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Intelligent Learning Environments

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Editorial

Virtual learning environments are available around the world every single day. Since March 2020, we are used to attend virtually many activities and education is not an exception. The SARS-CoV-2 virus provoked that learning activities migrate to virtual environments in all educational levels.

On the other side, Artificial Intelligence has impacted many activities and now we notice that many aspects of our lives have changed due to its non-stopping influence. In Education, we notice the emergence of new systems and apps that help students to learn online at their own peace.

Researchers are innovating by mixing theories and technology to provide learning environments that personalize learning processes for each student.

Researchers have applied several artificial intelligence techniques to develop educational software systems that students can use to gain knowledge and learn at their own pace in different virtual or digital environments. All new developments need to be made known through journals and other forums.

In this volume, our goal is to offer researchers an opportunity to show their work exploring new ways of applying AI techniques in the development of educational systems. We present seven research works, in various fields of intelligent learning systems.

The papers were carefully chosen by the editorial board based on three reviews by the specialists of the Technical Committee. To select the papers to be published the reviewers considered the originality, scientific contribution to the field, soundness, and technical quality of the papers.

Many people participated in preparation of this volume, we appreciate the support of RedICA (Conacyt Thematic Network in Applied Computational Intelligence) members that were part of the Technical Committee as well as members of Mexican Society for Artificial Intelligence (SMIA Sociedad Mexicana de Inteligencia Artificial). Last, but not least, we thank Centro de Investigación en Computación-Instituto Politécnico Nacional (CIC-IPN) for their support in preparation and publication of this volume.

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Guest Editors

October 2021

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CARLA 0.9: Now with more Analytics!

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Abstract. E-Learning offers new mechanisms for easing interactions with learning environments. In an earlier work the Conversational Agent based in viRtual reaLity with Analytics (CARLA) was introduced. This is a chatbot that provides interaction within a virtual reality E-Learning platform through spoken dialogue. However, its knowledge base was restricted to a local database. To expand it, a search engine is integrated into the chatbot. Furthermore, to recommend new knowledge a recommender system can be employed which is dependable on a semantic similarity measure. Therefore, in this work we improve the CARLA framework by including a search engine for the dialogue manager, and provide support for recommendations. In particular, the recommender system is built upon the Normalized Web Distance which allows semantic comparison of words and concepts using a large corpus. Results using the Google and Wikipedia search engines show a high correlation against expert and common knowledge respondents, emphasizing that the Normalized Web Distance can be employed to suggest users new knowledge through the chatbot based on topic similarity and user queries.

Keywords: conversational agent, virtual reality, natural language processing, search engine, recommender system.

1 Introduction

E-learning technologies are of increasing importance in education and Virtual Reality (VR) environments are key in this area [5]. VR provides contextualized knowledge, improves learning through exploration and repetition, and has several degrees of freedom [7]. Furthermore, as Natural Language Processing (NLP) technologies mature, more conversational agents are being adopted within VR E-learning platforms. These have a wide range of applications including (but not restricted to) tutoring, question answering, language conversation practice, learning companions, and so on [4]. A new VR chatbot is CARLA: a Conversational Agent in viRtual reaLity with Analytics. It is based on Google® speech to text, Stanford CoreNLP, and Microsoft® Azure's text to speech technologies [5]. It is designed to eventually serve as a tutoring system situated in a virtual reality environment. In its current state, CARLA provides knowledge and support to a given user through an interchange of spoken utterances for manipulating objects and navigating the virtual world.

Nevertheless, CARLA was restricted to its local knowledge defined by experts in an internal database. Its maintenance and management is expensive, time costly, and error prone. In this sense, the Dialogue Manager (DM) of any chatbot that is constrained to such setup cannot provide unknown information nor discover new knowledge. To ameliorate this, a Search Engine (SE) is added to the DM of the chatbot [2]. This is a tool for improving the existing knowledge domain by adding search capabilities using a large text corpus such as the world wide web (www). Even though today SEs are optimized to show high relevance results, this optimization is oriented to the advertising of commercial results. Such bias will not be desirable for educational purposes since SEs may provide results with little to no pedagogic value [2].

To improve this, a Recommender System (RS) can be employed, with Collaborative Filtering (CF) being the most prevalent type [3]. It clusters users or items by comparing user-user or item-item similarity, respectively. However, CF based only in local resources has two main drawbacks: it requires a large amount of data to avoid the sparsity in the similarity matrix, and it suffers from cold-start (new items which lack of knowledge). To avoid this, the Normalized Web Distance (NWD) has been employed [3]. The NWD can be used to identify similarity between topics, either in the local resources or collected from user queries, done through the SE which has a readily available large text corpus such as the www [6].

Therefore, in this work the CARLA framework is improved by 1) integrating a SE such that unknown knowledge in the current database can be found and provided to users on request, and 2) building a recommender system to suggest new learning resources based on items' semantic similarity given by the NWD. In particular, we compare the chatbot recommendations' ability against human expert and common knowledge respondents. For this, 20 triplet concepts (10 specific and 10 common topics) are compared using an online survey. In parallel, Google and Wikipedia SEs are used to calculate the NWD over the 20 triplets.

The results show that there is a high correlation between the scores obtained by humans and the NWD over the 20 triplets, specifically the ones obtained by the Wikipedia search engine. The rest of the paper is organized as follows: section 2 presents the materials and methods; section 3 presents the experimental setup and the results of the experimentation; section 4 presents conclusions and discusses future work.

2 Materials and Methods

CARLA is an embedded chatbot framework for Virtual Reality (VR) using low-cost or free technologies. As any other chatbot, its main components are the Natural Language Understanding (NLU), the DM, and the Natural Language Generator (NLG).

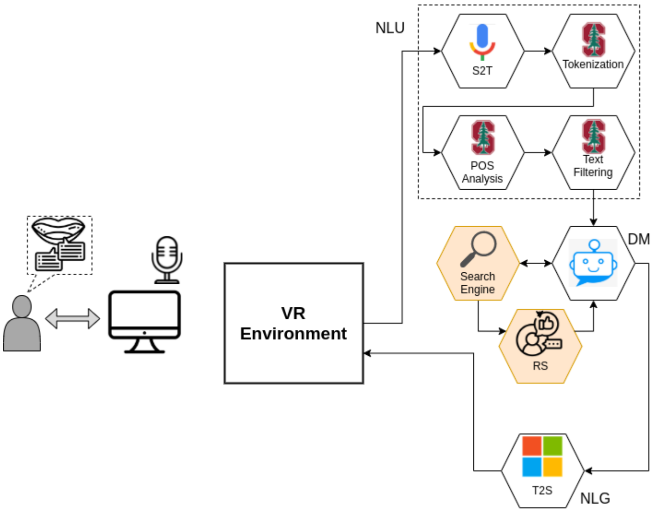

Fig. 1. CARLA framework with the DM and SE.

To improve the DM a search engine is added. This SE is used to create a recommender system based on the NWD. In Fig.1, we present the structure of the improved CARLA framework where the highlighted components represent the new additions.

2.1 Search Engine

A DM and SE are the two main components of any chatbot [2]. However, since CARLA was limited to its hard-coded database, it was necessary to implement a SE that could provide the user information unknown to CARLA. Also, the chatbot needs to be able to find answers in structured data and manipulate them in order to present them to the user. In this manner, when asking CARLA something, the DM checks if it has that information internally and if not, it asks the user if they would like to search for the information on a SE such as Google or Wikipedia; if the user confirms, CARLA will carry out the request and extract the first result given by the SE.

If the results obtained from the SE do not fully match what the user requested, they will be asked if they would like to hear the extract from the page anyway. Technically, the DM gets the information by requests to an API web service such as Google Search or the MediaWiki Action. Both are RESTful web services based on the *OpenSearch* bundle, a technologies collection which allows publishing search results in other websites and gathering results from multiple sources [1].

For example, the MediaWiki Action API allows searching and fetching information from any domain created for a Wikimedia project, such as the categories to which it belongs, images it contains, descriptions, page extracts, and even allowing page operations like creating or deleting a page. The Snippet 1.1 shows the results obtained by the API of a full-text search of *Computadora* from Wikipedia in Spanish with a

GET request to[4] which contains information such as the number of pages that contain the term, as well as information from all of them, including the title, its word count or an excerpt from every page.

Snippet 1.1. API results coded into json format

```
{
    "batchcomplete": "",
    "continue": {"sroffset": 10,"continue": "-||"},
    "query": { "searchinfo": {"totalhits": 13841},
        "search": [{
                "ns": 0,"title": "Computadora",
                "pageid": 8985,"size": 33529,
                "wordcount": 4085,
                "snippet": "La <span class=\"searchmatch\">
    computadora</span>[1]\u200b[2]\u200b (del ingl\u00e9s:
    computer y este del lat\u00edn: computare,[3]\u200b
    \u2018calcular\u2019), tambi\u00e9n denominada <span
    class=\"searchmatch\"> computador</span>[4]\u200b[1]
    \u200b u ordenador[5]\u200b (del",
                "timestamp": "2021-08-17T22:41:40Z"},
            {
                "ns": 0, "title": "Computadora port\u00e1til",
                "pageid": 9086,"size": 23757,
                "wordcount": 3222,
                "snippet": "Se denomina <span
    class=\"searchmatch\"> computadora</span> port\u00e1til,
    <span class=\"searchmatch\">computador</span>
    port\u00e1til u ordenador port\u00e1til, a un
    determinado dispositivo inform\u00e1tico que se puede
    mover o transportar con",
                "timestamp": "2021-07-30T20:29:57Z"
            }]}
}
```

2.2 Normalized Web Distance for Powering a Recommender System

A universal similarity measure is the Normalized Information Distance (NID), which allows identification of the similarity between two objects based on Kolmogorov complexity. However, the Kolmogorov complexity is not directly computable, thus, its practical application is cumbersome [8]. A measure which is based on the NID is the so called NWD. This measure employs the www and SE to approximate the semantic similarity (circumventing the need of estimating the Kolmogorov complexity) between two queries or concepts.

In particular, the NWD excels in determining the semantic similarity for *non-literal objects* that do not contain information within themselves [6]. Take the concept *wind* for example, the sequence of letters or the word itself does not contain any information

[4] https://es.wikipedia.org/w/api.php?action=\\query&list=search&srsearch=Computadora

regarding what *wind* stands for. Formally, if x and y are two different concepts within the set W of all web pages in the www corpus, i.e., $x, y \in W$, then, the NWD between these two is given by

$$NWD = \frac{\max\{\log f(x), \log f(y)\} - \log f(x,y)}{\log N - \min\{\log f(x), \log f(y)\}}, \tag{1}$$

where $f(x)$ and $f(y)$ are the number of pages containing term x and y respectively, $f(x,y)$ is the number of pages containing both x and y, and N is a large constant corresponding to the total number of indexed pages. The NWD is roughly between 0 and infinity, obtaining values close to zero for objects which are very similar, and one or larger for very dissimilar objects. In some cases the NWD can obtain values below zero if $f(x,y) > \max\{f(x), f(y)\}$, or infinite if objects do not appear together on the same page, but do occur separately.

Also, the NWD is considered a relative similarity measure between two concepts (due to its dependence to the SE) rather than a similarity metric [6]. On the other hand, for a proper usage of the NWD for powering a recommender system, the proper SE needs to be selected. It is the case that many SEs are optimized for advertisements. If we employ a biased SE to calculate the NWD, we can hinder new knowledge suggestions to a given user. Therefore, to evaluate this hypothesis we employ Google and Wikipedia as SEs. The first is the most popular SE, whereas the second is a free, multilingual, online encyclopedia written mainly by volunteers.

3 Experimentation

In the following, we analyze the level of knowledge agreement between humans and the NWD using two different SEs. First, we present the details of the survey answered by human participants. Then, we present the analysis of the results obtained by the two SEs, and the comparison with the survey results.

3.1 Survey and NWD Calculation

We elaborated a survey[5] with triplets of concepts where participants are requested to determine which of two options is the more closely related to a given concept. In the first part of the survey users informed consent and personal data is gathered. The latter is conformed by gender, age group, educational level, and country. It is worth mentioning that for the educational level we consider the following groups: primary, secondary, high school, undergraduate, and postgraduate.

The survey was responded 130 times by 56% male, 43% female, and 1% did not specify. Regarding the age group, 50% of the participants were older than 30, 44% were between 18 and 29 years old, and only 6% were between 12 and 17 years old.

Regarding the educational level, 38% of the participants were high school students, 36% of the participants had some postgraduate degree, 25% were undergraduate students, and only 1% were secondary school students. Regarding the nationality of

[5] https://forms.gle/sDBZdfVFgRTGiPXc7

the participants, 98% were Mexicans, and 2% from other countries. The second part of the survey assesses 20 triplets' (e.g., (A,B,C)) kinship using a Likert scale. This scale presents a given concept (e.g., A), and asks human participants to assess its similarity with two others (e.g., B and C), with one of them, for a physical or chemical reason, being more related to the main concept. Some triplets show highly related concepts, while others have concepts with high similarity to one another.

The intention is to determine the level of *agreement* between users and the NWD. The scale ranges from 0 to 10 (from left to right), and the concepts are presented in opposite sides. In this sense, if the human chooses 0, concept B is the most related to A; if instead human picks 10, concept C is the most related to A. If both concepts B and C are equally similar/dissimilar to A, then, humans need to pick the middle value of the scale (i.e., 5). The triplets are composed by 10 concepts in renewable energy and 10 from general domain. For the former, we only consider the answers of participants with some postgraduate degree given that more advanced knowledge is required; an example of this type of triplet is (*energía fotovoltaica, aerogenerador, panel solar*) (translated to English: photovoltaic energy, wind turbine, solar panel).

For the latter, the responses of all participants is considered; an example of this type of similarity assessment is $(\textit{manzana}, \textit{pera}, \textit{libro})$ (translated to English: apple, pear, book). To determine the similarity assigned by human participants, for each item of the survey the mean value of the responses is calculated. On the other hand, given a triplet of concepts we use the NWD and two different SEs, namely Google (NWD_G) and Wikipedia (NWD_W), to determine the similarity between the main concept and the other two. For both cases Eq. 1 is employed to calculate the similarity between the concepts i.e., $NWD_{G,W}(A,B)$ and $NWD_{G,W}(A,C)$. For each SE two results are obtained, thus, to determine the most related concept the lowest value (i.e., the most semantically related) is selected.

3.2 Similarity Comparison and its Use for Recommendation

Results about renewable energy and the general domain concepts for the survey and the $NWD_{G,W}$ are presented in Table 1 and Table 2, respectively. The most semantically related pair of concepts are highlighted in bold. First, observe that in the case of the survey with human participants, and for most of the items, a high polarization is shown i.e., tending to just one or the another concept. In contrast, results for the $NWD_{G,W}$ show less polarization. This is very interesting, since humans tend to provide more polarized answers, presumably because their knowledge is highly contextualized.

For example, for the last triplet of Table 1 which translates to (coal, mine, dam), humans with specialized knowledge provide a value of 0.15 which depicts a high similarity between *coal* and *mine*. In contrast, the NWD_G achieved a 0.69 and 0.55 for the NWD_W, which highlights similarity but not quite as sharply as human participants considered. Nevertheless, *for a given concept and two options, do humans and the NWD agree in picking the most similar concept?*

The answer is yes, with a linear correlation of $\rho = 0.99$ for the renewable energy concepts and $\rho = 0.95$ for the general domain concepts, regardless of the SE (with a $\rho = 1$ between the NWD_G and NWD_W). These results are encouraging since the NWD can be used to suggest new, semantically similar concepts or topics to a user given their history of already-reviewed topics. On the other side, regarding the agreement between survey participants' mean scores and the raw score obtained by the heuristic of picking the lowest NWD value, for the renewable energy domain, the NWD_G obtained a higher correlation $\rho(NWD_G) = 0.93$ in comparison to $\rho(NWD_W) = 0.9$, with a level of agreement between the two of $\rho(NWD_{G,W}) = 0.89$.

For the general domain concepts, the agreement with humans is $\rho(NWD_W) = 0.94$ and $\rho(NWD_G) = 0.89$, and an agreement between the two SEs of $\rho(NWD_{G,W}) = 0.87$.

These results are counterintuitive given that one would expect that the NWD_W, based on an encyclopedia, should be biased towards domain specific knowledge, whereas the NWD_G should work better for general domain concepts given its bias to the advertising optimization. This might be caused by the Wikipedia SE being constrained to its Spanish version whereas Google SE is open to any language.

Table 1. Survey and NWD results for renewable energy concepts.

Triplet	Survey	$NWD_G(A,B)$	$NWD_G(A,C)$	$NWD_W(A,B)$	$NWD_W(A,C)$
(energía fotovoltaica, aerogenerador, panel solar)	9.59	0.7	**0.01**	0.33	**0.22**
(energía geotérmica, volcán, marea)	0.34	**0.6**	0.77	**0.16**	0.76
(energía eólica, aerogenerador, panel solar)	0.13	**0.31**	0.47	**0.13**	0.71
(almacenamiento de energía, baterías, cable)	0.13	**0.55**	0.86	**0.44**	0.75
(combustible fósil, renovable, no renovable)	9	0.44	**0.33**	0.43	**0.22**
(electricidad, televisión, estufa)	0.88	**0.54**	0.63	**0.56**	0.69
(térmico, calor, luz)	0.54	**0.42**	0.66	**0.49**	0.91
(energía no renovable, energía hidráulica, central nuclear)	7.56	0.27	**0.05**	0.71	**0.32**
(energía renovable, gasolina, granja eólica)	9.88	0.77	**0.11**	0.58	**0.43**
(carbón, mina, presa)	0.15	**0.69**	0.75	**0.55**	0.92

Table 2. Survey and NWD results for general domain concepts.

Triplet	Survey	$NWD_G(A,B)$	$NWD_G(A,C)$	$NWD_W(A,B)$	$NWD_W(A,C)$
(manzana, pera, libro)	0.54	**0.42**	0.68	**0.55**	1.19
(nube, agua, algodón)	1.83	**0.36**	0.72	**0.74**	0.76
(experimento, laboratorio, datos)	2.85	**0.45**	0.53	**0.62**	1.15
(plato, cuchara, pelota)	0.51	**0.45**	0.82	**0.90**	1.12
(pepino, sándwich, ensalada)	8.91	0.6	**0.34**	0.67	**0.37**
(robot, ciencia, tarot)	0.35	**0.27**	1.57	**0.75**	0.8
(vehículo, movimiento, mar)	0.84	**0.56**	1.02	**0.84**	1
(sillón, silla, mesa)	1	**0.5**	0.7	**0.6**	0.73
(zapato, pie, mano)	0.29	**0.63**	0.76	**0.82**	1.1
(lentes, vista, oidos)	0.32	**0.71**	0.74	**0.72**	1.07

4 Discussion and Conclusion

Conversational Agent in viRtual reaLity with Analytics (CARLA) is a spoken chatbot built upon natural language tools such as Google NLU, Stanford CoreNLP library, and Microsoft NLG. However, CARLA was restricted to its local, limited, expert-curated knowledge database, which limited its pedagogical usage and made its maintenance expensive.

To ameliorate such burdens, we improve CARLA by adding to its dialogue manager a SE. This allows the exploration of a large text corpus such as the www, for knowledge not already available to CARLA. Moreover, the usage of a SE allows the DM to estimate the NWD which can be used to assess semantic similarity between topics.

This feature can be used by a recommender system to suggest new topics to a user, related to the knowledge already explored by them. Therefore, to assess the NWD potential for powering a recommender system, we compare the similarity assigned to triplets of concepts between humans and the NWD obtained using two different SEs (Google and Wikipedia). The agreement between humans and the NWD for the survey items as measured by the linear correlation is, in general, $\rho \geq 0.9$.

These results are encouraging since the NWD can be used to suggest new, semantically similar concepts or topics to a user given their history of already reviewed topics. Such topics can be located within CARLA's local knowledge base or in the pervasive www. However, which SE must be used to suggest new semantic similar topics is still an open question.

Therefore, future work will involve the construction of a semantic concepts network, built upon the NWD, which will be used by the chatbot to walkthrough a given knowledge area. Then, the users will be requested to evaluate the concepts roadmap using different SEs.

References

1. Clinton, D.: Spezifikation opensearch 1.1 draft 3 (2007), http://www.opensearch.org/Specifications/OpenSearch/1.1
2. Galitsky, B.: Developing Enterprise Chatbots. Springer International Publishing (2019)
3. Huang, T.C.K., Chen, Y.L., Chen, M.C.: A novel recommendation model with Google similarity. Decision Support Systems 89, 17–27 (2016)
4. Kerry, A., Ellis, R., Bull, S.: Conversational agents in e-learning. In: International Conference on Innovative Techniques and Applications of Artificial Intelligence. pp. 169–182. Springer (2008)
5. Macias-Huerta, P.I., Santamarıa-Bonfil, G., Ibanñez, M.: Carla: Conversational agent in virtual reality with analytics. Research in Computing Science 149(12), 15–23 (2020)
6. Santamaría-Bonfil, G., Díaz-Rodríguez, H.D., Arroyo-Figueroa, G., Batres, R.: Knowledge modelling for ill-defined domains using learning analytics: Lineworkers case. In: International Conference on EUropean Transnational Education. pp. 409–418. Springer (2020)
7. Santamaría-Bonfil, G., Ibáñez, M.B., Pérez-Ramírez, M., Arroyo-Figueroa, G., Martínez-Álvarez, F.: Learning analytics for student modeling in virtual reality training systems: Lineworkers case. Computers & Education p. 103871 (2020)
8. Vitanyi, P.M.B., Balbach, F.J., Cilibrasi, R.L., Li, M.: Normalized Information Distance, pp. 45–82. Springer US, Boston, MA (2009)

Model of Integration of Verbal and Nonverbal Expressions for Credible Virtual Agents

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Abstract. For the development of a credible virtual agent, it is important that this agent has characteristics to create a more immersive experience for users and increases the effectiveness of communication. One of these characteristics is the ability to interact through verbal and non-verbal communication. That is why in this work an integration model of dialogue, facial and gestural expressions are proposed, where it is essential to consider the attributes of emotions and personality because these directly influence the expressions. This paper proposes the use of an optimization method named ELECTRE III for the process of selection of dialogue, facial and gestural expressions, using a corpus characterized by diverse criteria based on the influence of personality and emotions.

Keywords: virtual agent, verbal expressions, nonverbal expressions, selection, ELECTRE III.

1 Introduction

The moment we enable a face-to-face conversation aspects like verbal and nonverbal language are involved. If we develop a virtual agent that can participate in conversations and has the appearance of a human, it would be expected that it acts like one. For this behaviour to be congruent it is important that it communicates through dialogue, also with facial and corporal expressions as well. For the integration of the different elements that implicate verbal and nonverbal expressions in a virtual agent, it is proposed a selection model based on an outranking method called ELECTRE III [6]. This will allow us to create a credible virtual agent that can respond to social interactions with a natural behavior similar to a human. This way it will be able to make the user immerse in the virtual environment and develop a feeling of social presence.

The development of a credible virtual agent involves elements that need to be considered so that the communication of the agent is coherent and it interacts in a similar way to the human behavior. To accomplish this, it is necessary to develop a process of integration, in which the following areas are taken into

pp. 17–24; rec. 2021-07-20; acc. 2021-09-29

consideration: face-to-face conversation where language is involved, nonverbal behavior, emotions and personality, because human behavior is influenced by these areas [7]. This way the agent will be able to hold a fluent conversation using dialogue, facial and corporal expressions simultaneously, in a natural way and accordingly to the presented situations.

2 Related Work

This paper will provide a brief description of the background of projects related to credible virtual agents and how these impact the development of this project.

The work of Gratch [7] was one of the first ones where different elements that need to be considered to build a credible virtual agent were formalized. For the author, an agent must look and act like a person and at the same time, be able to enable a conversation. The main goal of this work is to develop a modular architecture and interface standards that allow future researchers to study each one of the three key areas of virtual human development, which consist of: face-to-face conversation, emotions and personality, animation of the human figure. All these elements raised by the author will serve as a basis for the realization of this work.

The work of Rosis [11] and colleagues was to develop an agent that has a natural appearance and behavior, for this very reason a prototype of a talking 3D head named “Greta” was designed. To reach this goal a cognitive model was presented, which was named “mind”, where its beliefs, desires and intentions were established. This model is used to simulate how the agent reacts to the events that occur during a conversation. The second model that was intended to complement the cognitive model, was the “body”. This model has access to a repertoire of signals that the agent can use in its communication process, for example, the facial expressions, head movement, sight direction, etc. The union of mind and body modules allows that the different contents of the message are expressed by the agent.

Greta was designed as a BDI [5] (Beliefs, Desires, Intentions) agent, whose state of mind integrates a representation of the beliefs and goals that drive the feeling of emotions and the decision to show or hide them. This characteristics will allow the user to have the impression of communicating with a person and not with a computer. As it was mentioned, for an agent to have a natural appearance, similar to the one of a human being in a face-to-face conversation, it is important to automatically generate the nonverbal expressions from the dialogue.

Because of the nonverbal behavior being affected by the personality, it is important to generate expressions that go accordingly with the personality of the agent. The work of Ishii [9], shows how the personality can help to improve the prediction of the nonverbal behavior for the whole body, this is what we refer to head movement, eyes, hands and posture. For the making of this study, verbal and nonverbal information was recollected, personality traits of a human conversation were recollected as well.

The model that was used to represent the personality was Big Five [8] (approaching, conscience, extroversion, likeability and neuroticism), which is an indicator of personality traits and it is one of the most accepted in academic psychology. To evaluate the significance of the Big Five model in nonverbal language, models of behavior generation were implemented with and without the Big Five model. According to this experiment, it was proved that the Big Five model is useful to generate nonverbal expressions. With this work, it is possible to identify the importance and effect that personality produces in the generation of nonverbal expressions.

The work done by Delgado [3] was the development of an agent which integrates the element of personality in the process of selection of phrases from a corpus characterized through acts of speech, using the ELECTRE III selection method. Delgado proposes an architecture with five principal components that are required in a conversational agent: perception, memory and knowledge, behavioral model, answer selection and action. From these modules the author incorporates the influence of the personality for the selection of phrases from an agent, providing more realism and credibility.

At the same time another work that was analyzed, was the one made by Reyes [10], which goal was the development of a software mechanism that integrates the selection of phrases and nonverbal expressions in assistants and/or video games based on web platforms. This work is based on Delgado [3] for the selection of phrases and uses the character "Kathia" as a representation of the developed animations [12]. This paper proposes a deliberative agent architecture and the analysis done for their development.

The agent personality influences the process of selecting speech, facial and gestural expression from a characterized corpus while measuring the similarity based on outranking relationships and the impact of personality in the preferences of the user as a measure of expression selection.

3 Theoretical Framework

In this section, it will be presented the theoretical framework of the development of a conversational deliberative agent and the role of the personality in the selection process of expressions using the method ELECTRE III.

3.1 Conversational Deliberative Agent

A Conversational Deliberative Agent (CDA) [5] has to emulate human behavior within speech, facial and gestural expressions, so it needs its own traits and reasoning that defines its responses during a conversation. This kind of agent needs to integrate beliefs, desires and intentions, alongside its perception of the conversation environment to select an expression that responds appropriately to the context of the conversation. The selection of dialogue, facial and gestural expressions in this virtual agent is based in an outranking method called ELECTRE III.

3.2 ELECTRE III

The ELECTRE model consists of a family of methods that belongs to the area of multi-criteria assistance of decision making [6]. The goal of the ELECTRE III model is to order different alternatives in a problem, leading to the generation of diverse criteria. This model allows the incorporation of the imperfection and uncertainty that is always present in a decision-making process while defining the parameters of preference and indifference [2]. To achieve this is necessary to use a ponderation for the criteria.

Traditional methods of classification come from preference and indifference. In ELECTRE III for every pair of alternatives, there is a measurement of concordance and discordance, the goal of the model is to combine these two measurements to produce a measurement for the degree of over-classification, in other words, an index of credibility, which validates the process of decision-making of choosing one alternative over the other one in a problem [6]. For the application of the ELECTRE method, a matrix of performance needs to be developed [2]. Where each linguistic variable needs to be indicated and also needs to receive a weight of importance.

After establishing the values of these variables, making a matrix that compares the values of the alternatives against the criteria that were previously established for the problem and lastly making a matrix that takes into consideration the level of concordance, a decision can be made about which alternative is the best for solving the problem presented.

3.3 Personality

To take into consideration the personality attributes for the selection of the nonverbal expressions in the agent, the MBTI [1] (Myers-Briggs Type Indicator) model was used. The MBTI is a psychometric test designed to evaluate the personality type of people from four dichotomies that are defined as polar opposites in eight categories. Each category is represented by a letter and because of this the results are shown in 16 possible combinations of four letters. Based on these combinations, four big groups can be identified: analysts, diplomats, sentinels and explorers [4].

This paper will only show the description of the characteristics of the personality type that was selected for the agent: **IFNJ Lawyer-Diplomatic**, the people with this profile tend to look for meaning and connection in ideas, relations and material possessions. They want to understand what motivates people and they are really perceptive about others. They are conscious and committed to their values. They develop a clear vision about what is best to serve the common good, usually organized and decided on the implementing their vision [1].

4 Proposed Architecture for the Integration of the Selection of Verbal and Nonverbal Expressions of a CDA

This paper proposes the architecture presented in Fig. 1 as a means of building a CDA that integrates verbal and nonverbal communication. This architecture is constituted by five principal components: perception, behavioral model, internal state of the agent, selection model and animation. All of these components must exist in a virtual agent to be credible:

- Perception: through this module, the agent will be able to perceive the state of the dialogue that develops with the user, which means the perception of all the data of the environment that will serve to characterize said context.
- Behavioral model: this model is in constant change because the emotions and intentions of the agent are established here.
- Internal state of the agent: in this component, the parameters such as personality and motivation are defined, which will be maintained during the whole process.
- Model of selection of verbal and nonverbal expressions: this module is integrated by the management of dialogue and a kinesic model, which are influenced by the behavioral model and the internal state of the agent. this kinesic model has two phases, the first phase is the emotional expression, that as its name indicates is the one that solves the emotional behavior, this first phase will have the responsibility of categorizing and choosing the nonverbal expressions of the agent, which means the gestural, postural and facial expressions. Subsequently, the second phase is the model of integration, which will have the responsibility of choosing in a definitive manner and combining the verbal and nonverbal selections to generate the animation. This module is where the contribution of this paper is centered.
- Animation: the last module will have as an input the verbal and nonverbal expressions previously selected and will be reported to the user.

4.1 Agent Personality

To model the personality expression and identify the facial and corporal expressions a video analysis of the interactions of the 4 personality type was done.For example, was observed that a person with a diplomatic type, is a person that smiles on a few occasions, which is one of the characteristics of an introverted person and, according to the personality type description it is a characteristic trait in them, however, in spite of showing seriousness it is an empathetic person that shows caring for others.

Regarding the corporal movements, they were almost null, there was no arm movement, even if there was movement from one side to the other. The video analysis of the interaction was used associated with the literature to establish the characteristic expressions of each of the personality types and thus obtain the characterization of the corpus according to the personality.

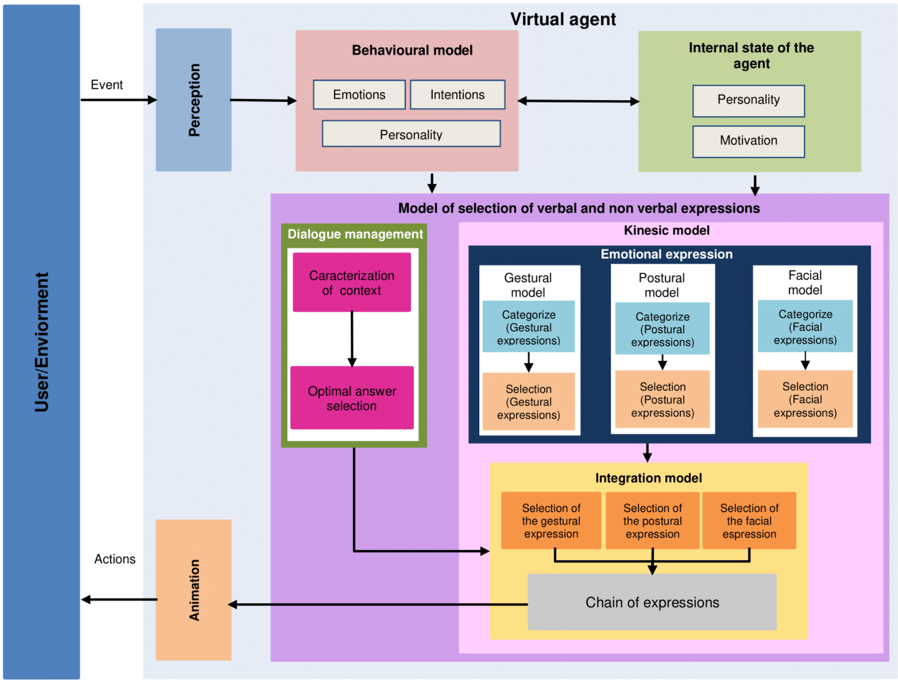
User/Enviorment
Event
Actions
Virtual agent
Perception
Behavioural model
Emotions
Intentions
Personality
Internal state of the agent
Personality
Motivation
Model of selection of verbal and non verbal expressions
Dialogue management
Caracterization of context
Optimal answer selection
Kinesic model
Emotional expression
Gestural model
Categorize (Gestural expressions)
Selection (Gestural expressions)
Postural model
Categorize (Postural expressions)
Selection (Postural expressions)
Facial model
Categorize (Facial expressions)
Selection (Facial expressions)
Integration model
Selection of the gestural expression
Selection of the postural expression
Selection of the facial espression
Chain of expressions
Animation

Fig. 1. Proposed architecture.

4.2 Corpus

The process of selection requires a corpus characterized by diverse criteria. The criteria used to characterize the corpus dialogue was the one applied by Delgado [3]. 33 criteria were proposed for this work to characterize the nonverbal expressions of the agent. Table 1 shows the criteria grouped into 4 categories: intention (21), emotion (4), context (4) and personality (4).

Table 1. The criteria proposed as characterized features of the corpus of facial and gestural expressions.

item	Criteria groups	Criteria
1	Intention	Sorry, Complaint, Sentimental expression, Attitudes, Affirmation,Statement, Explanation, Report, Suggestion, Petition, Question, Order, Mandate, Baptize, Inaugurate, Name, Dismiss, Promise, Oath, Offer,Threat.
2	Emotion	Joy, Fear, Sadness, Angry
3	Context	Social, Historic, Cultural, Educational
4	Personality	Analytical, Diplomatic, Sentinel, Explorer

5 Experimentation and Results

In this section, the CDA architecture is validated through a case study based on a dialogue between a student and tutor to compare the forecast of the expressions given by architecture and the expressions of people. From the 4 persons recorded, it was selected the person with the diplomatic personality type. This person had the role of the tutor. The components of the body evaluated were for facial expression, eye, eyebrow and mouth movements, and for gestural expressions, arms. Table 2 shows the results of 12 different interactions.

Where we can see a comparison between the expected expression that reinforces the selected sentences, that is, the expression used by the person with the role of tutor, versus the expression that was assigned by the ELECTRE III method. Were Fn is the variable that represents facial expressions and Gn represents gestural expressions. A complete accuracy of 67% was obtained, and the percentage achieved for the partial accuracy of facial expression was 75% and gesture expression was 75%.

Table 2. Comparison of the expressions resulting from the experimentation of 12 interactions with a diplomatic personality type.

Interaction	Expected expression	Assigned expression
1	F5, G5	F5, G5
2	F5, G5	F5, G5
3	F5, G5	F5, G5
4	F5, G5	F5, G5
5	F5, G5	F5, G5
6	F2, G5	F2, G5
7	**F5, G5**	**F3,G1**
8	**F2, G5**	**F5, G2**
9	F5, G5	F5, G5
10	F5, **G5**	F5, **G2**
11	**F1**, G5	**F2**,G5
12	F1, G5	F1, G5

As can be seen in the table, the identifiers of the expressions in bold were the inconsistencies between the expected expressions and the assigned expressions.

6 Conclusion and Future Work

This paper proposes the use of ELECTRE III, an optimization method for the integration of dialogue, and nonverbal expressions that use a corpus characterized by various criteria based on the influence of personality and emotions. In this work, the dialogue, facial expression, and gestural expressions are independent processes, using the same method ELECTRE III. In the future, seeking better results, nonverbal expression will also be determined by the phrase selected to reinforce verbal expression and evaluated with the four personality types.

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References

1. Analytics Limited, NERIS: Tipos de personalidad (2011), https://www.16personalities.com/es/descripcion-de-los-tipos
2. Cuc, I.: Aplicación del método Electre III en la clasificación de clústeres de artesanías. INGE CUC 7(1), 16 (2011)
3. Delgado-Hernández, X.S., Morales-Rodriguez, M.L., Rangel-Valdez, N., Cruz-Reyes, L., Castro-Rivera, J.: Development of conversational Deliberative Agents Driven by Personality via Fuzzy Outranking Relations. International Journal of Fuzzy Systems 22(8), 2720–2734 (2020), http://link.springer.com/10.1007/s40815-020-00817-w
4. Díaz, J.: MBTI y tipos de personalidad: qué, cómo y por qué (2020), https://javierdisan.com/2020/01/22/mbti/
5. Fernández, C.A.I., Ayestarán, M.G., Cristóbal, J.C.G.: Definición de una metodología para el desarrollo de sistemas multiagente. p. 322
6. Gento, A.M., Redondo, A.: Comparación del método ELECTRE III y PROMETHEE II: Aplicación al caso de un automóvil p. 11
7. Gratch, J., Rickel, J., Andre, E., Cassell, J., Petajan, E., Badler, N.: Creating interactive virtual humans: some assembly required. IEEE Intelligent Systems 17(4), 54–63 (2002), conference Name: IEEE Intelligent Systems
8. G.Y. Lim, A.: Big Five Personality Traits (2020), https://www.simplypsychology.org/big-five-personality.html
9. Ishii, R., Ahuja, C., Nakano, Y.I., Morency, L.P.: Impact of Personality on Nonverbal Behavior Generation. In: Proceedings of the 20th ACM International Conference on Intelligent Virtual Agents. pp. 1–8. ACM, Virtual Event Scotland UK (2020), https://dl.acm.org/doi/10.1145/3383652.3423908
10. Reyes Nájera, P.D.: Integración de Motor de Selección de Frases basados en Superación para Desarrollo de Asistentes Web. Reporte de Residencias, Instituto Tecnológico de Ciudad Madero, Cd. Madero, Tamps. (2020)
11. Rosis, F.d., Pelachaud, C., Poggi, I., Carofiglio, V., Carolis, B.D.: From Greta's mind to her face: modelling the dynamics of affective states in a conversational embodied agent. International Journal of Human-Computer Studies 59(1-2), 81–118 (2003), https://linkinghub.elsevier.com/retrieve/pii/S107158190300020X
12. Villarreal Hernández, J.A.: Framework para el diseño y animación de personajes renderizables en entornos web. Tesis de Licenciatura, Instituto Tecnológico de Ciudad Madero, Cd. Madero, Tamps. (2017)

AR Application for Learning Electrical Circuits

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Abstract. In the learning of the exact sciences, especially those related to engineering, there has been difficulty in achieving effective learning in the complex topics that these areas of knowledge include, affecting the motivational state of the students. Currently, some applications are based on the use of technology as a learning management tool. However, not all available tools are being used to better capture students' attention. This work aids with the learning of the topic "Electric circuits" in first-grade engineering students by promoting learning, understanding, and application of the benefits that augmented reality technology provides. In addition to being able to change content to each student's learning pace, the fuzzy logic technique based on student interaction allows for content adaptation.

Keywords: augmented reality, fuzzy logic, intelligent learning environments.

1 Introduction

Recently, the use of new technologies aimed at improving the teaching-learning process of students has been increasing considerably, especially in Science, Technology, Engineering, and Mathematics (STEM) from preschool to post grade [1]. Every day, people use mobile devices increasingly often, allowing them to perform various tasks such as making a video call or making an electronic transaction, with smartphones having the highest frequency of use [12]. The increment in the demand for the use of a mobile and the increase in the hardware capacity of the devices has contributed to the integration of technologies, such as 3D virtual environments, virtual reality, and augmented reality, which have proven to be effective to promote learning [4].

Augmented reality (AR) is a technology that complements user's perception of the real world through a contextual layer of three-dimensional information [2], giving the user the possibility of real-time interaction with the over posed digital elements, allowing the user the possibility of visualizing abstract and complex elements, difficult to imagine. On the other hand, artificial intelligence has impacted various areas, and education is no exception, whether it is applying computer vision to evaluate tasks or articles, evaluating students and teachers through adaptive learning methods or

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personalized learning approaches, or create interactive learning environments through facial recognition, virtual laboratories, augmented or virtual reality [13]. The main contribution of this work is the design and implementation of a learning environment that, based on AR technology, supports engineering students to complement their learning process in a complex subject with a high level of abstraction, as it is electrical circuits.

To achieve this, AR has been combined with a fuzzy logic system, to guide the student in a personalized way to solve the different exercises that are presented, superimposing information about the exercise using 3D models to represent the components of electronic circuits and thereby promote active learning.

This work is organized as follows: Section 2 presents related works on the use of augmented reality in education and fuzzy logic applied to educational environments; in section 3 the structure of the learning environment is discussed and explained; section 4 discuss the results obtained from the implementation of the application with students; and finally, section 5 offers the conclusions and future work.

2 Related Works

This section presents related works within AR focused on STEM learning, and works that use fuzzy logic focused on learning. In the area of AR focused on the educational field, studies are aimed at improving the motivation and spatial ability of the student.

Liao [3] designed an assistant system to solve a Rubik's cube using AR, showing clues and aids in the solution process and examining the effects in terms of student improvement, and learning concepts of volume and surface of geometric figures.

Rossano [6] designed Geo+, an application aimed to solve geometry problems in elementary school children, highlighting the ease of use, spatial skills, and the learning gain of the students.

Hruntova [7] created an application aimed at increasing the efficiency of learning based on the laws of physics applied in a laboratory, facilitating the training and cognitive activities of students and improving the quality of the acquisition of knowledge, promoting interest in a topic and the development of research skills.

Ibáñez **[**11] presents the acquisition of knowledge of students where the subject of electromagnetism is evaluated, comparing students who use a Web platform against students who use a mobile application using augmented reality. In this work, variables related to the students' learning flow are measured, concluding that the students who used the AR application had greater user satisfaction, but that there were aspects to improve in terms of usability in it.

Also, Ibáñez [4] presented a review of the state of the art in AR, reviewing 28 applications to promote STEM learning, classifying them, and making an analysis of the measurements they take. One conclusion is that the studies of the papers presented mainly measure affective and cognitive parameters of the students through cross-sectional experiments and that there is a need to diversify the measures to obtain a deeper understanding that goes beyond helping to remember facts and content.

On the other hand, there are also works where fuzzy logic models are implemented to evaluate different aspects of the student in learning systems. Ozdemir [8] propose to determine the effect of a mobile game on the attitude of engineering students using fuzzy logic and variations of the same model, concluding that for situations where the condition is uncertain, fuzzy logic is an effective technique.

Rathore [14] uses a fuzzy inference system to predict student placement in a school using spreadsheets and Matlab, and choosing fuzzy logic due to a large amount of data and variables involved, managing to predict and analyze large sets from students.

Gogo [15] develop a model that recommends relevant learning content to students, using a context-aware approach to obtain student-related data, and then use a fuzzy logic model to recommend learning content taken from a content database of books, tutorials, and videos, reducing the time in which a student manages to obtain learning content according to their level of mastery of a subject.

Karaci [9] proposes an intelligent tutor that uses fuzzy logic to detect errors while the students take questionnaires, creating a model that allows them to choose the following questions that will be asked in a personalized way, improving the overall performance of the students.

3 Structure of the Learning Environment

CircuitAR is a learning tool designed to solve Ohm's law problems, focused on learning electrical circuits in first-grade engineering students. The tool provides the student 3D elements that allow visualizing the physical form, description, and composition of the electrical circuit using batteries and resistors.

For the development of CircuitAR, a methodology for software development with an iterative and incremental approach was used [16], in which the most important requirements are developed in a first version of the software, and later versions are released to meet the other requirements, allowing to take into account the feedback of the previous versions. The learning environment is made up of a mobile application and a web application.

3.1 Architecture

CircuitAR is a learning tool using AR developed in Unity 2020 for Android devices, which implements Vuforia for AR, and Firebase for data persistence. As a complement, CircuitWeb was developed as a web application, that is responsible for manage all the information generated by the intervention with the students, as well as for download the markers. The platform contains 2 main clients: CircuitAR mobile application and CircuitWeb application. Both applications make requests to Google Firebase, which offers different services for the development of cloud platforms.

The services used are (1) *auth*: Registration and authentication of students. (2) *storage*: markers storage. (3) *Firestore*: Document-oriented NoSQL database. It is used for the storage of the data of the students, exercises, markers, and applied exams. Figure

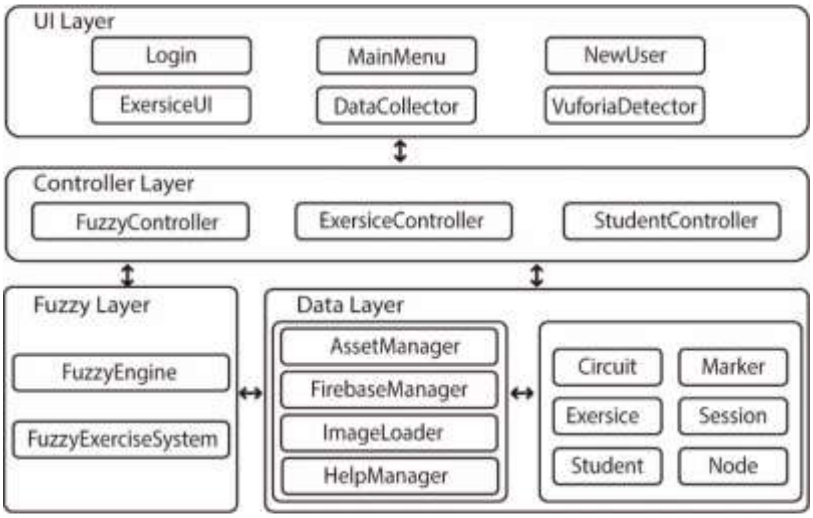
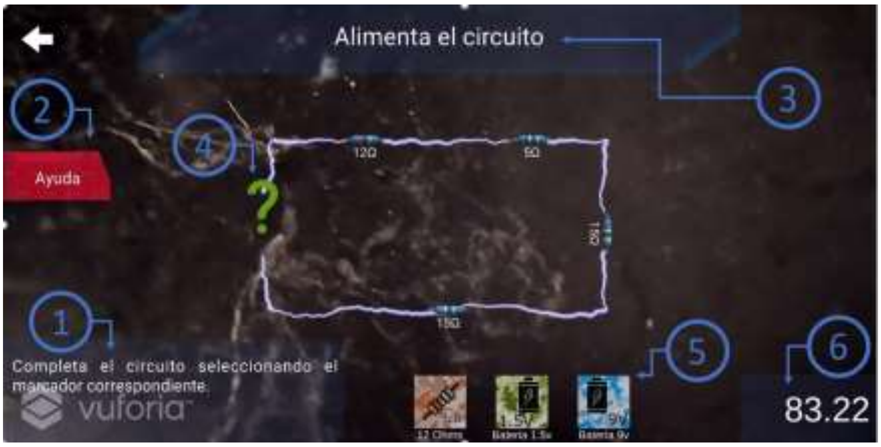


Fig. 1. CircuitAR architecture.



Completa el circuito seleccionando el marcador correspondiente.

Fig. 2. UI interface of one of the exercises to solve.

1 shows the architecture of the CircuitAR mobile application, with its layers and components that make it up. CircuitAR components are described below.

In the ***UI layer***, there is the *ExerciseUI* component, which uses the camera of the mobile device to carry out the AR. It uses *VuforiaDetector* to interpret its image and combine reality with virtual elements for each exercise proposed by the platform. The application will show an incomplete electrical circuit, as well as graphical interface elements that serve the student as didactic support. Examples of these items are aids, instructions, the name of the exercise, and the timer.

For the students to be able to solve the exercises, the AR Engine (Vuforia) needs to recognize a marker, placing it within below the device's camera. When Vuforia recognizes the marker, it superposes the digital elements over it and loads the possible components to complete the circuit shown.

Each marker is uniquely recognized, which allows the Unity Engine to process augmented output according to the position of the marker provided by the student [5].

Figure 2 shows the graphical interface of a CircuitAR exercise, where each number refers to the components to solve the exercise: (1) instructions for solving the exercise; (2) button to request help; (3) the title of the exercise; (4) marker required, where the element generated by the markers should be positioned; (5) markers available for possible response to the exercise; and (6) the timer to solve the current exercise.

The *Controller layer* contains components that receive requests from the *UI layer*, either requesting or sending information. Its function is to coordinate and organize the logic of the application. This applies to each of the application modules, these being: student (*StudentController*), exercises (*ExerciseController*), and the fuzzy logic (*FuzzyController*). The *UI layer* manages the user's graphical interfaces through which the student registers and authenticates in the system. *ExerciseUI* is the component with which the student performs the exercises. It relies on *VuforiaDetector* to be able to carry out AR and on *DataCollector* to obtain information about how the student is performing during the exercises.

The *Data layer* contains components that perform communication tasks with Firebase through *FirebaseManager*, whose function is to manage, store and obtain the data necessary for the student to complete the exercises. *ImageLoader* gets the files hosted on that platform. *HelpManager* stores and suggest the clues to solve a problem. All this interaction will occur through objects of the domain component. Within the fuzzy component, *FuzzyExerciseSystem* and *FuzzyEngine* are in charge of taking the student's performance data and applying the rules of the fuzzy model. The *Fuzzy Layer* is described below.

3.2 Fuzzy Logic Model

The *Fuzzy layer* is responsible to adapt the content of an exercise to be solved according to the student's performance, a fuzzy logic model was implemented that evaluates the level of complexity of the following exercise based on the linguistic variables that correspond to the number of errors made by the student, the aids requested, and the time necessary to solve the exercise per shift. The *FuzzyController* subcomponent selects the exercises that students should perform, based on the recommendations made by the fuzzy inference machine, and provides relevant feedback to the student.

The fuzzy inference machine adapts the pedagogical model according to the student's performance, considering the input variables, fuzzy sets, and defined labels. The result of the inference is a fuzzy output variable called "nextLevel", which represents the level of difficulty applicable to the next exercise with fuzzy values of *beginner*, *easy*, *medium*, and *hard*. Once the linguistic variables are defined, the fuzzy system applies the fuzzy rules for each set of values of the 3 input variables. Each fuzzy variable is normalized in a range between 0 and 1. Since there are 4 input variables, 3 of them with 3 possible values and one with 4, 81 rules have been defined, each giving a corresponding value to the output variable. An example of a fuzzy rule is:

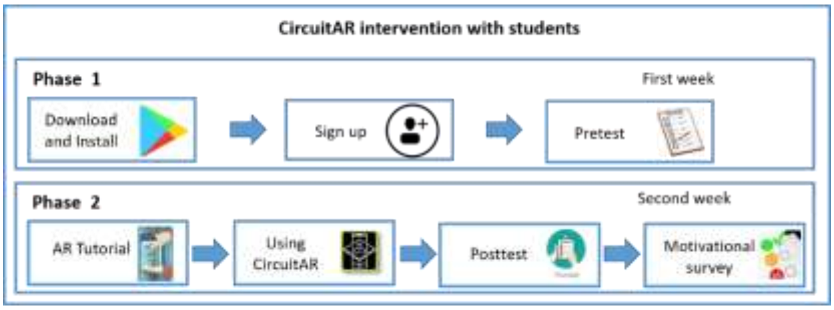


Fig. 3. Steps of the intervention with the learning tool.

IF prevLevel IS beginner AND errors IS None AND helps IS low AND time IS fast THEN nextLevel IS easy.

4 The Experiment, Evaluation, and Results

To evaluate the effectiveness of CircuitAR, two aspects were considered: the functionality of the platform and the intervention with students from the second semester of the electronic engineering career, from the Technological Institute of Mazatlán, in a distance mode. Our proposal was adapted to the COVID-19 pandemic's needs, and we implemented the intervention using a distance learning tool and an online platform. The following adjustments were made: (1) markers for AR were available on CircuitWeb, either for printing or viewing from the web; (2) the application was available for download in Android Google Play[1], avoiding distribution and permission problems in the equipment, as well as increasing the confidence of the students by being in an environment known to them; (3) pretest and posttest questionnaires are also available on CircuitWeb platform.

These actions allowed better control of the experiment, thus achieving that the sessions with the students could be carried out remotely. Similarly, because the pretest and posttest were accessible through the web platform, students were more motivated to complete them because they didn't have to leave the application to answer them. Regarding the functionality of the platform, feedback was received from the students during the sessions using the tool. For this, observations were collected that allowed us to improve the learning environment for future iterations of development.

The intervention was designed in 2 phases: In the first phase, the students download and install the application. Once installed, the student proceeds to sign up. When the student signs in, the pretest option is enabled to respond the questionnaire for 15 minutes. Phase 2 begins with a video tutorial about the use of AR, as well as an example of how to use the marker collision technique, lasting 10 minutes. Subsequently, instructions are provided on how to interact with CircuitAR, and for 20 minutes, students must solve the exercises proposed in the application.

[1] https://play.google.com/store/apps/details?id=com.mcc.circuitar

Table 1. Data analysis from pretest and posttest.

		Pretest			Posttest			
School	**N**	**Pass**	**Fail**	**M**	**Pass**	**Fail**	**M**	**t**
School 1	30	14	16	5.40	18	12	6.23	-3.192 *
School 2	28	12	16	5.42	18	10	6.28	

* p-value < 0.05

During that time, the research team attends and solves student difficulties with the handling of the application.

Once the interaction is finished, the student must answer a posttest questionnaire for 15 minutes, with the same degree of complexity as the pretest.To end the session, the student must answer a motivational survey, made up of 36 questions with 5 possible answers in 20 minutes. Figure 3 shows the steps of the intervention with CircuitAR.

During the intervention with CircuitAR, 58 students from two different schools were evaluated. According to the data obtained from the pretest from School 1 (N=30, M=5.40, SD=2.30), 14 students obtained a score higher than 6.0 and 16 students obtained a score lower than 6.0. Regarding to the data obtained from School 2 (N=28, M=5.42, SD=2.36), 12 students obtained a score higher than 6.0 and 16 students obtained a score lower than 6.0. Similarly, the data obtained from the post-test were analyzed. The students of School 1 (M=6.23 SD=2.21), 18 obtained a score higher than 6.0 and 12 students obtained a score lower than 6.0.

Regarding School 2 (M=6.28 SD=2.29), 18 students obtained a score higher than 6.0 and 10 students obtained a score lower than 6.0. Table 1 shows the results of pretest and posttest from both schools. A paired sample T-test was conducted to the data, grouping both schools to compare the learning outcomes of the students based on the data from the pretest and posttest. The result indicated that there was a difference statistically significant between the students' knowledge before the intervention and after using CircuitAR, t (58) = -3.192, *p*=0.002, it can be established that the students had improved the learning outcome by using the AR learning tool.

5 Conclusions

CircuitAR is a learning tool that guides students to learn electronic circuits using AR effectively. With The fuzzy logic model designed and implemented to be able to choose which exercises to show the student based on their previous performance, it is effective to have a greater learning gain. The information generated by the students' intervention carried out, and the data of pretest and posttest questionnaires reflect that the students gained a significant learning outcome compared to before interacting with the application, demonstrating that the combination of augmented reality to improve the learning experience of electrical circuits.

On the other hand, students expressed felt identified with the elements provided by the application, arguing that the learning tool is unique and effective for learning, in addition to having provided feedback on the usability and performance of the application on different devices, indirectly collaborating to detect and propose possible solutions to display and performance problems within CircuitAR.

This study had a limited sample size, due to the distance modality and because of the time in which the intervention was carried out.

For this reason, the size of the sample should be increased and other interventions with students should be carried out to analyze the impact of the tool in different contexts. As future work, it is planned to expand the didactic proposal of the platform, increasing the number of available exercises, and the variety of electrical elements that students use to improve their learning. Also, integrating new types of exercises apart from the one proposed in this work, and, integrating a greater degree of feedback during the intervention with augmented reality exercises, through sound effects and animations.

References

1. Gonzalez, H. B., Kuenzi, J. J.: Science, technology, engineering, and mathematics (STEM) education: A primer. Washington, DC: Congressional Research Service, Library of Congress (2012)
2. Azuma, R. T.: A survey of augmented reality. Presence: Teleoperators & Virtual Environments, 6(4), pp. 355–385 (1997)
3. Liao, Y. T., Yu, C. H., Wu, C. C.: Learning geometry with augmented reality to enhance spatial ability. In: 2015 International conference on learning and teaching in computing and engineering, IEEE, pp. 221–222 (2015)
4. Ibáñez, M. B., Di Serio, Á., Villarán, D., Kloos, C. D.: Experimenting with electromagnetism using augmented reality: Impact on flow student experience and educational effectiveness. Computers & Education, 71, pp. 1–13 (2014)
5. Patil, S., Prabhu, C., Neogi, O., Joshi, A. R., Katre, N.: E-learning system using Augmented Reality. In: 2016 International Conference on Computing Communication Control and automation (ICCUBEA) (2016)
6. Rossano, V., Lanzilotti, R., Cazzolla, A., Roselli, T.: Augmented Reality to Support Geometry Learning. IEEE Access, 8, pp. 107772–107780 (2020)
7. Hruntova, T. V., Yechkalo, Y. V., Striuk, A. M., Pikilnyak, A. V.: Augmented reality tools in physics training at higher technical educational institutions. In: Proceedings of the 1st International Workshop on Augmented Reality in Education, 2257, pp. 33–40 (2018)
8. Ozdemir, A., Balbal, K. F.: Fuzzy logic based performance analysis of educational mobile game for engineering students. Computer Applications in Engineering Education, 28(6), pp. 1536–1548 (2020)
9. Karaci, A.: Intelligent tutoring system model based on fuzzy logic and constraint-based student model. Neural Computing and Applications, 31(8), pp. 3619–3628 (2019)
10. Woolf, B. P.: Building intelligent interactive tutors: Student-centered strategies for revolutionizing e-learning. Morgan Kaufmann (2010)
11. Deloitte Global Mobile Consumer Survey. May-Jun 2018, May-Jun 2019 (2019)
12. Holmes, W., Bialik, M., Fadel, C.: Artificial intelligence in education. Boston: Center for Curriculum Redesign (2019)
13. Rathore, R. K., Jayanthi, J.: Student prediction system for placement training using fuzzy inference system. ICTACT Journal on Soft Computing, 7(3), pp. 1143–1446 (2017)

14. Gogo, K. O., Nderu, L., Mwangi, R. W.: Fuzzy logic based context aware recommender for smart e-learning content delivery. In: 5th International Conference on Soft Computing & Machine Intelligence (ICSCMI), pp. 114–118 (2018)
15. Alshamrani, A., Bahattab, A.: A comparison between three SDLC models waterfall model, spiral model, and Incremental/Iterative model. International Journal of Computer Science Issues, 12(1), pp. 106 (2015)

Decision Tree-Based Model to Determine Student's Dropout Factors in a Mexican Higher Education Institution

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Abstract. The current context in which higher education institutions operating in Mexico is adverse and multifactorial. In this work, the data obtained from a survey applied to 1,582 students are analyzed to determine the main factors that influence school dropout in a pre-COVID19 stage. With this information, an analysis of the decision tree was developed, detecting the main routes that influence school dropout. This study can be useful both to the public and to the instances involved in decision-making, to try to create an environment conducive to allow students to continue with their university education.

Keywords: learning analytics, higher education, decision making.

1 Introduction

Data analytics is a technique used in many fields of research, one of them is Education, being very useful for finding patterns in large data sets, and with it optimize and predict results that allow improving the management and administration of Higher Education Institutions (HEIs), since it is very useful for the detection and prevention of specific problems and decisions makes. Higher Education Institutions (HEIs) are in a complex landscape, where their resources are limited, and situations are changing.

According to a diagnosis of the year 2019 made by the Subsecretaria de Educacion Superior (SES), the Asociacion Nacional de Universidades e Instituciones de Educacion Superior (ANUIES), and the Asociacion Mexicana de Organos de Control y Vigilancia en Instituciones de Educacion Superior, A.C. (AMOCVIES), there are nine entities in Mexico whose universities have been in economic crisis for several years: Morelos, Oaxaca, Zacatecas, Chiapas, Estado de Mexico, Tabasco, Michoacan, Nayarit, and Sinaloa. The magnitude of the accumulated deficit of the nine universities is equivalent to 71% of their ordinary public subsidy (23,461 million pesos), with a range ranging from 29% to 190%. Under this unfavorable economic and social environment, there is a need to detect transversal problems such as school dropout and the multiple causes that originate it, through various techniques.

pp. 35–41; rec. 2021-07-21; acc. 2021-09-29

One of them could be using learning analytics. Elias [1] mentions that learning analytics refers to the collection and analysis of data about learners and their environments to understand and improve learning outcomes.

The Facultad de Contaduria y Ciencias Administrativas (FCCA) of the Universidad Michoacana de San Nicolas de Hidalgo (UMSNH) can enroll approximately 5,000 students from many states of the country in different degrees and modalities offered. However, the data reported by the UMSNH in the last five years of the number of students who start their studies decreases significantly with the number of students who graduate. The main objective of this work is to try to find the combination of factors that generates a greater risk of dropout out in students.

2 Related Work

In [2], a predictive model is proposed using data mining techniques through a Web interface that facilitates the identification of students vulnerable to school dropout at the Universidad Tecnologica de Izucar de Matamoros (UTIM), in Mexico. In [3], a classification model is designed to detect early dropout in the Facultad de Ingenieria of the Universidad La Salle, through the application of the CRISP-D methodology (Cross Industry Standard Process for Data Mining).

In this work, a review of the literature from 1982 to 2017 was made, in which the applications of machine learning and data mining are analyzed to board the problem with methods such as decision tree, neural networks, vector support machines (SVM), naive bayes, uniform random, k-nearest neighbor (KNN), logistic regression (LR), among others, with which prediction rules are generated based on a group of management indicators that can be used in the design of educational policies to determine the reasons for some inefficiencies of the HEIs.

The work [4] carries out a master's thesis work, where the objective of the research was based on using multivariate statistical techniques: SVM, Discriminant Analysis (DA), KNN, and LR to classify undergraduate students at the Universidad Nacional de Colombia located in two towns of Medellin (with the possibility or not of dropout), based on the information that was available on the variables defined and identified as determinants of student dropout University.

For this study, the information provided by the students who entered at the Universidad Nacional de Colombia from the first semester of 2009 to the first semester of 2016 was used, their corresponding academic performance in each enrolled period and the identification of which of them lost the quality of student at the university due to poor performance and which continued with their studies, which allowed to have a percentage of data that were used for the training of the models and the rest of the data as validation. The results allowed us to identify the technique to obtain the model with a lower percentage of error and greater sensitivity, and that could be used to make predictions of dropout in new individuals from the information of the selected variables.

There are related works in which the use of techniques of expert systems and data mining allow to establish prediction models, with which we help the person in charge in the taking of these. The paper [5] shows the results of research whose purpose is to evaluate the technical efficiency of HEIs in Colombia between the years 2011-2013, through the application of data envelope analysis and data mining techniques.

In [6], a model is proposed to detect possible dropouts in Higher Education in a public university, where they suggest two proposals for the quantification of dropout: The first, is established as the proportion of students who graduate in a certain time that corresponds to the duration of the career; and the second is simply the number of students who dropout.

To reduce dropout, these investigations propose to improve the mechanisms of early detection of potential deserters. To elaborate their research, they used some methods: logistic regression, k-nearest neighbors, decision trees including random forests, Bayesian networks, neural networks, among others.

3 Method

For this project, variables were chosen that identified each student of the Facultad de Contaduria y Ciencias Administrativas of the UMSNH, studies previously prepared by researchers from other universities were taken as a reference, as is the case of the Universidad Complutense de Madrid, where they carried out a study to determine academic success/failure, using the techniques of multiple linear regression and logistic regression [7].

In this part of the work, the variables that are considered to have an impact on the dropout rate of the students of the bachelor's Degrees in Facultad de Contaduria y Ciencias Administrativas of the UMSNH will be described. In addition, the conceptual model is presented that will allow us to understand the interaction of the variables to later develop the Data Analysis Model.

[8] Take into consideration making a rigorous separation of the types of dropouts for their study. The authors explain that student dropout can be understood from two points of view: temporal and space. As a temporary concept, they identify three types of dropouts:

1. Premature dropout: when a student leaves a program before been accepted.
2. Early dropout: when the program is abandoned during the first four semesters.
3. Late dropout: understood as abandonment from the fifth semester onwards.

Secondly, as a space concept, reference is made to the fact that a student:

1. Change programs within the same institution.
2. Change educational institutions.
3. Leave the educational system, where there is the possibility of re-entry in the future, either to the same or to another campus in the country.

For the analysis that will be carried out in this work, the dropout will be taken as a decision to abandon the academic program, which may become temporary or definitive. With the data that we have from the Control Escolar of the UMSNH, it is difficult to track whether the students who have enrolled have temporarily dropped out, therefore, it must be conceived of dropout in general and therefore a survey will be applied in which the reasons for dropout will be detected to analyze the data.

Table 1. Entry registration against graduation of students from five universities in Mexico. The school year 2010-2011 to 2015-2016.

	UNAM		IPN		UAM		UV		UMSNH	
School year	**MI**	**ME**	**MI**	**ME**	**MI**	**ME**	**MI**	**ME**	**MI**	**ME**
2010-2011	180,763	58,584	95,743	13,478	40,712	4,854	56,582	5,025	37,264	5,637
2011-2012	187,195	58,855	95,743	13,820	41,325	4,448	58,497	5,625	39,646	5,942
2012-2013	190,707	60,748	98,624	13,077	42,242	4,674	58,212	4,767	38,561	5,706
2013-2014	196,565	60,749	100,854	12,915	43,762	5,334	58,995	5,129	31,439	5,561
2014-2015	201,206	63,346	104,125	13,630	44,301	5,063	59,284	4,779	37,139	4,355
2015-2016	204,940	Nd	104,409	12,684	44,712	5,147	59,583	5,643	nd	nd

It is not the first time that there is talk of dropout in the UMSNH, it is a very perceptible problem, especially in the schools or Faculties with an admission of low students, that is, with less than 200 new students. [9]

She analyzed the dropout of students at the Universidad Michoacana de San Nicolas de Hidalgo (UMSNH), and a comparison with the Universidad Nacional Autonoma de Mexico (UNAM), the Instituto Politecnico Nacional (IPN), the Universidad Autonoma Metropolitana (UAM), the Universidad de Veracruz (UV). The data that analyzed the entrance enrollment against the graduation enrollment. The following figure shows the results.

As seen in Table 1, 6 school cycles were analyzed. The column with MI heading corresponds to the registration of start or new entry and the column with the heading ME, refers to the registration of graduation. Data labeled nd indicates that there is no data. With this study it is appreciated it is not a problem exclusive to the UMSNH or the State Universities, it is a national-level problem.

To elaborate the table 2, the total number of new and graduate students was added to determine the average of each of them and be able to obtain the average graduation rate of the last four school cycles, which corresponds to 51%, in other words, half of the students who enter complete their university studies. Another interesting fact is the dropout rate, which is 49%.

Subsequently, a research instrument was designed in the form of a survey. Which was developed in the Google Forms application that allows you to prepare questionnaires, store the results to be able to consult them, and generate some graphs.

The questions that were asked were: age, sex, state, and hometown, marital status, family income, bachelor's degree, modality, semester, the status of the student, which can be regular students (who do not repeat subjects for the second time) and irregular student (who does repeat or recurs one or more subjects). These questions were applied to identify the interviewees, however, for the elaboration of the decision tree model, this information was not used.

A dropout factor was determined, from the related studies, a series of qualitative variables are identified that can influence the student to drop out. They are asked about personal aspects that could influence the decision to drop out of college. The questions were: due to lack of time, fail one or more subjects, due to personal problems, because you did not like the career, due to work, due to family impediment, health problems, or

Table 2. Figures of Entry and Exit of the Facultad de Contaduria y Ciencias Administrativas of the UMSNH. Last 4 School cycles (2015-2016 to 2018-2019).

Total: graduates	Total: entry	Average graduation	Average entry	Average graduation rate	Average dropout
2,832	5,563	708	1,392	51%	49%

Table 3. Question Options

No. option	Question
Opc1	Lack of time
Opc2	Fail to pass one or more subjects
Opc3	Due to personal problems
Opc4	Because you did not like the career
Opc5	By work
Opc6	Family impairment
Opc7	Health problem
Opc8	Economic problems
Opc9	Because you have another academic option (change university or a different bachelor)

economic problems, when you have another academic option (change degree or university).

4 Results

In the 2019-2020 school year in which the survey was applied to determine the causes of dropout in FCCA students, 3,290 were enrolled, and the survey was applied to 1,582 students. According to the determination of the sample size made, it was determined that the sample size is adequate. To perform the data analysis, the R Studio tool was used [10]. R Studio is the primary integrated development environment for R.

It is available in open source and commercial editions on the desktop (Windows, Mac, and Linux) and from a web browser to a Linux server running R Studio Server or R Studio Server Pro. In the survey applied to FCCA students, the question where the dropout factor is determined, quotes, "If you had to leave the University, what would be the reason? (You can select one or more)". The options are shown in the following Table 3:

One of the main contributions of this work is the decision tree model from a predictive method, shown in Figure 1, which from a certain behavior of the data tries to delimit the path through which it is crossed to reach a certain point, in addition, each option has a certain score, the answers selected will depend on determining which final score the respondent will obtain. The model logically predicts if a certain condition is met, the probability of deserting that would be obtained.

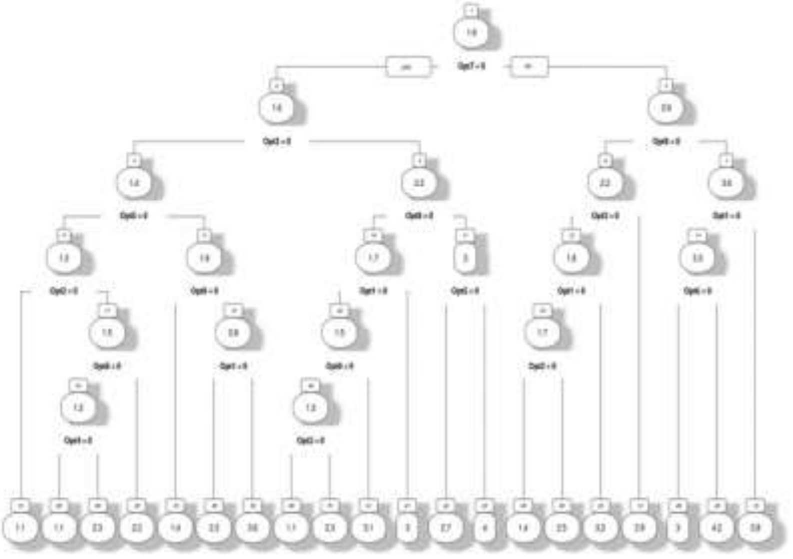

Fig. 1. Predictive Decision Tree Model to determine the dropout factor in the FCCA of the UMSNH.

Different personal situations can be represented in the students of the F.C.C.A of the Decision Tree Model, some of it could be the following: In the model indicates that, if the student does not have health problems, option 7, but if he has economic problems, option 8 and lack of time, option 1, the probability of deserting is the highest, it would have a score of 5.8. , now, if a student has health problems, option 7, personal problems, option 3, economic problems, option 8, and lack of time, option 1, their score is 3.

Another personal situation that would not considerably affect the decision to dropout would be that, if someone has health problems, option 7, personal problems, option 3, and option 2, which fails one or more subjects, the score will be 1.1. The options that a student can choose are very diverse, therefore, the scores obtained depending on the personal situation of each student.

5 Conclusions

This paper addressed issues that are currently of great concern in different areas of administrative, educational, and technological research, to try to solve common problems. While it is true that most Higher Education Institutions have serious problems, the directors of the Facultad de Contaduria y Ciencias Administrativas of the UMSNH must make decisions with the help of adequate research and technological tools such as data mining through the predictive model of decision trees where it hierarchizes the most significant characteristics that affect the level of student dropout.

Although funding problems may prevail at the UMSNH, late dropout rates must be avoided [11] to increase enrollment and decrease their dropout rates, otherwise, there will be negative consequences, which can impact not only on the aspect of FCCA enrollment but also on university enrollment and even more on the population in general.

References

1. Elias, T.: Learning analytics. Learning, pp. 1–22 (2011)
2. Orea, S. V., Vargas, A. S., Alonso, M. G.: Minería de datos: predicción de la deserción escolar mediante el algoritmo de árboles de decisión y el algoritmo de los k vecinos más cercanos, 779(73), pp. 33 (2005)
3. Felizzola, H. A., Arias, Y. A. J., Pedroza, F. V., Pastrana, A. M. C.: Modelo de predicción para la deserción temprana en la Facultad de Ingeniería de la Universidad de la Salle. Encuentro Internacional de Educación en Ingeniería (2018)
4. Madrid-Echeverry, J. I.: Propuesta de un modelo estadístico para caracterizar y predecir la deserción estudiantil Universitaria. Escuela de Ingeniería de la Organización (2017)
5. Cadavid, D. V., Mendoza, A. M., Rodríguez, E. C.: Eficiencia en las instituciones de educación superior públicas colombianas: una aplicación del análisis envolvente de datos. Civilizar: Ciencias Sociales y Humanas, 16(30), pp. 105–118 (2016)
6. Noboa, C., Ordóñez, M., Magallanes, J.: Statistical Learning to Detect Potential Dropouts in Higher Education: A Public University Case Study. Learning Analytics for Latin America, 2231, pp. 12–21 (2018)
7. Jiménez, M. V. G., Izquierdo, J. M. A., Blanco, A. J.: La predicción del rendimiento académico: regresión lineal versus regresión logística. Psicothema, 12(Su2), pp. 248–525 (2000)
8. Vásquez-Velásquez, J., Castaño-Vélez, E. A., Gallón-Gómez, S. A., Gómez- Portilla, K.: Determinantes de la deserción estudiantil en la Universidad de Antioquia (2003)
9. Rodriguez, M. G. O.: Deserción de estudiantes de licenciatura de la UMSNH Análisis y propuesta de solución. Economía y Sociedad, 22(38), pp. 15–32 (2018)
10. Gandrud, C.: Reproducible research with R and R studio. CRC Press (2013)
11. Vélez, E. C., Gómez, S. G., Portilla, K. G., Velásquez, J. V.: Análisis de los factores asociados a la deserción y graduación estudiantil universitaria. Lecturas de economía, 65, pp. 9–36 (2006)

Generation of Twitter Information Databases: A Case Study for the Mobility of People Infected with COVID-19

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Abstract. Social networks are fundamental tools today for common day life but also for research purposes. The main objective of social network platforms is allowing the users to interact among them using internet. This user interaction generates a significant amount of data daily. However, accessing this information can be quite difficult for inexperienced developers. The objective of this paper is to detail the process for extracting unstructured information from the social network Twitter, and structuring it in a database. which can be used for analysis in data mining processes. This process is presented through a case study that analyzes possible places of contagion of the pandemic disease COVID 19 in Mexico.

Keywords: social networks, twitter extraction, user mobility.

1 Introduction

Social networks generate a large amount of data as result of users interaction. Two goods examples of this big data generation through the social networks are Twitter and Facebook [1]. Several research groups in the world has found the advantages that can be obtained by analyzing the different data generated in social networks within the category of big data [2].

The large amount of data generated by the users' interaction in social networks has given rise to new disciplinary fields, such as data science, computational social sciences and even other disciplinary initiatives [3].

As an example of the large amount of data produces by social networks, the social network Twitter has more than 300 million users that produce an average of 7,000 tweets per second [4]. In this way, Twitter has become one of the most conducive virtual environments for collecting large volumes of data. However, one of the main issues in the use of big data coming from social networks is the access to the information, which could be complicated for inexperienced developers.

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This paper presents the process of extracting unstructured information from the social network Twitter and structuring it to be stored in a database. In order to demonstrate the proposed process, a case study is presented that use Twitter data for the analysis of possible places of contagion of the pandemic disease COVID 19 in Mexico. The paper is organized as follows: Section 2 shows the background and related works. Section 3 presents the description of our proposal. Section 4 details the generation of databases for data mining. Section 5 shows the tests carried out, and finally section 6 shows the conclusions and future work.

2 Background and Related Work

2.1 Social Networks: Twitter

Social networks are defined as web-based services that allow individuals to construct a public or semi-public profile within a bounded system, to articulate a list of other users with whom they share a connection, and also enables the use to view and traverse their list of connections and those made by others within the system [5].

One of the advantages of social networks is the possibility of use the location of user for monitoring the changes that exist in human mobility. The extraction of information from social networks allows exploring a wide range of fields of study, including public health, surveillance, migration, among others [6].

Twitter is a social network to share ideas and information in short messages of up to 280 characters. This social network has 322 million active users, and it is based on the publication and display of user content for followers as well as open publications that can be seen for any Twitter user [4]. Currently, there are two endpoints that can be used to access user tweets: Filtered stream and Search Tweets

2.2 Related Work

This section presents research works focus on obtaining information from the Twitter social network, as well as works related to the mobility of people considering the information obtained from Twitter. Some authors have focused on how to structure the data considering the mentions, retweets and replies that are generated, hashtags used and what resources have been shared, be they images, web pages or other resources [7].

Some other authors apply techniques to obtain the information from the Twitter social network to make an automatic linguistic analysis of the Twitter texts [8]. However, the social network Twitter makes updates that require modifications to the way for accessing the twitter data. Other related works are focused on the use of Twitter data for analyzing mobility of people through the information they publish in the app.

For example, in [9], the authors proposed an approach to analyze and predict the regularities in human mobility. In research work [10], the authors propose the use of Twitter to obtain valuable information on human mobility. Therefore, their objective was to discover the patterns and mobility of Location-Based Social Networks, such as Twitter. In the research work [11], the authors addressed the exploitation of data from social networks, such as Twitter, to understand human mobility in an urban site. This research work predicts the next locations of users, using geolocated tweets. In research work [12], new data acquisition and evaluation methods were studied, with an approach aimed at reducing the transmission rate of SARS-COV-2 in the population and evaluating the geographical spread.

3 Description of the Proposal

This section presents an overview of the proposed approach to generate a database from the information collected from the Twitter social network. Our proposal is composed of four main processes (Figure 1): definition of the problem in which the user defines the information to be analyzed in tweets, request authorization to access to Twitter data, development of the app to extract data, and, finally information validation. In order to illustrate our proposal, a case study of the COVID 19 Pandemic was performed, where data is extracted from users of Twitter in Mexico referring to current pandemic.

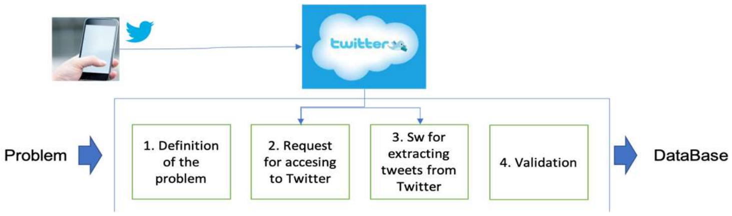

twitter
Problem
1. Definition of the problem
2. Request for accesing to Twitter
3. Sw for extracting tweets from Twitter
4. Validation
DataBase

Fig. 1. Overview of the proposed approach.

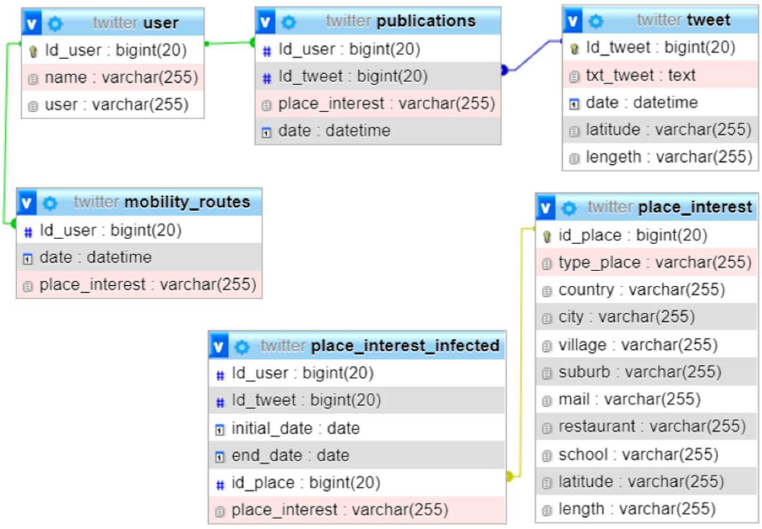
4 Generation of Databases for Data Mining Purposes

Following, the main four phases of the proposed approach are presented in detail.

4.1 Definition of the Problem

The first step to generate a database on a specific subject is to establish a research objective and to define the data that are needed to achieve that objective. In the problem addressed in this paper, a database needs to be created that allows to identify the mobility of people suffering from COVID-19 over a period of time.

The data obtained from Twitter should allow us to trace the places visited by persons who use Twitter and posted that they were infected with COVID-19 virus. This information permits the identification of the possible places of infection. To do this, it is necessary to obtain the states, municipalities or places of interest where the tweets were published. Figure 2 shows the database that was used to identify the mobility of people commenting they are suffering from the COVID disease using twitter.



twitter user
- Id_user : bigint(20)
- name : varchar(255)
- user : varchar(255)

twitter publications
- Id_user : bigint(20)
- Id_tweet : bigint(20)
- place_interest : varchar(255)
- date : datetime

twitter tweet
- Id_tweet : bigint(20)
- txt_tweet : text
- date : datetime
- latitude : varchar(255)
- lengeth : varchar(255)

twitter mobility_routes
- Id_user : bigint(20)
- date : datetime
- place_interest : varchar(255)

twitter place_interest
- id_place : bigint(20)
- type_place : varchar(255)
- country : varchar(255)
- city : varchar(255)
- village : varchar(255)
- suburb : varchar(255)
- mail : varchar(255)
- restaurant : varchar(255)
- school : varchar(255)
- latitude : varchar(255)
- length : varchar(255)

twitter place_interest_infected
- Id_user : bigint(20)
- Id_tweet : bigint(20)
- initial_date : date
- end_date : date
- id_place : bigint(20)
- place_interest : varchar(255)

Fig. 2. Database for the COVID monitoring case study.

This database contains six tables representing users, publications, tweets, routes, interest points and the point of interest visited by people infected.

4.2 Request for Accessing to Twitter API

The second step of our proposal is the request process to access the API Twitter. A registration form must be completed, which is made up of two sections. In the first section, the user must answer the question: Which best describes you?.

The second step consists of filling out a form that is made up of four steps or blocks, which are: Basic info, Intended use, Review, and finally, Terms. The information requested in basic information field is some easy data to be provided.

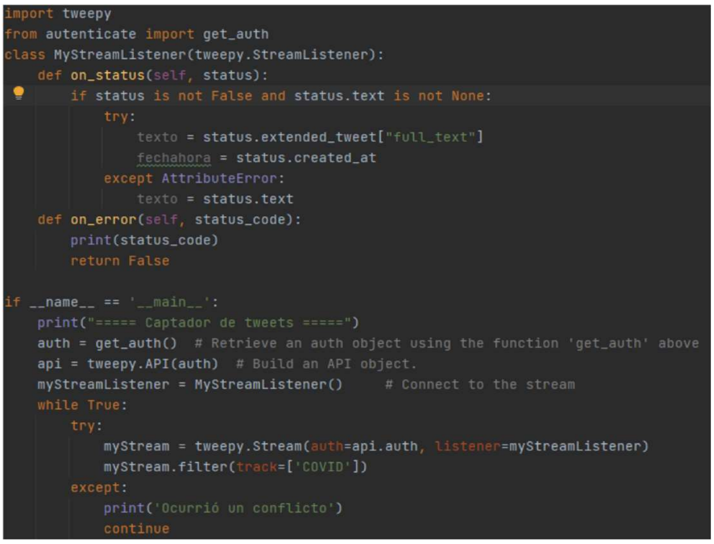
In the Intended use section, the Twitter API tries to discover the use that will be given to the information. In this section, the user must answer questions related to the use of the information and functionalities of twitter. In addition, the user must explain in depth the intended use of the data. This explanation is relevant because it will the factor that use Twitter staff to approve or decline the account request. In the Review section, the user must check that the information provided is correct. Finally, in Terms section, the terms for the use of the Twitter API need to be accepted.

4.3 Software for Extracting Tweets From Twitter

The third step of our proposal is the development of the application for extracting tweets from the social network twitter. The twitter API allows access to its functions or endpoints. There are two ways to extract tweets from Twitter: *Search Tweets endpoi*nt and the *Filter real-time tweets endpoint*. The *Search Tweets endpoint* option allows the user to programmatically access filtered public tweets posted over the last week. The option *Filter real-time tweets endpoint* allows to receive posts at the moment they are generated, following a real-time approach. The application will generate, for the first time, the keys and tokens needed to access the Twitter information. These keys and tokens must be kept in a safe place.

All the information on the twitter APIs can be consulted at [13]. The endpoints offered by twitter are grouped into three categories: Tweets, User, Spaces and these can be consulted in [14]. In our case study, the python programming language and the Tweepy [15] library was used for coding. Tweepy looks to be the best-known open source library to access the API from Python.

A class was developed that implements *tweepy.StreamListener* to be instantiated from the main method. This class defines the attributes to be obtained from the twitter API in real time. Figure 3 shows the code used to extract data from twitter. A filter is made by the keyword "COVID", the tweets, the date and time of publication are extracted; and they are stored in the variables text and datetime respectively.

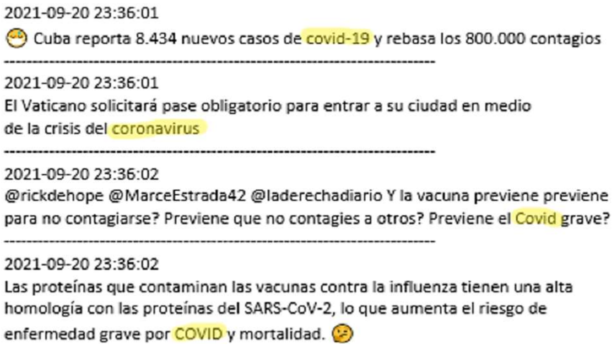


```
import tweepy
from autenticate import get_auth
class MyStreamListener(tweepy.StreamListener):
    def on_status(self, status):
        if status is not False and status.text is not None:
            try:
                texto = status.extended_tweet["full_text"]
                fechahora = status.created_at
            except AttributeError:
                texto = status.text
    def on_error(self, status_code):
        print(status_code)
        return False

if __name__ == '__main__':
    print("===== Captador de tweets =====")
    auth = get_auth()  # Retrieve an auth object using the function 'get_auth' above
    api = tweepy.API(auth)  # Build an API object.
    myStreamListener = MyStreamListener()     # Connect to the stream
    while True:
        try:
            myStream = tweepy.Stream(auth=api.auth, listener=myStreamListener)
            myStream.filter(track=['COVID'])
        except:
            print('Ocurrió un conflicto')
            continue
```

Fig. 3. Main code to extract data from twitter.

4.4 Validation

The fourth step is the validation of the code functionality. This validation consisted of executing the code and verifying that the tweets displayed in the console matched the filter keywords. The filter used was the following: myStream.filter (languages = ['es'], track = ['COVID, COVID-19, coronavirus']). Figure 4 shows some tweets that match the keyword filter. In this Figure, the keywords were highlighted in those tweets.



```
2021-09-20 23:36:01
😷 Cuba reporta 8.434 nuevos casos de covid-19 y rebasa los 800.000 contagios
--------------------------------------------------------------------------------
2021-09-20 23:36:01
El Vaticano solicitará pase obligatorio para entrar a su ciudad en medio
de la crisis del coronavirus
--------------------------------------------------------------------------------
2021-09-20 23:36:02
@rickdehope @MarceEstrada42 @laderechadiario Y la vacuna previene previene
para no contagiarse? Previene que no contagies a otros? Previene el Covid grave?
--------------------------------------------------------------------------------
2021-09-20 23:36:02
Las proteínas que contaminan las vacunas contra la influenza tienen una alta
homología con las proteínas del SARS-CoV-2, lo que aumenta el riesgo de
enfermedad grave por COVID y mortalidad. 🤔
```

Fig. 4. Partial view of Tweets that matched keywords in validation.

Another validation carried out was made to verify that some tweets published by ourselves that contained the filter keywords were shown in the console. For example, we publish the following tweets at runtime: *"Creo que tengo coronavirus mañana me hago la prueba", "Lamento informarles que di positivo a covid", "El covid-19 sigue mutando espero que mi vacuna me proteja".* The console of our application received correctly these published tweets.

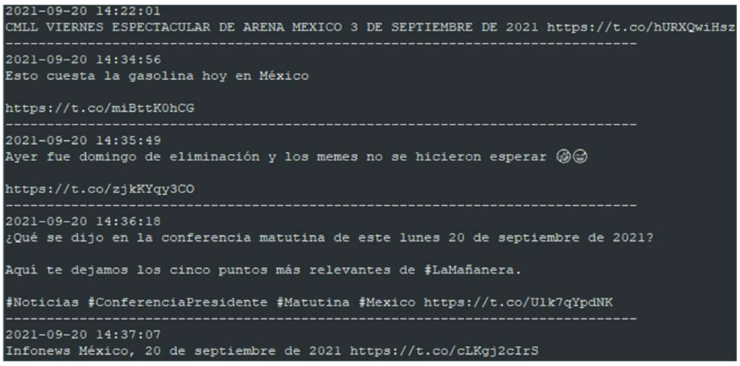
5 Test and Results

This section shows the tests and results. The tests carried out consisted of executing the process for tweets extraction for 30 minutes in 3 different times. Different filters were applied in each of these extractions. We choose to run the process for 30 minutes to preserve the resources provided by Twitter. However, the process can be executed until Twitter closes the connection when allowed resource quota is reached.

In the first run, 19 tweets were obtained and the following filter was applied: myStream.filter (track = ['September Mexico']) which means that the twitter API stream would search for those tweets having the keywords: *september* and *México*. In this case, a conditional "and" was applied between these two terms, because there is a blank space between the two terms. The filtering parameters to make requests can be consulted at the following link: https://developer.twitter.com/en/docs/twitter-api/v1/tweets/filter-realtime/guides/basic-stream-parameters

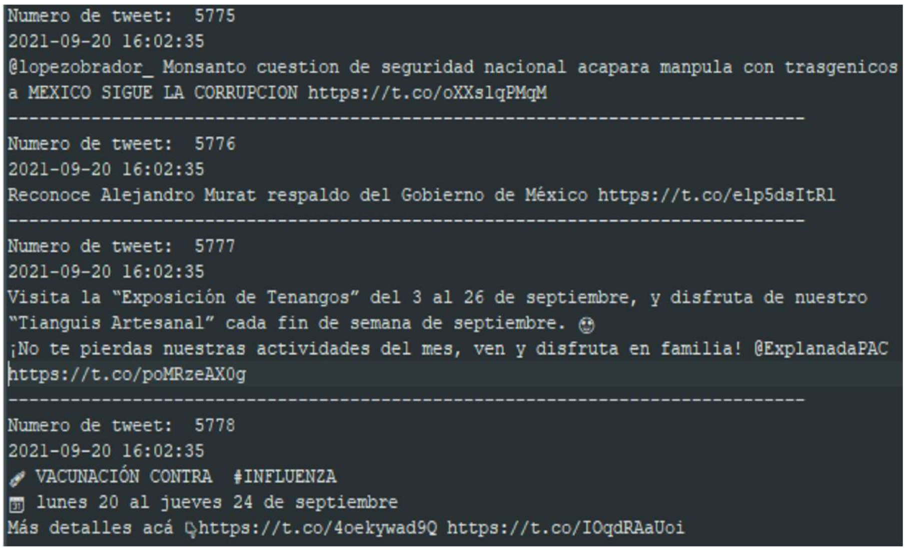
The twitter API shortens the URL's in the tweets resulting in some search words not appearing in the tweets because they are part of the URL's. Figure 5 shows some of the feedback that was obtained from the first run.

In second run, 5778 tweets were obtained applying the following filter: myStream.filter (track = ['September, Mexico']), which means that the twitter API stream would search for those tweets that had the keywords: September or México, that is, a conditional OR would be applied because "the comma" means OR. For this reason, a higher number of tweets was obtained compared to the first run. Figure 6 shows some of the comments that were obtained during the second run. The third test carried out



```
2021-09-20 14:22:01
CMLL VIERNES ESPECTACULAR DE ARENA MEXICO 3 DE SEPTIEMBRE DE 2021 https://t.co/hURXQwiHsz
---------------------------------------------------------------------------
2021-09-20 14:34:56
Esto cuesta la gasolina hoy en México

https://t.co/miBttK0hCG
---------------------------------------------------------------------------
2021-09-20 14:35:49
Ayer fue domingo de eliminación y los memes no se hicieron esperar 🤣😅

https://t.co/zjkKYqy3CO
---------------------------------------------------------------------------
2021-09-20 14:36:18
¿Qué se dijo en la conferencia matutina de este lunes 20 de septiembre de 2021?

Aquí te dejamos los cinco puntos más relevantes de #LaMañanera.

#Noticias #ConferenciaPresidente #Matutina #Mexico https://t.co/Ulk7qYpdNK
---------------------------------------------------------------------------
2021-09-20 14:37:07
Infonews México, 20 de septiembre de 2021 https://t.co/cLKgj2cIrS
```

Fig. 5. Partial view of the results obtained with terms filtered with an and.



```
Numero de tweet:  5775
2021-09-20 16:02:35
@lopezobrador_ Monsanto cuestion de seguridad nacional acapara manpula con trasgenicos
a MEXICO SIGUE LA CORRUPCION https://t.co/oXXslqPMqM
---------------------------------------------------------------------------
Numero de tweet:  5776
2021-09-20 16:02:35
Reconoce Alejandro Murat respaldo del Gobierno de México https://t.co/elp5dsItRl
---------------------------------------------------------------------------
Numero de tweet:  5777
2021-09-20 16:02:35
Visita la "Exposición de Tenangos" del 3 al 26 de septiembre, y disfruta de nuestro
"Tianguis Artesanal" cada fin de semana de septiembre. 😍
¡No te pierdas nuestras actividades del mes, ven y disfruta en familia! @ExplanadaPAC
https://t.co/poMRzeAX0g
---------------------------------------------------------------------------
Numero de tweet:  5778
2021-09-20 16:02:35
💉 VACUNACIÓN CONTRA  #INFLUENZA
📅 lunes 20 al jueves 24 de septiembre
Más detalles acá 👇https://t.co/4oekywad9Q https://t.co/IOqdRAaUoi
```

Fig. 6. Partial view of the results obtained with terms filtered with an or.

obtained 1352 tweets and this was applied to the case study presented in section 4.1. The following keyword filter was applied: myStream.filter (languages = ['es'], track = ['COVID, COVID-19, coronavirus']).

6 Conclusions and Future Work

Currently, the collection of data that can be obtained from social networks provides an excellent source of data that can be used and analyzed to discover information. This paper presents the process for generating a database of information extracted from the social network Twitter. Therefore, the steps that an inexperienced developer must take to carry out the information extraction are discussed. This process will allow her/him to avoid common mistakes when carrying out this extraction process from Twitter.

Each of the steps presented is detailed using a case study. The main challenge in the work presented as future work is to develop a tool that allows us to analyze the mobility patterns that Twitter users have, facing the fact that currently, Twitter has restricted the exact location where a tweet is published for user safety reasons. The next objective of the system will be to produce statistics and draw reliable routes that allow the behavior and interaction of sick people to be analyzed.

References

1. Puyol, J.: Una aproximación a Big Data. Revista de Derecho UNED. (14), pp. 471–503, (2014)
2. Song, X., Shibasaki, R., Jing, N., Xing, X., Li, T., Adachi, R.: DeepMob: Learning Deep Knowledge of Human Emergency Behavior and Mobility from Big and Heterogeneous Data. ACM Transactions on Information Systems, 35, pp. 1–4 (2017)
3. Rocha, M., Elena, M.: Grandes datos, grandes desafíos para las ciencias sociales. Revista Mexicana de Sociología, 80, pp. 2–6 (2018)
4. Statista, https://es.statista.com/estadisticas/636174/numero-de-usuarios- mensuales-activos-de-twitter-en-el-mundo, last accessed 2021/09/20
5. Boyd, D., Ellison, N. B.: Social Network Sites: Definition, History and Scholarship. Journal of Computer-Mediated Communication. Journal of Computer-Mediated Communication, 13, pp. 210–230 (2007)
6. Osorio, J.: Análisis de los patrones espacio-temporales de eventos a partir de datos de Twitter: el caso de la World Pride 2017 en Madrid. Estudios Geográficos, 81, pp. 1–12, (2020)
7. Domingo, M., Minguillón, J.: Modelado, extracción y análisis de información del flujo de datos de Twitter. Universitat Oberta de Catalunya, (2012)
8. Blasco, E.: Aplicación de técnicas de minería de datos en redes sociales/web, Master. Universidad Politécnica de Valencia, (2015)
9. Comito, C., Human Mobility Prediction through Twitter. Procedia Computer Science, 134, pp. 129–136 (2018)
10. Al-Jeri, M.: Towards Human Mobility Detection Scheme for Location-Based Social Network. pp. 1–7, (2019)
11. Comito, C.: Minería de la movilidad humana de los medios sociales para apoyar la informática urbana. pp. 514–521 (2019)
12. Gao, S., Rao, J., Kang, Y., Liang, Y., Kruse, J.: Mapping county-level mobility pattern changes in the United States in response to COVID-19. 12, pp. 16–26 (2020)
13. Twitter API, https://developer.twitter.com/en/docs/twitter-api, last accessed 2021/09/20
14. Twitter API v2, https://documenter.getpostman.com/view/9956214 / T1LMiT5U#4a6cc2e6-5c99-421a-b1f0-ba9f170dce97, last accessed 2021/09/20
15. Tweepy, http://www.tweepy.org, last accessed 2021/09/20

Training Readability Comparators for Academic Texts at Different Levels

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Abstract. Developing machine learning tools to aid students in the process of writing a thesis document is of great interest to students, universities, supervisors and evaluation committees. This article presents the construction and evaluation of readability comparators based in Spanish-written thesis documents of four different academic levels: Advanced College Level Technician (ACT), Undergraduate, Master and Doctoral. Specifically, we provide comparators that can evaluate, between two thesis texts which one is more readable than the other; the thesis sections we focus are: Problem Statement, Results and Justification. The successful completion of these different comparators, as shown in our results, opens the possibility for building a web-based API that analyzes an input thesis draft section and determines whether corresponds to its academic level or requires further improvement.

1 Introduction

The quest for aiding students in the production of a thesis document is a longtime problem that affects universities, thesis supervisors, and committees. According to [1], students in general demand flexible forms and structures of research that can explode the extensive use of new technologies. Our aim is to provide the basis to develop these new technologies, specifically for writers in Spanish.

Computational-linguistic technologies such as word correctors or grammar checkers have aided students in the production of a thesis document. We now face a Machine Learning revolution, where tools such as Grammarly[3], advertised as the world's most accurate online grammar checker, assists students and public in general in writing documents of any kind. Such tools are very helpful but have some limitations: first, they were developed for English, and secondly, they are specifically focused on grammar. We need to develop, first these kind of tools for

[3] https://www.grammarly.com

pp. 51–58; rec. 2021-07-22; acc. 2021-09-30

Spanish, and then, we must include deeper linguistic analysis in them. In this work, we report the first steps to reach a readability evaluator of thesis.

According to [2], text readability is the sum of all elements in textual material that affect a reader's understanding, reading speed, and level of interest in the material. Our aim in this work is to build and contrast machine learning-based comparators that are capable to judge between a couple of thesis document sections, indicating which one is more readable than the other. We tackle this task through the use of thesis documents of four different academic levels and we build the comparators based on a previously proposed methodology [9].

The document is organized as follows. Section 2 details related work to our research. Section 3 presents the data-set along with its statistics. Section 4 describes the methodology for the comparators and the experiments. Results and analysis appear in Section 5, and we conclude in Section 6 with future directions.

2 Related Work

To obtain an extensive background on how readability of texts is assessed automatically we found [3]. They review the state-of-the-art algorithms in automatic modeling and predicting the reading difficulty of texts, and also list new challenges and opportunities in the area. In general, studies on this area fall within regression and classification, however, one can find research that treats this task as a pairwise problem. This paper allowed to point out the not so explored idea of utilizing comparators as a machine learning tool to evaluate text readability on documents written in Spanish.

The work of [9] successfully builds a comparator through machine learning that can judge text readability between two texts. They then utilize this comparator to sort a set of texts and present an application which retrieves texts with readability similar to that of a given input text. Here, we employ this comparator construction scheme but we implement it for Spanish-written theses and focus on specific sections.

To build our comparator, a document representation suited for our type of documents is needed. In [6], they combine lexical, syntactic, and discourse features to produce a highly predictive model of human reader's judgments of text readability. This is a work that treats readability prediction as a pairwise preference learning problem, thus estimating the relative difficulty of pairs of documents instead of assigning a specific level. Through this work, we could obtain state-of-the-art feature representation for our comparator.

Finally, since our interest is to use the comparators as tools to help students in the process of thesis writing, papers as [7] are pertinent. They evaluate the quality of eBooks through text analytics and identify parts that need improvement. In [4], they theorize about the generation of an automatic validation for a text that contains information pertaining to a medical procedure, and give future approaches on why these tools are viable and important subject of research.

3 Document Collection

For our research, we use the document collection of [5]. The data set consists of theses and proposals of different academic levels, such as: Advance College-level Technician[4] (ACT), Undergraduate, Master, and Doctoral. The following sections were extracted from each document: Problem Statement, Justification, and Results. Table 1 includes the number of theses of each level in the collection (All), the selected theses (i.e. documents with more than one paragraph), and the number of sections of interest. Word/token statistics for the three sections in the document collection is given in Table 2, that includes average, larger text (Max) and shorter text (Min).

Table 1. Collection data by academic level

	All	**Selected**	**Problem Stmt**	**Justification**	**Results**
ACT	227	202	80	104	102
Undergraduate (UG)	150	136	28	21	77
Master	269	254	92	81	179
Doctoral	66	64	21	13	43

Table 2. Statistics of tokens per section and academic level.

	Problem Stmt			**Justification**			**Results**		
	Avg.	**max.**	**min.**	**Avg.**	**max.**	**min.**	**Avg.**	**max.**	**min.**
ACT	409.33	1708	75	385.07	1123	110	493.55	1883	138
UG	477.60	1253	114	342.33	820	109	508.92	2386	121
Master	399.39	1063	121	407.81	1612	113	656.65	5184	137
Doctoral	754.85	1643	310	433.84	802	247	840.27	3765	59

4 Methodology

4.1 Comparator Construction

Each comparator is trained through machine learning and can judge, given two texts, which one is more readable than the other. To build the comparator, we have to first determine a representation for documents and then train the model.

Document Representation Our dataset consists of theses of different academic levels, each thesis is divided into sections and we extract sections of interest from each document. To get a vector to feed in the machine learning model, we must have two texts from different theses, each of the same kind of section but different academic levels. Let call these texts $a, b \in S$, with S the

[4] A two year program offered in some countries

set of texts selected from all the thesis documents. To build the feature vectors V_a and V_b, we extract local and global characteristics from a and b, as shown in the lower part of Figure 1, where each V_a and V_b has its local and global features. By local characteristics, we mean the frequency of each word divided by the frequency of the number of words in the text, i.e. the relative frequency. By global features, we refer to the log frequency of the 5000 most common words in Spanish[5].

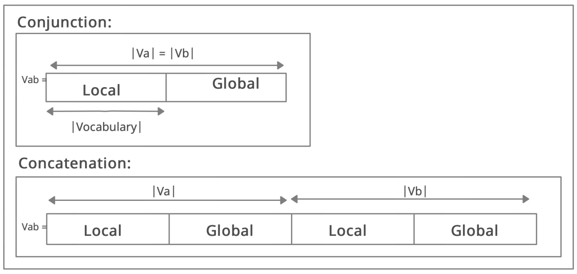

Fig. 1. Feature representation for text documents

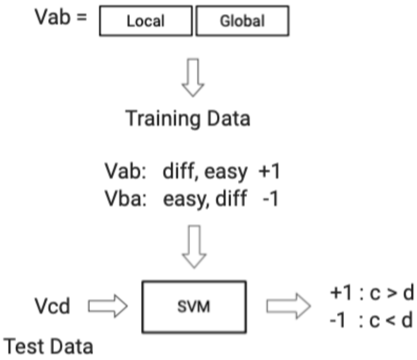

Fig. 2. Training and testing diagram for comparator

Now, a single vector from vectors V_a and V_b is obtained by operate them. In Figure 1, we can observe that the conjunction operation of V_a with V_b produces a V_{ab} vector of the same size, since this considers two possible operations: vector difference and vector division. As the lower part of Figure 1, the concatenation operation corresponds to placing together vector V_a and V_b, thus resulting in a V_{ab} vector with twice the size of V_a or V_b. These two types (Conjunction and Concatenation) of V_{ab} vectors are used to train the different comparator models.

[5] [8] is a dataset created by the Royal Academy of (Spanish) Language, that provides statistics of the most common words.

Table 3. Accuracy percentage for comparators trained with vector operated by difference on three different machine learning models across all sections.

Comparator	Problem Stmt			Justification			Results		
	SVM	KNN	Perceptron	SVM	KNN	Perceptron	SVM	KNN	Perceptron
ACT-Undergraduate	36.65	41.59	37.39	64.70	53.61	63.87	46.38	56.26	42.41
ACT-Master	54.41	55.55	53.18	61.99	64.93	56.97	64.14	62.17	69.43
ACT-Doctoral	81.09	55.46	82.14	83.58	67.69	73.33	82.14	65.87	81.15
Undergraduate-Master	57.53	47.42	47.81	70.84	50.34	65.31	77.67	**74.96**	81.73
Undergraduate-Doctoral	**90.58**	**77.64**	**87.64**	**90.58**	**77.64**	**87.64**	**86.11**	62.64	**85.64**
Master-Doctoral	77.64	67.64	64.11	77.64	67.64	64.11	74.35	53.20	75.40
Average	66.31	57.55	62.04	74.88	63.64	68.53	71.79	62.51	72.62

Training the comparator. V_{ab} vectors come from a set of sections of two different academic levels, let call them A and B, with $a \in A$, $b \in B$, $|A| = n$ and $|B| = m$. Each vector of a document in A is operated with each of the vectors of documents in B and classified as $+1$ if A is of a higher academic level than B and -1 otherwise, leading to $n \times m$ vectors V_{ab}.

We also perform this procedure the other way around, i.e. with B first, and thus obtaining $m \times n$ vectors V_{ba}. This is done since V_{ab} vectors are not the same as V_{ba} vectors and their classification differs. So, we end up with a matrix of size $2 \times n \times m$ for training.

This matrix is used to train the selected machine learning models for our comparator, as illustrated in Figure 2, where vectors of the form V_{ab} and V_{ba} are fed into a Support Vector Machine (SVM). After training, Figure 2 also depicts a V_{cd} vector input to the machine, that was created from two texts: c and d. These texts were vectorized and operated, leading to the V_{cd} vector which can be fed to the trained SVM to get an evaluation of their relative readability.

4.2 Experiments

Given that texts are of four different academic levels, and each of the comparators is built from two different academic levels, we can construct six: ACT-Undergraduate, ACT-Master, ACT-Doctoral, Undergraduate-Master, Undergrad-Doctoral and Master-Doctoral. Likewise, for each thesis document, we extracted three sections of interest: Problem Statement, Justification and Results. Finally, in order to operate the vectors we have three vector operations: division, difference, and concatenation.

We set experiments where for each vector operation, we trained the six possible comparators for each section with three different machine learning models: SVM, K-Nearest Neighbors (K-NN), and Perceptron.

5 Results and Analysis

5.1 Comparators Trained with Vectors Operated as Difference

In Table 3, we can observe that the comparator with the worst efficacy is ACT-Undergraduate across all sections.

The best result corresponds to Undergraduate-Doctoral comparator followed by ACT-Doctoral. As to average, SVM produces the best averages across Problem Statement and Justification, and Perceptron slightly better in Results

Table 4. Accuracy percentage for comparators trained with vector operated as division, with three different machine learning models across all sections.

Comparator	**Problem Stmt**			**Justification**			**Results**		
	SVM	**KNN**	**Perceptron**	**SVM**	**KNN**	**Perceptron**	**SVM**	**KNN**	**Perceptron**
ACT-Undergraduate	48.73	53.15	42.33	54.97	49.69	50.00	41.97	56.61	43.38
ACT-Master	58.61	51.06	61.31	59.35	52.79	58.74	65.45	64.74	66.59
ACT-Doctoral	65.33	56.51	50.00	71.53	**60.00**	50.00	82.14	64.88	78.67
Undergraduate-Master	57.93	45.73	55.65	59.25	49.13	**61.24**	72.47	**71.40**	71.54
Undergraduate-Doctoral	**65.81**	58.16	**66.83**	**73.52**	50.58	50.00	**82.25**	68.05	**83.48**
Master-Doctoral	62.50	**59.72**	50.00	57.35	44.41	50.00	69.55	53.20	73.39
Average	59.81	54.05	54.35	62.66	51.10	53.33	68.97	63.14	69.50

Table 5. Accuracy percentage for comparators trained with vectors operated as concatenation, with three different machine learning models across all sections.

Comparator	**Problem Stmt**			**Justification**			**Results**		
	SVM	**KNN**	**Perceptron**	**SVM**	**KNN**	**Perceptron**	**SVM**	**KNN**	**Perceptron**
ACT-Undergraduate	35.08	44.53	41.38	64.55	48.26	65.38	45.41	61.19	44.22
ACT-Master	52.77	56.29	61.35	61.76	53.77	56.90	65.65	66.84	**62.43**
ACT-Doctoral	79.83	**57.14**	**86.97**	83.58	68.71	87.69	80.35	**68.25**	50.00
Undergraduate-Master	57.34	52.08	68.45	71.19	47.75	72.31	**80.74**	67.29	60.23
Undergraduate-Doctoral	**74.48**	40.81	64.79	**88.23**	**75.29**	**80.58**	80.24	66.35	50.00
Master-Doctoral	69.04	50.79	79.16	78.82	61.17	64.41	67.78	56.25	50.00
Average	61.42	50.27	67.01	74.68	59.15	71.21	70.02	64.36	52.81

5.2 Comparators Trained with Vectors Operated as Division

Table 4 shows that the comparator that performed worst across all sections is again ACT-Undergraduate. The comparator with the best results is ACT-Doctoral followed by Undergraduate-Doctoral. As for average of models, SVM has the best results in Problem Statement and Justification sections. In Results, Perceptron again slightly outperforms SVM.

5.3 Comparators Trained with Vectors Operated as Concatenation

We can notice in Table 5 that the comparator with the worst results across all sections is ACT-Undegraduate. On the contrary, the comparators with the best results are Undergraduate-Doctoral followed by ACT-Doctoral. As for the averages of machine learning models, Perceptron achieves the best results for Problem Statement section and SVM for the Justification and Results sections.

5.4 Result Analysis and Discussion

General behaviors observed across Tables 3, 4 and 5 are: The comparator with the best results is Undergraduate-Doctoral followed by ACT-Doctoral; and the comparator with the worst results is ACT-Undergraduate. As for operators, we can observe that difference operator obtains on average the best results; followed by concatenation and lastly division. Based on machine learning models, SVM obtains the best results in two out of three sections, in the three experiments.

Perceptron performs well three times (twice in Results and one in Problem Statement). K-NN did not compete. So, SVM showed a more consistent performance. As final remarks, further experimentation with concatenation operation is not viable since takes too much time, thus we conclude that the difference operator is our ideal operator. Based on comparators, a nice observed feature is that comparators trained with more distant academic levels obtain higher classification accuracy values, e.g. ACT-Undergraduate is lower on accuracy results than ACT-Doctoral. This one being an important observation, since it validates our results and provides insight into the learning capabilities of our machine learning models.

6 Conclusion

The present work successfully built and evaluated machine learning based readability comparators trained with Spanish-written thesis documents of four different academic levels. These comparators can decide between two different thesis sections, which one is more readable. In general, results across all sections showed that the best comparator was Undergraduate-Doctoral, the most stable model to train them was SVM, and representation with difference operator is both efficient and lightweight. Based on this information, we can conclude that these types of comparators can definitely serve as a base tool, not only to compare readability between sections of documents, but also to evaluate the academic level of the document.

Comparators have limitations, and though we present comparators with good accuracy level, we have to design a process to employ them to assess new documents in progress (drafts). So as future work, we plan the creation of evaluators, where we will take a representative document for each academic level, and use it to evaluate the level of a draft. We will also explore the possibility of incorporating a pairwise ranking model as that of [10], that brings deep learning in our research. Finally, we are interested in deploying our machine learning-based comparator in a web-based API that, given an input document, estimates its readability level.

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References

1. de Anglat, H.D.: Las funciones del tutor de la tesis doctoral en educación. Revista Mexicana de Investigación Educativa 16(50), 935–959 (2011)
2. Chall, J.S., Dale, E.: Readability revisited: The new Dale-Chall readability formula. Brookline Books (1995)

3. Collins-Thompson, K.: Computational assessment of text readability: A survey of current and future research. ITL-International Journal of Applied Linguistics 165(2), 97–135 (2014)
4. Glaser, I., Bonczek, G., Landthaler, J., Matthes, F.: Towards computer-aided analysis of readability and comprehensibility of patient information in the context of clinical research projects. In: Proceedings of the Seventeenth International Conference on Artificial Intelligence and Law. pp. 260–261 (2019)
5. González-López, S., López-López, A.: Colección de tesis y propuesta de investigación en tics: un recurso para su análisis y estudio. In: XIII Congreso Nacional de Investigación Educativa. pp. 1–15 (2015)
6. Pitler, E., Nenkova, A.: Revisiting readability: A unified framework for predicting text quality. In: Proceedings of the 2008 conference on empirical methods in natural language processing. pp. 186–195 (2008)
7. Relan, M., Khurana, S., Singh, V.K.: Qualitative evaluation and improvement suggestions for ebooks using text analytics algorithms. In: Proceedings of Second International Conference on Eco-friendly Computing and Communication Systems, Solan, India (2013)
8. Sánchez, M.S., Cintas, C.D.: El banco de datos de la rae: Crea y corde. Per Abbat: boletín filológico de actualización académica y didáctica (2), 137–148 (2007)
9. Tanaka-Ishii, K., Tezuka, S., Terada, H.: Sorting texts by readability. Computational linguistics 36(2), 203–227 (2010)
10. Wang, L., Shen, X., de Melo, G., Weikum, G.: Cross-domain learning for classifying propaganda in online contents. arXiv preprint arXiv:2011.06844 (2020)

A Brief Review of Educational Data Mining to Improve Intelligent Learning Environments

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Abstract. Learning environments and educational platforms have become ubiquitous in current education. These systems produce an increasing volume of data about different aspects of education. The analysis of this data yields useful knowledge to understand the interrelations and individual states of actors in education, such as students, pedagogical actions, tutorial decisions, learning strategies and learning outcomes. These insights can be used in many ways to improve learning and education, for example, improving intelligent tutoring systems and intelligent learning environments. We are developing two intelligent tutoring systems and we are analyzing data from educational contexts to model the different components of the intelligent tutors through applying several educational data mining techniques. The initial mining approach is presented along with a brief review of literature on educational data mining.

Keywords: educational data mining, intelligent tutoring systems, intelligent learning environments, student modeling.

1 Introduction

Traditionally, education has been one of the favorite fields to prove computational theories with the aim of supporting the teaching and learning processes; for example, the artificial intelligence has produced several applications to improve the learning process through adaptive teaching and tutoring. As a result, there are several educative platforms such as intelligent tutor systems (ITS), learning management systems (LMS), e-learning systems, serious and educational games, and massive open online courses (MOOC), in addition to administrative computer-based systems. These educative platforms have produced a growing volume of data about the interaction of students with learning environments, student preferences, student states, tutorial decisions, tutorial situations, pedagogical strategies, and their impact in learning. The educational data can help to know the students, to understand different aspects of the interaction of the students with the systems, and to comprehend the learning process itself, and therefore to improve the systems and processes.

The Educational Data Mining (EDM) is an emerging discipline, interested in the development of methods to explore the exceptional data that comes from educational environments, and concerned in the use of these methods to understand students and the environments in which they learn [10]. EDM is based on statistical methods and machine learning algorithms.

There is extensive research to understand educative processes. On the one hand, researching is interested in knowing which are the characteristics of students with more impact in learning; for example, emotions, motivation, self-efficacy, among other characteristics, or to know the context or circumstances where the tutorial/teaching actions are successful, and therefore to improve the learning environments. On the other hand, research is also interested in obtaining useful knowledge for teachers, pedagogists, education managers, researchers in educational psychology and learning sciences, and other stakeholders to improve their functions. For example, the prediction of drop-out is a very investigated problem.

We are developing two intelligent learning environments, the first is intended to teach math to kids from elementary school, and the second one is being designed to support undergraduate and graduate students to learn mathematical logic. We want to know which aspects of the learning should be modeled to improve. Therefore, we are analyzing several educational datasets with EDM techniques. In a first stage, we are analyzing public datasets, but also, we are planning to gather our own data. Mainly, we are interested in understanding the impact of psychological constructs in learning, such as motivation, self-efficacy, and self-regulated learning.

We present a brief review of relevant work on EDM, and we depict a proposal to apply educational data mining to understand important factors in learning. The paper is organized as follows: section 2 presents a description of the EDM field; section 3 presents a brief review of literature on educational data mining; section 4 depicts our approach for applying data mining techniques on educative contexts. Finally, section 5 outlines our conclusions and future work.

2 Educational Data Mining

Nowadays, plenty of data is generated, since almost every aspect of our daily life can be tore apart in pieces of information. The imperative necessity of solving problems led to the analysis of the growing data and gave birth to data mining. Data mining is defined as the process of discovering patterns in data. The process must be automatic or semiautomatic. The patterns discovered must be meaningful in that they lead to some advantage [11].

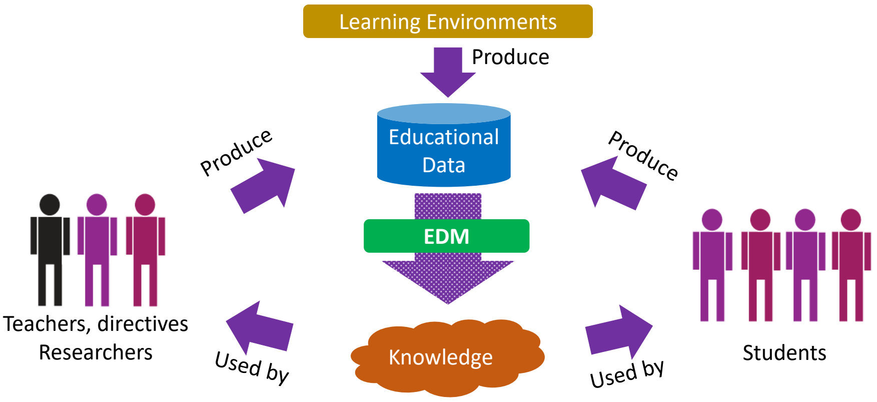

Fig. 1. Educational Data Mining knowledge discovery cycle [10].

Machine learning is the technical basis in data mining. Machine learning is concerned with the ability of a system to acquire and integrate new knowledge through observations of users and with improving and extend itself by learning rather than by being programmed with knowledge [11]. These techniques organize existing knowledge and acquire new knowledge by intelligently recording and reasoning about data. For example, observations of the previous behavior of students will be used to provide training examples that will form a model designed to predict future behavior.

Data from educational contexts can be analyzed to obtain knowledge about learning and students, and to have a better, smarter, more interactive, engaging, and effective education. Educational Data Mining (EDM) is an emerging research field concerned with the application of data mining, machine learning and statistics to data generated by educational settings (schools, universities, Intelligent Tutoring Systems, Learning Management Systems, and MOOCs). EDM seeks to develop and improve methods for exploring this data to discover insights about how people learn. EDM still has many pending issues; but it has the potential to support the development of other fields related to education. This requires advances in artificial intelligence and machine learning, human intelligence understanding and learning theories [7].

As in data mining, in EDM several computing paradigms and algorithms converge, such as decision trees, artificial neural networks, machine learning, Bayesian learning, logic programming, statistical algorithms, among others. However, traditional mining algorithms needs to consider the characteristics of the educational context to support instructional design and pedagogical decisions [10].

Educational data has meanings with multiple levels of hierarchy, which need to be determined by means of the properties of the data itself. Time, sequence, and context play an important role in the study of educational data. EDM supports the development of research on many problems in education, since it not only allows to see the unique learning trajectories of individuals, but it also allows to build increasingly complex and sophisticated learning models [4].

The knowledge uncovered by EDM algorithms can be used not only to help teachers manage their classes, understand learning processes of their students, and reflect it in their own teaching methods, but also to support reflections of the student about the situation and give feedback to them [8]. Although one might think that there are only these two stakeholders in EDM, there are other groups of users, who see EDM from different points of view, according to their own objectives [10]. For example, education researchers, universities, course developers, training companies, school supervisors, school administrators, could also benefit from the knowledge generated by EDM [7]. Fig. 1 shows the interrelationships of educational environments, stakeholders and the EDM process.

3 Review of Educational Data Mining Research

The improvement of computing has admitted to store and process huge data which some years ago was impossible. As a result, educational technologies have been instrumented to collect large amounts of data which in turn is analyzed to understand the several aspects and interrelations of the educative processes.

Many researchers are interested in the development of early detection of struggling students. For example, Hung and colleagues [6] propose a novel predictive modeling method to address the research gaps in existing performance prediction research., their focus is on:

i) the lack of existing research focused on performance prediction rather than identifying key performance factors

ii) the lack of common predictors identified for both K-12 and higher education environments

iii) the misplaced focus on absolute engagement levels rather than relative engagement levels.

The predictive modeling technique was applied in two datasets, one from higher education and the other from a K-12 online school with 13,368 students in more than 300 courses. Some experiments were conducted. First, because a student's engagement level has been identified as a key predictor in predicting performance, the input variables will be converted from absolute values to relative values. A K-fold model for training and validation will be applied to compare accuracy and recall rates between absolute and relative models.

Authors assume the prediction accuracy can be improved by the relative transformation. Secondly, because prediction errors are inevitable in the process of predictive modeling, they propose a two-stage approach by constructing three related predictive models (the successful model, the at-risk model, and the coordination model).

Authors assume the dual-stage, three-model approach can further improve the model's accuracy and capture more at-risk students during the semester. Finally, because ensemble and deep learning models will be adopted as the major algorithms, the surrogate model approach will be applied to reveal the key at-risk predictors. The results will assist in identifying common at-risk predictors across K-12 and higher education learning environments [6].

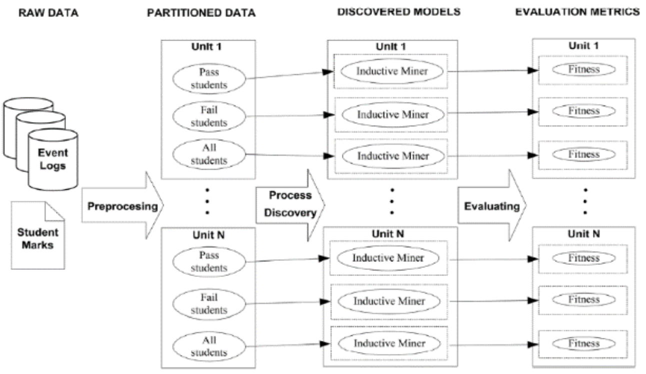

Fig. 2. Educational Processes Mining process from raw data to algorithm interpretation [2].

The results showed the newly suggested approach had higher overall accuracy and sensitivity rates than the traditional approach. In addition, two generalizable predictors were identified from instruction-intensive and discussion-intensive courses. Authors suggest that for future research, researchers should consider applying this dual-stage approach to other predictive modeling tasks. Combining online discussion content and online behaviors, reflected by student efforts in online courses, might further improve the analytical results reported [6].

On the other hand, the content assessment through educational data mining has received attention and it has also been broadly improved in e-learning scenarios in recent decades. Cerezo and colleagues [2] state that the e-Learning process can give rise to a spatial and temporal gap that poses interesting challenges for assessment of not only content, but also acquisition of core skills such as self-regulated learning. Their research is focused in to discover self-regulated learning processes of students during an e-Learning course by using Process Mining Techniques.

They applied a new algorithm in the educational domain called Inductive Miner over the interaction traces from 101 university students in a course given over one semester on the Moodle 2.0 platform. Data was extracted from the platform's event logs with 21,629 traces to discover self-regulation models of students that contribute to improving the instructional process.

The Inductive Miner algorithm discovered optimal models in terms of fitness for both Pass and Fail students in this dataset, as well as models at a certain level of granularity that can be interpreted in educational terms, which are the most important achievement in model discovery.

Authors conclude that although students who passed did not follow suggestions of the instructors exactly, they did follow the logic of a successful self-regulated learning process as opposed to their failing classmates. They state that the Process Mining models allows them to examine which specific actions were performed by the students. They found interesting a high presence of actions related to forum-supported collaborative learning in the Pass group and an absence of those in the Fail group [2]. This process is depicted in Fig. 2.

Another research is interested is measure several psychological constructs. For example, Li and colleagues are concerned in developing models to measure self-regulated behavior and identify significant behavioral indicators in computer-assisted language learning courses. In their models, the behavioral measures were based on log data from 2454 freshman university students from Art and Science departments for a year. These measures reflected the degree of self-regulation, including anti-procrastination, irregularity of studying intervals, and pacing.

Authors apply clustering analysis to identify typical patterns of learning pace, and hierarchical regression analysis was performed to examine significant behavioral indicators in the online course. The results of learning pace clustering analysis revealed that the final course point average in different clusters increased with the number of completed quizzes, and students who had procrastination behavior were more likely to end up with lower final course points. Furthermore, the number of completed quizzes and studying intervals irregularity were strong predictors of course performance in the regression model. This clearly indicated the importance of self-regulation skills, in particular the completion of assigned tasks and regular learning.

In the context of intelligent tutoring systems research, the student model has received more attention that the other components since it enables the ITS to respond to the needs of the students. The student modeling has been improved due to educational data mining. These authors build a student model based on the data log of a virtual reality training system that has been used for several years to train electricians. They compared the results of this data-driven student model with a student model built by an expert. For the knowledge representation, authors rely on Bayesian networks to build the student models.

Bayesian networks have been used in ITS to model student knowledge, predict student behavior and make tutoring decisions due to their strong mechanisms for managing the involved uncertainty. The model relies on Bayesian networks to probabilistically relate behavior and actions of the students with their current knowledge. The tree augmented naive Bayes algorithm and the GeNIe software package were used to learn the Bayesian model from the data from the system for electrical training. They conducted an initial evaluation comparing the data-driven student model with a student model built with expert knowledge. And both models obtain good results in predicting the student state [5].

Another plentiful source of educational data are forums, chats, social networks, assessments, essays, among others, which produce a massive volume of data, especially in text format. According to Ferreira and colleagues [3], documents pose exciting challenges on how to mine text data to find useful knowledge for educational stakeholders. These authors conducted a systematic overview of the current state of the Educational Text Mining field. Their final goal is to answer three main research questions: Which are the text mining techniques most used in educational environments? Which are the most used educational resources? And which are the main applications or educational goals? Authors state although there is much research published in educational text mining, it also has gaps to be filled in, and there are some hot and new topics to develop. More specifically, they propose the next most interesting future research lines:

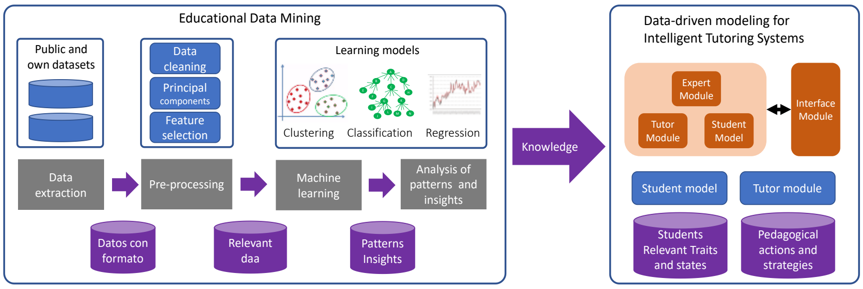

Fig. 3. Data-driven approach to intelligent tutoring systems modeling.

i) analyzing online discussion collaboration,
ii) writing analytics,
iii) natural language generation.

4 Applying EDM to Improve Learning Environments

Educational data mining plays an important role in understanding the different aspects of the learning process and in building and improving intelligent learning environments. These techniques organize existing knowledge and acquire new knowledge by intelligently recording and reasoning about data. For example, observations of the previous behavior of students will be used to provide training examples that will form a model designed to predict future behavior of students [12].

We are developing two intelligent tutoring systems (ITS). The first one aims to teach math to kids of elementary school. The second one targets to tech mathematical logic to undergraduate and graduate students. We want to design the components of the ITS considering the knowledge generated by data coming from educational contexts. We are using a standard approach for data mining, which is shown in Fig. 3.

We are following two strategies. The first one consists of analyzing public datasets and the second one is interested in gathering our own data. In this moment, we are analyzing several public datasets at repositories as DataShop, which is a big repository of learning interaction data. Such data can be used to help advance our understanding of student learning and learning process itself [7].

We are applying techniques for feature selection and principal components analysis, to detect those relevant attributes for learning and to eliminate those attributes which do not provide information to the model. The datasets which we are working on are diverse and heterogenous, have many attributes and they were gathered with different purposes. Therefore, we are training the predictive models using algorithms for clustering, classification, and regression.

With the knowledge generated by the EDM process, we are designing the intelligent tutoring systems. In this first stage, we are working on the student model, and in the tutor module, therefore, we will have data-driven student models. The student model is an important component of the ITS because it allows the ITS to provide adaptive instruction to students; and the tutor module make decisions about the tutorial actions to be presented to the students based on the student model.

As first steps, we need to identify the relevant attribute in students which have positive impact in learning. In our previous research, we have identified emotions, personality, and goals as important players in motivation and learning. But now, we want to explore other relationships. We are trying to model self-efficacy and self-regulated learning; therefore, we are working in identifying the indicators of self-efficacy and self-regulated learning to include them in the student model of the ITS.

Self-efficacy is a personal judgment of how well or poorly a person can cope with a given situation based on the skills they have and the circumstances they face. Self-efficacy affects every area of human endeavor. By determining the beliefs a person holds regarding their power to affect situations, self-efficacy strongly influences both the power a person actually has to face challenges competently and the choices a person is most likely to make [1]. Also has been recognized that self-efficacy is a key trait of self-regulated learners [9]. Self-regulated learning refers to one’s ability to understand and control one’s learning environment. Self-regulation abilities include goal setting, self-monitoring, self-instruction, and self-reinforcement [9].

5 Conclusions and Future Work

The ubiquity of computers and mobile devices in classrooms, the distance education and the learning everywhere produce data every second. Educational data is rich in insights about the different aspects of students, teachers, learning processes and learning management. Therefore, machine learning techniques can be used to understand those aspects, and in turn to design and improve intelligent learning environments. A goal of educational data mining is having better educational technologies. This objective requires further advances in artificial intelligence and in human learning theories. Educational data mining is an emerging discipline that can be useful towards these aims due to its potential to support the development of fields related to education.

In this paper, we present a brief review of relevant research in educational data mining, an also we propose the modeling and designing of intelligent tutoring systems based on a data-driven approach. The ITS are being built considering the knowledge produced by the educational data mining techniques. We are analyzing public educational datasets, but also, we are gathering data by means of a controlled experiments with an online course and under graduated and graduated students participating. Despite, this research is in an initial stage, we visualize potential in the educational data mining techniques based on our previous work in intelligent learning environments.

References

1. Bandura, A.: Guide for constructing self-efficacy scales. Self-efficacy beliefs Adolesc. pp. 307–337 (2006). https://doi.org/10.1017/CBO9781107415324.004

2. Cerezo, R. et al.: Process mining for self-regulated learning assessment in e-learning. J. Comput. High. Educ. 32, 1, pp. 74–88 (2020). https://doi.org/10.1007/s12528-019-09225-y
3. Ferreira-Mello, R. et al.: Text mining in education. Wiley Interdiscip. Rev. Data Min. Knowl. Discov. 9, 6, (2019). https://doi.org/10.1002/widm.1332
4. Fischer, C. et al.: Mining Big Data in Education: Affordances and Challenges. Rev. Res. Educ. 44, 1, pp. 130–160 (2020). https://doi.org/10.3102/0091732X20903304
5. Hernández, Y. et al.: Data-driven construction of a student model using bayesian networks in an electrical domain. In: 16th Mexican International Conference on Artificial Intelligence, MICAI 2017. pp. 481–490 Springer Verlag (2017). https://doi.org/10.1007/978-3-319-62428-0_39
6. Hung, J.L. et al.: Improving Predictive Modeling for At-Risk Student Identification: A Multistage Approach. IEEE Trans. Learn. Technol. 12, 2, pp. 148–157 (2019). https://doi.org/10.1109/TLT.2019.2911072
7. Koedinger, K.R. et al.: New Potentials for Data-Driven Intelligent Tutoring System Development and Optimization. AI Mag. 3, pp. 27–41 (2013)
8. Merceron, A. et al.: Learning Analytics: From Big Data to Meaningful Data. J. Learn. Anal. 2, 3, pp. 4–8 (2016). https://doi.org/10.18608/jla.2015.23.2
9. Panadero, E.: A review of self-regulated learning: Six models and four directions for research. Front. Psychol. 8, APR, 1–28 (2017). https://doi.org/ 10.3389/fpsyg.2017.00422
10. Romero, C., Ventura, S.: Educational data mining and learning analytics: An updated survey. Wiley Interdiscip. Rev. Data Min. Knowl. Discov. 10, 3, pp. 1–21 (2020). https://doi.org/10.1002/widm.1355
11. Witten, I.H. et al.: Data Mining: Practical Machine Learning Tools and Techniques. Morgan Kaufmann, Cambridge (2017)
12. Woolf, B.P.: Student modeling. In: Nkambou, R. et al. (eds.) Studies in Computational Intelligence. pp. 267–279 Springer (2010). https://doi.org/10.1007/978-3-642-14363-2_13

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