations encountered and possible future changes in both the tools and protocols used.

5 Future Work

Based on the work carried out in this paper, the following lines of research are considered of interest given the global boom in this technology:

- Develop trust frameworks for its implementation with legal validity according to the laws and regulations in force.
- Develop mechanisms for interoperability of DIDs between different blockchains.
- A solution to overcome the current mechanisms of revocation of Verifiable Credentials.
- Comparison of use and interaction capacity between different communication protocols such as DIDComm and OpenID.
- Analyze the various accessibility considerations required to ensure this technology is usable and available to all users.

References

[1] DIDComm Working Group (2023). DIDComm Messaging v2.x Editor's Draft. Decentralized Identity Foundation. https://identity.foundation/didcomm-messaging/spec/
[2] EU Blockchain (2018). EU Blockchain. Comisión Europea. https://www.eublockchainforum.eu/
[3] Christopher Allen (2016). The Path to Self-Sovereign Identity. Life With Alacrity. http://www.lifewithalacrity.com/2016/04/the-path-to-self-sovereign-identity.html
[4] M. Sporny, A. Guy, M. Sabadello, D. Reed. (Julio 2022). Decentralized Identifiers (DIDs) v1.0 - Core architecture, data model, and representations. W3C. https://www.w3.org/TR/2022/REC-did-core-20220719
[5] European Commission (2014). eIDAS Regulation. https://digital-strategy.ec.europa.eu/en/policies/eidas-regulation
[6] European Commission (2021). EUID Regulation. https://digital-strategy.ec.europa.eu/en/policies/eudi-regulation
[7] Hyperledger Indy (2023). Hyperledger Indy. https://hyperledger-indy.readthedocs.io/en/latest/index.html
[8] Hyperledger Aries (2023). Hyperledger Aries. https://www.hyperledger.org/projects/aries
[9] Hyperledger Aries (2024). Aries Cloud Agent Python. https://aca-py.org/v0.12.1/
[10] Lissi GmbH (2023). Lissi ID-Wallet . https://www.lissi.id/for-users

Applicability of Quality 4.0 Characteristics in the Software Development Process

Kristian Petkoff Bankoff, Rocío Muñoz, Ariel Pasini, and Patricia Pesado

Institute for Research in Computer Science LIDI (III-LIDI), Faculty of Computer Science, National University of La Plata, Argentina
{kpb,rmunoz,apasini,ppesado}@lidi.info.unlp.edu.ar

Abstract. This paper explores the integration of Quality 4.0 into software engineering, showcasing how its frameworks enhance software development. It discusses 11 key Quality 4.0 elements—from data management to skill improvement—and their importance in software projects. The analysis suggests that DevOps and Agile boost Quality 4.0's data, analytics, collaboration, and connectivity aspects, crucial for creating an adaptable and collaborative software environment. Traditional quality models, however, still support management, scalability, compliance, and leadership effectively. It also emphasizes the essential role of app development in software engineering, regardless of the quality approach used.

Keywords: Quality 4.0, TQM, Software Engineering, DevOps, Agile Methodologies

1 Introduction

Quality 4.0 marks a major evolution in quality management by integrating traditional practices with the innovative technologies of Industry 4.0. This approach stems from the ongoing Fourth Industrial Revolution, noted for merging physical, digital, and biological technologies[11].

The concept of Quality 4.0 derives from the broader idea of Industry 4.0, initially introduced at the 2011 Hannover Fair. It highlighted how these technologies are transforming manufacturing[4]. In quality management, Quality 4.0 involves not only adopting new technologies but also transforming organizational cultures and aligning quality goals with digital transformation strategies.

Central to Quality 4.0 is the incorporation of digital technologies into quality management. IoT devices are crucial as they collect data directly from manufacturing equipment, enabling real-time monitoring and control that were once impossible. This data is analyzed using big data analytics to provide predictive insights on quality and maintenance, helping to prevent defects and failures, thereby reducing waste and enhancing efficiency[2].

AI and machine learning expand these capabilities by facilitating sophisticated data analysis and decision-making without human intervention. These technologies detect patterns and insights from large data sets to enhance quality and optimize production processes[12].

The adoption of Quality 4.0 has significant implications for quality assurance. It supports improved product quality through continuous monitoring and feedback, allows for greater product customization, and enables quicker responses to quality issues. Moreover, Quality 4.0 can enhance customer satisfaction by ensuring higher product standards and faster service[9].

2 Traditional Software Product Quality

Traditional software quality concepts have always focused on ensuring that software products meet specific requirements, are free from defects, and perform reliably. These concepts are crucial in software development and cover a wide range of practices, from defining initial requirements to providing maintenance and support after the software is deployed[5].

Software quality can be seen through several lenses, including correctness, maintainability, efficiency, reliability, usability, integrity, and adaptability. This broad approach aims to ensure that software not only functions as intended under certain conditions but also meets wider performance criteria that enhance user satisfaction and operational efficiency[7].

In a traditional setting, software quality assurance (SQA) is about a systematic process to check the quality of software. This process includes development standards, code reviews, system testing, and performance evaluations, all designed to prevent defects. Quality control, however, focuses on finding defects in the finished products. It is reactive, addressing defects after they occur, unlike the preventive nature of SQA. Adherence to international standards such as ISO 9001 can help integrate these practices into a comprehensive quality management system, providing guidelines that ensure quality is maintained throughout software development.

3 Relation between Software and Quality 4.0

Software plays a vital role in applying Quality 4.0 across various industries. As Quality 4.0 focuses on data-driven decisions, real-time monitoring, and the use of new technologies, software offers the infrastructure needed to gather, process, and analyze vast amounts of data[8]. It also supports the connectivity and interoperability of devices and systems in the IoT framework, facilitating data exchange between the physical and digital realms[15]. Utilizing artificial intelligence and machine learning to detect patterns, predict defects, and refine processes in real-time significantly enhances operations[13].

Flexibility and adaptability are crucial for adopting continuous improvement, iterative development, and customer-focused strategies. A core aspect of Quality 4.0 involves creating tailored software applications to address an organization's unique needs[4]. Furthermore, the principles of Quality 4.0 deeply influence the software industry, enabling software engineering teams to make informed decisions, spot defects early, and enhance software quality[1].

Quality 4.0 also complements agile methodologies, which support iterative development, continuous customer feedback, and team collaboration. These methodologies help deliver products that are more aligned with customer needs[1]. By focusing on customer-centric strategies and involving stakeholders throughout the development process, software engineering can more effectively meet user preferences, resulting in superior software products[5].

Quality 4.0 encourages software development to adopt data-centric practices, including real-time monitoring, predictive analytics, and error prediction models. These practices allow for ongoing monitoring of software systems and foster a culture of continuous learning and improvement[14].

4 Quality 4.0 in Software Development Process

The 11-axis model proposed by the LNS Research Group provides a comprehensive framework for implementing Quality 4.0 within organizations. This model is designed to guide companies in integrating modern digital technologies with traditional quality management systems, aligning them with the requirements of Industry 4.0[6].

Such axis are: sophisticated data management tecnologies for data-driven decision making; analytics for more complex predictive and prescriptive analytics using big data and machine learning technologies; connectivity to enable integration of information technology and operational technology; collaboration to focus on enhancing cooperation across various functional areas; app development to facilitate the execution of Quality 4.0 processes; scalability to address the capability of quality management systems to expand and adapt to the scope of data and operations; management systems that automate workflows and consolidate data and processes; compliance to meet regulatory and industry standards, facilitated through advanced technologies that automate compliance processes; quality-centric organizational culture that encourages continuous improvement; leadership to drive the adoption and implementation of Quality 4.0 initiatives; competency to enhance the skills and knowledge base of employees to effectively utilize Quality 4.0 technologies and practices.

DevOps, a compound of development and operations, inherently supports Quality 4.0 by fostering a culture of continuous integration and continuous deployment (CI/CD). This approach emphasizes automation, monitoring, and collaboration between software developers and other IT professionals. By automating repetitive tasks and integrating various stages of the software development lifecycle, DevOps facilitates a seamless flow of work, thereby enhancing productivity and ensuring more reliable software releases[3, 10].

Agile methodologies complement DevOps in enabling Quality 4.0 by providing the framework for adaptability and customer-focused development. Agile's iterative process allows for regular reassessment of development projects to align closely with customer requirements and market changes. This adaptability is crucial for Quality 4.0, which must be flexible enough to respond to the dynamic nature of digital markets.

5 Conclusions

The integration of Quality 4.0 within the software engineering domain is significantly facilitated through the adoption of DevOps and agile methodologies.

As shown in Figure 1, while DevOps and agile methodologies enable and enhance the implementation of several key axes of Quality 4.0 in software engineering, such as Data, Analytics, Collaboration, and Connectivity, traditional quality models continue to robustly support Management Systems, Scalability, Compliance, Culture, Leadership, and Competency. The development of applications, while crucial, is a standard practice in software engineering and intrinsic to the industry itself, suggesting a holistic approach is needed to fully realize Quality 4.0 in software development. This integration across methodologies and models ensures a comprehensive alignment with the digital transformation goals of Industry 4.0, enhancing software quality and operational efficiency across the board.

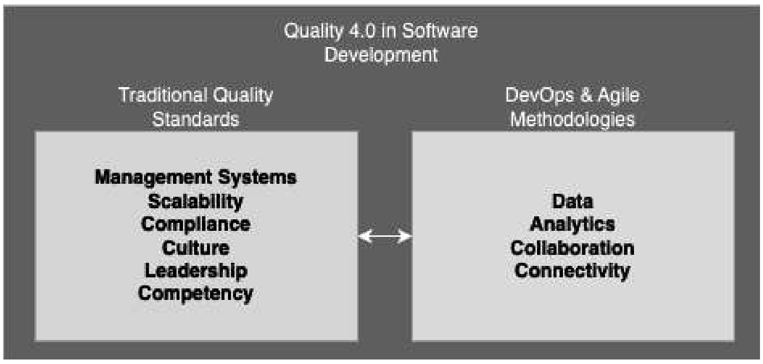

Fig. 1. Holistic view of Quality 4.0 in Software Development

References

1. Bankoff, K.P., Muñoz, R., Pasini, A., Pesado, P.: Calidad 4.0 en Ingeniería de Software: propuesta de un marco de trabajo. XXIX Congreso Argentino de Ciencias de la Computación - CACIC 2023 (2024)
2. Brettel, M., Friederichsen, N., Keller, M., Rosenberg, M.: How virtualization, decentralization and network building change the manufacturing landscape: An Industry 4.0 Perspective. International journal of information and communication engineering **8**(1), 37–44 (2014)

3. Ebert, C., Hochstein, L., Ebert, C.: DevOps in Practice. IEEE Software **40**, 29–36 (2023). https://doi.org/10.1109/MS.2022.3213285
4. Henning, K.: Recommendations for implementing the strategic initiative INDUSTRIE 4.0. In: (2013). https://api.semanticscholar.org/CorpusID:117540617
5. ISO/IEC, *ISO/IEC 25010:2011, Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — System and software quality models*, (2011).
6. Jakob, D.: Quality 4.0 Impact and Strategy Handbook, https://www.lnsresearch.com/research-library/research-articles/-ebook-quality-4.0-impact-and-strategy-handbook (2018). [Online; accessed 15-March-2024].
7. Jones, C.: Software Quality: Analysis and Guidelines for Success. Thomson Learning (1997)
8. Mourtzis, D., Vlachou, K., Milas, N.: Industrial Big Data as a Result of IoT Adoption in Manufacturing. In: pp. 290–295 (2016). https://doi.org/10.1016/j.procir.2016.07.038
9. Oesterreich, T., Teuteberg, F.: Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. Computers in Industry **83** (2016). https://doi.org/10.1016/j.compind.2016.09.006
10. Perera, P., Silva, R., Perera, I.: Improve software quality through practicing DevOps. 2017 Seventeenth International Conference on Advances in ICT for Emerging Regions (ICTer) (2017). https://doi.org/10.1109/ICTER.2017.8257807
11. Schwab, K.: "The Fourth Industrial Revolution". In: World Economic Forum, 2016. Chap. 1. ISBN: 978-84-9992-699-5.
12. Susto, G.A., Schirru, A., Pampuri, S., Mcloone, S., Beghi, A.: Machine Learning for Predictive Maintenance: A Multiple Classifier Approach. Industrial Informatics, IEEE Transactions on **11**, 812–820 (2015). https://doi.org/10.1109/TII.2014.2349359
13. Tao, F., Sui, F., Liu, A., Qi, Q., Zhang, M., Song, B., Guo, Z., Lu, S., Nee, A.: Digital twin-driven product design framework. International Journal of Production Research **57**, 1–19 (2018). https://doi.org/10.1080/00207543.2018.1443229
14. Wang, G., Gunasekaran, A., Ngai, E., Papadopoulos, T.: Big data analytics in logistics and supply chain management: Certain Investigations for research and applications. International Journal of Production Economics **176** (2016). https://doi.org/10.1016/j.ijpe.2016.03.014
15. Xu, L.D., Duan, L.: Big data for cyber physical systems in industry 4.0: a survey. Enterprise Information Systems **13**(2), 148–169 (2019). https://doi.org/10.1080/17517575.2018.1442934

Analysis of factors for the acceptance and use of technology for the design of digital services in Ecuador

Pablo Pintado[1,2(✉)] [0000-0002-1356-0248] and Elsa Estevez[3(✉)] [0000-0002-2596-4397]
[1] Universidad del Azuay, Cuenca, Ecuador
ppintado@uazuay.edu.ec

[2] Facultad de Informática, Universidad Nacional de la Plata (UNLP), La Plata, Argentina

[3] Departamento de Ciencias e Ingeniería de la Computación, Universidad Nacional del Sur (UNS), Instituto de Ciencias e Ingeniería de la Computación (UNS-CONICET), Bahía Blanca, Argentina
ecestevez@gmail.com

Abstract. The adoption of digital services depends on different factors related to the acceptance and use of technologies. Despite a variety of research on techniques and models for technology acceptance and use, scarce research explores the factors of acceptance and use of technologies depending on the digital service's economic activity and the user's demographic characteristics in the Ecuadorian context. This article presents and analyzes a conceptual framework of the factors of acceptance and use of digital services in the Ecuadorian context. Its main contribution is to serve as a guide identifying major factors that policy makers and software developers need to consider when planning and designing digital services in Ecuador, so to facilitate their usage and adoption.

Keywords: Conceptual framework for technology acceptance and use; acceptance and use factors; digital services in Ecuador.

1 Introduction

According to the United Nations 2030 Agenda for Sustainable Development, Ecuador has a high rate of online services. However, for them to be successful, users must adopt them. Thus, it is necessary to consider the factors of acceptance and use of technologies and certain software development practices used as part of government digital transformation efforts. There is literature related to acceptance and usage factors, like [1], which proposes a conceptual model that integrates concepts from the technology acceptance model (TAM); the technology, organization, and environment (TOE) framework; institutional theory and the institutionalization change model. In [2], they propose a conceptual model based on trust, technology acceptance, and empowerment theory to understand the digital citizen participation of Filipinos. In [3], they examine the factors affecting teachers' intention in training and use of mobile augmented reality

(MAR) in teaching through the mobile augmented reality acceptance model (MARAM).

As part of our research work, in [4], we propose taxonomies of the factors of acceptance and use of technologies of digital services, both following a general approach and refined by economic activity. In [5], we propose a characterization that represents how the priority factors of acceptance and use of technologies are differentiated by economic activity of the digital service and by demographic characteristics of the user in the context of Ecuador.

From our literature review related to conceptual frameworks on acceptance and use of technologies, we observe that most studies focus on specific areas, such as education, citizen participation, and augmented reality, among others; and they only consider specific models of acceptance and use. Therefore, we understand that there is a gap in the state of the art for studying such factors in the Ecuadorian context. For this reason, in this paper, we propose a conceptual framework of the factors of acceptance and use of digital services in Ecuador.

The remainder of this paper is structured as follows. Section 2 presents a literature review on related work. Section 3 explains the research methodology applied for this study. Section 4 introduces the proposed conceptual framework, while Section 5 discusses its validation. Finally, section 6 summarizes conclusions and recommendations.

2 Related literature

A selective literature review was conducted in IEEE Xplore and Springer to identify research papers on conceptual frameworks for the acceptance and use of technologies. For this purpose, we searched in February 2024 on papers published in the last five years containing the following keywords in the abstract:

(("Abstract":Acceptance and use of technology) AND ("Abstract":Framework))

As result of the search, we reviewed 178 publications in IEEE Xplore and 303 in Springer. We selected papers after reading the abstract and considering their relevance to our research. From this, we identified eight articles. In the following, we provide a summary of the selected articles.

In [1], they authors propose a conceptual model that integrates concepts from TAM, TOE, institutional theory, and the institutionalization change model. The paper in [3] examines factors affecting teachers' intention to use MAR in teaching through MARAM proposed based on TAM. The model comprises four components: perceived relative advantage, perceived enjoyment, facilitating conditions, and mobile self-efficacy. In [6], they explore the relationship between acceptance and adoption of metaverse (AAM) and e-Learning adoption using TAM on users' behavioral intention toward AAM.

In [7], they propose an integrated framework to investigate the impact of security and privacy with technology familiarity to measure users' trust in the use of IoT in healthcare services in Oman. In [2], through a survey and machine learning algorithms, they propose a conceptual model based on trust, technology acceptance, and empowerment theory to understand digital citizen participation in the Philippines.

Upon reviewing existing studies on conceptual frameworks for the acceptance and use of technologies, we observed a shared focus on specific areas such as education, IoT, citizen participation, and augmented reality, among others, using specific models of acceptance and use. This led us to identify a gap in the state of the art. Drawing from the taxonomies [4] and characterization of the priority factors of acceptance and use of digital services in Ecuador [5], in this paper, we propose a novel conceptual framework for the factors of acceptance and use of digital services in Ecuador.

3 Research methodology

The research methodology used, as adopted in [8], was the foundation of our previous research [4] [5]. This approach helped us to identify the models and theories of acceptance and use of technologies such as TAM*, UTAUT*, ISO 9241-210, ISO-IEC-25010; certain software development practices for digital transformation such as problem identification and resolution, agile development methods, process simplification and automation [4]; and user demographic attributes, like gender, age, education level, place of residence, and digital channels used for digital services [5].

This research focuses on two main questions, explored in two phases: 1) *¿What are the models for assessing the acceptance of technologies and certain software development practices for digital transformation applied for designing digital services?* and 2) *¿What are the main factors of acceptance and use of technologies for digital services in Ecuador?* The former question has been explored through a systematic literature review (SLR), documented in [4]. We addressed the latter through analyzing a case study and a survey, both based on the Ecuadorian context, explained in [5].

In phase one, as mentioned, we conducted a SLR, validated with Cohen Kappa, yielding reliable results. In phase two, we used a case study [9] and a survey [10] validated with Spearman-Brown, ensuring the reliability of our findings.

The data analysis from phase I encompassed 55 primary studies identified through the SLR. We used a quantitative analysis of descriptive statistics to identify the relevant factors and practices using a general approach and another refined by economic activity. The results produced two taxonomies [11]: 1) Taxonomy of factors of acceptance and use of technology and certain Digital Transformation (DT) practices with a general approach, and 2) Taxonomy of factors of acceptance and use of technology and DT practices by economic activity [4].

The data analysis from phase II [5] was done based on the 420 replies received from the survey. Through them, we detected differences in the priority factors according to approaches of the digital service's economic activity and the user's demographic. We documented such differences in characterization [10]. Based on the results achieved, we proceeded to synthesize a conceptual framework for the acceptance and use of technologies for digital services in Ecuador, which is presented in the following section.

4 Conceptual framework

A conceptual framework is an organizational structure of concepts for solving a particular problem. It organizes and makes sense of key concepts related to each other. It guides the stages of an investigation, from formulating research questions to the coherent interpretation of results [8].

On the one hand, the SLR unveiled ten relevant factors and practices of acceptance and use of technology following a general approach. These factors include: 1) perceived usefulness, 2) interaction ergonomics, 3) performance expectation, 4) facilitating conditions, 5) effort expectation, 6) ease of use, 7) usability, 8) design thinking, 9) Business Process Management (BPM), and 10) SCRUM. Additionally, the economic activity of the digital service revealed five cross-cutting factors such as 1) perceived usefulness, 2) interaction ergonomics, 3) effort expectation, 4) ease of use, and 5) usability. On the other hand, the study of the case study and the survey focusing on the economic activity of the services identified 18 relevant factors: 1) to 7) as in the general approach, plus 8) security, 9) accessibility, 10) digital culture, 11) habit, 12) behavior intention, 13) usage behavior, 14) adoption, 15) hedonic motivation, 16) perceived enjoyment, 17) operability, and 18) social influence. Considering the user's demographic aspects, we discovered some were important and others not, depending on the aspect.

Figure 1 synthesize our findings. For each of the identified factors, it includes the reference to the model or theory in which the factor is described and includes an "*" in the case that the factor is relevant to the analysis of the generic approach, to the economic activity of the service, and each of the user's demographic characteristic. If the cell is in grey, the factor is irrelevant to such approach/characteristic. For example, security, accessibility, digital culture, habit, hedonic motivation, perceived enjoyment, and social influence are not relevant factors for accepting and using technology, considering a general approach. In the case of demographic characteristics, while age and gender are relevant for all factors, the rural location does not affect operability and social influence; also, PhD and primary education level do not influence effort expectation, ease of use, and usability.

5 Validation

Our research, which involved validations in each phase, i.e., in the SLR [4], case study and survey [5], was further strengthened by the use of an empirical methodology of focus groups with 31 experts over three sessions [12]. The results of this validation were compelling. In particular, 98% of the experts agree that the factors of acceptance and use, as well as specific software development practices used in digital transformation, exhibit differences between approaches based on the economic activity of the digital service and the demographic characteristics of the users, when considering the acceptance and use factors of digital services in Ecuador.

Factor / Constructor	Models / Theories	Generic approach	Economic activity	User demographics						
				Age	Gender	Location	Rural location	Education	PhD education	Basic education
Security			*	*	*	*	*	*	*	*
Accessibility	WCAG 2.1 Accessibility		*	*	*	*	*	*	*	*
	ISO 9241 Accessibility		*	*	*	*	*	*	*	*
Perceived usefulness	UTAUT* Perceived usefulness	*	*	*	*	*	*	*	*	*
	TAM* Perceived usefulness	*	*	*	*	*	*	*	*	*
Interaction ergo-nomics	ISO 9241 Interaction ergonomics	*	*	*	*	*	*	*	*	*
Performance expectation	UTAUT* Performance expectation	*	*	*	*	*	*	*	*	*
	ISO 9241 Productivity	*	*	*	*	*	*	*	*	*
	ISO-25010 Performance efficiency	*	*	*	*	*	*	*	*	*
Digital culture	UTAUT* Experience		*	*	*	*	*	*	*	
	TAM* Experience		*	*	*	*	*	*	*	
	ISO 9241 Improve user experience		*	*	*	*	*	*	*	
Habit	UTAUT* Habit to use		*	*	*	*	*	*	*	*
Behavior intention	UTAUT* Behavior intention	*	*	*	*	*	*	*	*	*
	TAM* Behavior intention	*	*	*	*	*	*	*	*	*
Usage behavior / adoption	UTAUT* Usage behavior	*	*	*	*	*	*	*	*	*
	TAM* Usage behavior	*	*	*	*	*	*	*	*	*
Hedonic motivation	UTAUT* - Hedonic motivation		*	*	*	*	*	*	*	*
Perceived enjoyment	TAM* - Perceived enjoyment		*	*	*	*	*	*	*	*
Facilitating condi-tions / Operability	UTAUT* Facilitating conditions	*	*	*	*	*		*		*
	ISO 9241 Easy understand	*	*	*	*	*		*		*
	ISO-25010 Portability	*	*	*	*	*		*		*
Effort expectation	UTAUT* Effort expectation	*	*	*	*	*	*	*		
Ease of use / Usability	UTAUT* Perceived ease of use	*	*	*	*	*	*	*		
	TAM* Perceived ease of use	*	*	*	*	*	*	*		
	ISO 9241 Easy understand	*	*	*	*	*	*	*		
	ISO-25010 Usability	*	*	*	*	*	*	*		
Social influence	UTAUT* Social influence		*	*	*	*		*	*	

Fig. 1. Diagram of acceptance and use factors by user demographics and economic activity of the digital service – Ecuador

6 Discussion

This research aimed to synthesize a conceptual framework for the factors of acceptance and use of digital services in Ecuador. Our methodology used in previous research [4] [5] includes a selective literature review in IEEE Xplore (178 articles) and Springer (303 articles). The key inputs for our synthesis were the taxonomies explained in [4] and the characterization of the priority factors of acceptance and use of digital services in Ecuador [5].

Based on the SLR taxonomies [4] and the characterization of the case study in the Ecuadorian context [5], the differences in the priority acceptance and use factors were synthesized in Figure 1. In particular, the SLR based on the generic approach obtained ten relevant factors. In comparison, the case study obtained 18 relevant factors. With the approach by economic activity in the SLR, we obtained five cross-cutting factors: perceived usefulness, interaction ergonomics, effort expectation, ease of use, and usability, followed by five relevant factors such as behavior intention, usage behavior, adoption, facilitating conditions and operability; while the case study identified 18 relevant factors. The approach by user demographic characteristics revealed that the priority factors for digital service adoption vary by demographic characteristics from 13 to 18 relevant factors (See Fig. 1). For example, to design a digital service for a user with PhD education level is irrelevant operability, effort expectation, ease of use, and usability; while for a user with primary education is not relevant digital culture, effort expectation, ease of use, usability, and social influence; also, for a user from a rural location is irrelevant facilitating conditions, and social influence to adopt the digital service.

The conceptual framework for the acceptance and use of digital services in Ecuador proposed in this research is valuable and practical for software developers, researchers, and others interested in the relevant factors of acceptance and use of digital services in the Ecuadorian context. It provides a foundation for ensuring the successful adoption of the implemented digital services.

References

[1] J. Atcharaporn and T. Bundit, "An Exploratory on Factor Influencing of Digital Transformation and Institutionalization in Thai Maritime Industry," in *2022 7th International Conference on Business and Industrial Research (ICBIR)*, 2022. doi: 10.1109/ICBIR54589.2022.9786443.

[2] A. A. Hernandez *et al.*, "Predicting Intention to Recommend Digital Citizen Participation using Machine Learning," in *ICSET 2023 - 2023 IEEE 13th International Conference on System Engineering and Technology, Proceeding*, Institute of Electrical and Electronics Engineers Inc., 2023, pp. 129–134. doi: 10.1109/ICSET59111.2023.10295107.

[3] K. George, M. T. Anastasios, M. Dimitrios, and C. Christos, "The mobile augmented reality acceptance model for teachers and future teachers," *Educ Inf Technol (Dordr)*, 2023, doi: 10.1007/s10639-023-12116-6.

[4] P. Pintado, I. Jaramillo, D. Prado, and E. Estevez, "The Taxonomy of Factors of Acceptance and Use of Technologies for Human Computer Interface in Digital Services," 2023. doi: 10.24215/16666038.23.e14.

[5] P. Pintado, S. Wiesner, D. Prado, and E. Estevez, "Examining Factors of Acceptance and Use of Technology in Digital Services in the Context of Ecuador," in *Communications in Computer and Information Science*, Springer Science

and Business Media Deutschland GmbH, 2023, pp. 171–185. doi: 10.1007/978-3-031-40942-4_13.

[6] A. Alhalaybeh and A. Althunibat, "Measuring Acceptance of Adoption Metaverse in eLearning by Using TAM Model," in *2023 International Conference on Information Technology (ICIT)*, 2023, pp. 361–366. doi: 10.1109/ICIT58056.2023.10226171.

[7] M. N. Alraja, M. M. J. Farooque, and B. Khashab, "The Effect of Security, Privacy, Familiarity, and Trust on Users' Attitudes Toward the Use of the IoT-Based Healthcare: The Mediation Role of Risk Perception," *IEEE Access*, vol. 7, pp. 111341–111354, 2019, doi: 10.1109/ACCESS.2019.2904006.

[8] E. Estevez and T. Janowski, "Electronic Governance for Sustainable Development - Conceptual framework and state of research," *Gov Inf Q*, vol. 30, no. SUPPL. 1, Jan. 2013, doi: 10.1016/j.giq.2012.11.001.

[9] P. Runeson, M. Host, A. Rainer, and B. Regnell, *Case study research in software engineering : guidelines and examples*. Wiley, 2012.

[10] R. Hernández Sampieri, C. Fernández Collado, and P. Baptista Lucio, "Metodologia de la Investigación (Sexta edición)," *Mc Graw Hill*, 2014.

[11] R. Nickerson, J. Muntermann, U. Varshney, H. Isaac, and H. I. Taxonomy Devel-, "Taxonomy development in information systems: developing a taxonomy of mobile applications," 2009. [Online]. Available: https://halshs.archives-ouvertes.fr/halshs-00375103

[12] M. Mendoza-Moreno, C. González-Serrano, and F. J. Pino, "FOCUS GROUP AS A SOFTWARE ENGINEERING PROCESS: AN EXPERIENCE FROM THE PRAXIS," vol. 80, pp. 51–60, 2013.

Industry 5.0. IIoT platform as enabler for smart manufacturing

Industria 5.0. Plataformas IIoT como facilitadoras de la producción inteligente

Ayelen Cayuqueo[1], Guillermo Riquelme[1], Luciano Loyola[1], Joel Acosta[1], Gustavo Guitera[2], Federico Walas Mateo[1] *

[1] Chaska Analytics, La Plata. Argentina.
[2] Siemens Argentina,
*federicowalas@chaska.com.ar

Abstract. The work develops concepts about Industrial Internet of Things (IIoT) platforms and how this paradigm can give insights to empower industrial operation managers. The concepts are followed by an adoption case in a company in the food sector. The case give visibility to the possibilities generated by the adoption of IIoT in an industry that deliver high quality supplies to the food value chain. The article includes concepts on data integration in the industry, the IIoT architecture and its components, and the technological ecosystem that facilitates the adoption of the solution.

The adoption of the IIoT platform in industrial firms occurs within the framework of the evolution towards the Industry 5.0 model. The article discusses the adoption process, the integration of different hardware and software components, according to the ISA 95 standards. In the described case, the IIoT platform is an industrial solution from Siemens that works with open components such as Node-RED or Grafana. Among the achievements achieved by the project, the fact of obtaining indicators (KPIs) that can be viewed on dashboards stands out, thus facilitating decision-making for process engineers. Finally, the article conclude on the importance of the IIoT platform to continue the evolution from descriptive analytics to prescriptive analytics.

Keywords: IIoT, Industry 5.0, data analytics, Lean 4.0, UN SDG.

1 Introduction

Previous works of the authors of the article [1,2], develop concepts about IIoT, and the role of this architecture to generate data that facilitates the management of operational processes aligned to the planning of the company. In addition, this technological paradigm is made visible as a facilitator of process optimization based on descriptive analytics and is considered as the starting point to evolve towards prescriptive analytics [3].

The market penetration of devices in IIoT architecture, equipped with detection and communication capabilities, has allowed companies to connect devices in plants, developing cyber-physical systems capable of generating and collecting data throughout the industrial space [4]. This has also contributed to a renewed interest in the topic of Operations Technology/Information Technology (OT/IT) convergence, identified by [5] among the main areas of investment in the short term.

2 Conceptual background

Initiating the conceptual analysis of the work [1], it presents an investigation based on a bibliometric analysis on the impact of IIoT for the success of prescriptive data models as a process optimization engine in I5.0. The work validates the hypothesis, although it highlights the intrinsic complexity that this type of solution presents, observes the novelty of the subject, and finally that the subject is dominated by the academic scientific field, but there is limited application in the industry.

Within the framework of smart production systems, the manufacturing ecosystem is made up of a wide variety of devices that collect data from different industrial processes. [6] states that IIoT is a new generation of technology that is enriched by the existence of solutions that collect data at the plant floor level (sensors, actuators, etc.) with high degrees of precision. Thus, visibility into operations has advanced to new levels that facilitate the acquisition of vast amounts of data and virtually instant feedback. In this way it is possible to adopt Artificial Intelligence (AI) algorithms that facilitate productivity and efficiency in processes.

To start the discussion on the generation of data from the industrial process, the article [7] highlights the need to consider the systems approach when addressing research on the integration of industrial information. The text presents the modelling and integration of information flows for linking business information through the architecture proposed by IIoT.

The paper [8] highlights the conceptual framework of information technology (IT) and operational technology (OT) infrastructure that enables the I5.0 model. The convergence of OT/IT is critical for the integrating data in the industrial decision-making process, creating the basis for a cognitive plant. The paper includes a real case that fulfils the specific needs of OT and IT, achieving fast and homogeneous transfer of large volumes of data towards the IT layer.

3 Case Study

The management of the firm understand the need to align operations to 2030 agenda and make process more efficient. Industrial process digitalization evolving into I5.0 model was seen as a driver to reach this milestone.

The company's production system responds to the continuous process scheme, and at the beginning of the project it had a SCADA architecture for the management of industrial processes, and an Enterprise Resource Planning (ERP) platform for business management.

Based on the initiative of the company's Management, a diagnosis of digital maturity was made that made visible the need to advance in a greater integration of data to evolve in the I5.0 model.

Within this framework, it was decided to advance in the adoption of an IIoT architecture. For this, a gateway type device was incorporated to take the data of the plant operation, which is found in the OT network, to the cloud. For the integration of the information of the processes, the OPC UA server that incorporates the existing SCADA platform in the company is used and enables the interoperability of the data so that it can finally be viewed on the IIoT Insight Hub platform [9].

Insight Hub is an open, cloud-based IIoT operating system developed by the German company Siemens. It is capable of connecting all your equipment and systems, extracting its data and converting it into information. This platform has an open action protocol and various functionalities such as remote access to Amazon Web Service cloud services or the PaaS (Platform-as-a-Service) service.

Being an open platform, Insight Hub allows connecting with other open platforms such as Node-Red [10].

Node-Red is a programming tool for connecting hardware devices, APIs, and online services. It provides an editor over a web browser that makes it easy to develop flows using preconfigured nodes. This tool is based on Node.js, and is event driven.

Once the integration of the operation information from SCADA was generated, a dashboard system was developed to show different KPIs of the operation, which can be viewed outside the plant environment without affecting the security conditions required by the OT network. Figures 1 and 2 show different ways of viewing the KPIs and equipment status generated with operation data.

Figures below show some of the dashboards that can be obtained. Figure 1 shows three KPIs, Productivity, Availability, and OEE of daily operation. Figure 2 makes visible the boiler steam and gas flow, and boiler operating status showing productive time (green), and unproductive times (blue and grey).

Fig. 1. KPI of the daily operation that is shown in the dashboard generated on the IIoT platform. Source: Authors.

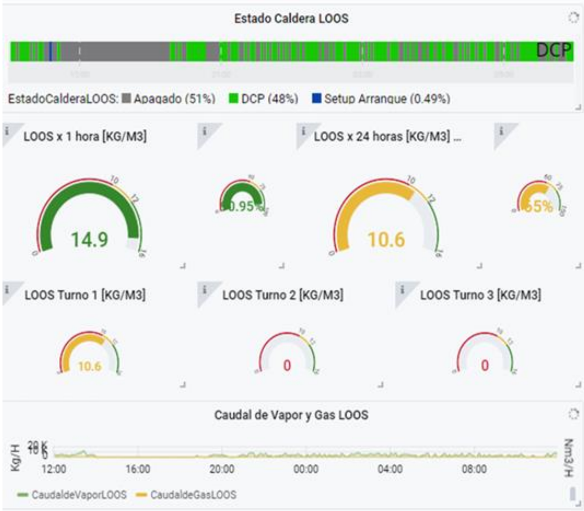

Fig.2. Dashboard that shows the status of a boiler from data gathered by the IIoT architecture. Source: Authors.

4 Conclusions

As the first emerging of this work, the fact of achieving a robust IIoT structure from connecting various solutions in a simple way from open architectures, which facilitate the convergence of data, stands out.

One issue that stands out among the results is the possibility of extracting data outside the plant without violating cybersecurity protocols. Achieving the security of the SCADA data is an added value that generates the value proposition of the project. It is worth mentioning that during emergencies that required access to the SCADA from outside the plant, important divergences arose with the company's security standards. The most notorious event occurred during the restrictions imposed by the COVID pandemic.

On the other hand, the empowerment of the people involved in the process was achieved by visualizing the data in a more intuitive way available in different platforms.

An observation that deserves consideration is the fact that the OT infrastructure had a state-of-the-art SCADA platform that incorporated the functionality of the OPC UA server. Without this functionality, the project would have become more complex and would have consumed more resources.

The IIoT platform generates information that streamlines the process of continuous improvement of the industrial processes carried out by the company. Visualization of the state of production through digital platforms on monitors located in the boiler area and in the process control room. This allows analyzing the state of the assets and the operational processes to address the elimination of waste proposed by the Lean Manufacturing approach, this view integrated with the I5.0 strategy, leads the company to operate within the Lean 4.0 model.

The impact of the deployment of the solution in the plant pushed the direction of the company to advance in the adoption of the solution in the other 4 plants of the Group.

In addition, the scope of the project will continue to evolve with the integration of the ERP business management system to generate indicators that link operational processes with business planning. In this way, the IIoT platform will be able to display indicators that contextualize the information provided by the operation data with planning information.

References

1. Walas Mateo, F., Redchuk, A. "Artificial Intelligence as a Process Optimization driver under industry 4.0 framework and the role of IIoT, a bibliometric analysis". – JIIM. Journal of Industrial Integration and Management Innovation & Entrepreneurship. ISSN (print): 2424-8622 | ISSN (online): 2424-8630. (2020)
2. Walas Mateo, F., Redchuk, A. "A review of IIoT/IoT and AI/ML as Process Optimization driver under industry 4.0 model". Journal of Computer Science & Technology (JCS&T). Vol 21. ed. 2, pp 170-176. (2021).
3. Lepenioti, K., Pertselakis, M., Bousdekis, A., Fenareti Lampathaki, A. L., Apostolou, D., Mentzas, G., Anastasiou. S. "Machine Learning for Predictive and Prescriptive Analytics of Operational Data in Smart Manufacturing." Dupuy-Chessa S., Proper H. (eds) Advanced Information Systems Engineering Workshops. CAiSE 2020. Lecture Notes in Business Information Processing, vol 382. Springer, Cham. https://doi.org/10.1007/978-3-030-49165-9_1
4. Tapoglou, N.; Mehnen, J.; Butans, J. Energy Efficient Machining Through Evolutionary Real-Time Optimization of Cutting Conditions on CNC-Milling Controllers. In Experiments and Simulations in Advanced Manufacturing; Springer: Berlin/Heidelberg, Germany, 2021; pp. 1–18.
5. Gartner. When IT and Operational Technology Converge. Available online: https://www.gartner.com/smarterwithgartner/when-it-and-operational-technology-converge (accessed 3rd February 2023).
6. E. Yalcinkaya, A. Maffei, H. Akillioglu, M. Onori. (2021). Empowering ISA95 compliant traditional and smart manufacturing systems with the blockchain technology. Manufacturing Review. 8, 15
7. W. He, L. Xu. (2014). Integration of Distributed Enterprise Applications: A Survey. IEEE Transactions on Industry Informatics, 10(1), pp. 35-42.
8. Patera, L.; Garbugli, A.; Bujari, A.; Scotece, D.; Corradi, A. A Layered Middleware for OT/IT Convergence to Empower Industry 5.0 Applications. Sensors 2022, 22, 190.
9. Siemens. https://new.siemens.com/es/es/productos/software/mindsphere.html (accessed 3rd February 2024).
10. OpenJS Foundation & Contributors. Node-RED. https://nodered.org.Author, F.: Contribution title. In: 9th International Proceedings on Proceedings, pp. 1–2. Publisher, Location (2010).