A semiconductor and IC teaching BOT for accurate knowledge democratization

Un BOT de enseñanza de semiconductores y circuitos integrados para la democratización precisa del conocimiento

Juan Andrés Lopez-Cubides[1], Fredy Segura-Quijano[2], Juan Sebastian Moya-Baquero[3]

Lopez-Cubides, J.A; Segura-Quijano, F; Moya-Baquero, J.S. A semiconductor and IC teaching BOT for accurate knowledge democratization. *Tecnología en Marcha*. Vol. 37, special issue. June, 2024. IEEE Latin American Electron Devices Conference (LAEDC). Pág. 5-14.

https://doi.org/10.18845/tm.v37i5.7213

1 CMUA - Universidad de Los Andes. Colombia.
ja.lopezc12@uniandes.edu.co
2 Member, IEEE. CMUA - Universidad de Los Andes. Colombia.
fsegura@uniandes.edu.co
https://orcid.org/0000-0001-7757-1432
3 CMUA - Universidad de Los Andes. Colombia
juan2178217@correo.uis.edu.co
https://orcid.org/0000-0001-5676-4024

Keywords

Chatbot; NLP; NLU; education; microelectronics; integrated circuit design.

Abstract

The pandemic of 2020 impacted different areas of society, such as health, the economy, and education. In addition, inequity to Internet access, to consumer electronic devices, and economic inequality increase the educational gap between developed and developing countries. Still, technological advances allow the possibility of mitigating the negative impacts by developing different tools to preserve the quality of education. Artificial Intelligence is a tool that has risen exponentially in the last years, primarily when it is used as an information browser. However, this tool must be more mature to guarantee the correct transmission of knowledge, especially in fields needing more available information. We present Silibot, a Chatbot that uses artificial intelligence models to support autonomous learning in semiconductor and integrated circuits fields. It is a tool developed to reduce inequity regarding access to education and complement the professors' work during the classes. We implemented Silibot in Dialogflow CX with more than 90 % accuracy.

Palabras clave

Chatbot; NLP; NLU; education; microelectronics; integrated circuit design.

Resumen

La pandemia de 2020 impactó diferentes áreas de la sociedad, como la salud, la economía y la educación. Además, la inequidad en el acceso a Internet, a los dispositivos electrónicos de consumo y la desigualdad económica aumentan la brecha educativa entre los países desarrollados y en desarrollo. Aún así, los avances tecnológicos permiten la posibilidad de mitigar los impactos negativos mediante el desarrollo de diferentes herramientas para preservar la calidad de la educación. La Inteligencia Artificial es una herramienta que ha crecido exponencialmente en los últimos años, principalmente cuando se utiliza como navegador de información. Sin embargo, esta herramienta debe ser más madura para garantizar la correcta transmisión del conocimiento, especialmente en campos que necesitan más información disponible. Presentamos Silibot, un Chatbot que utiliza modelos de inteligencia artificial para apoyar el aprendizaje autónomo en los campos de semiconductores y circuitos integrados. Es una herramienta desarrollada para reducir la inequidad en el acceso a la educación y complementar el trabajo de los profesores durante las clases. Implementamos Silibot en Dialogflow CX con más del 90 % de precisión.

Introduction

Four years have passed since the pandemic's beginning caused by the Covid-19 virus [1], [2]. Several restructuring measures were implemented during the pandemic to mitigate the impact of the virus on different areas of society. One of those areas is education since several tools were developed to counter the measures imposed by the governments of staying at home to reduce the propagation of the virus. Some of those tools are still present to complement and enhance post-pandemic education.

Several of the tools used nowadays and positively impacting education and learning incorporate artificial intelligence (AI) models to transmit knowledge more informally and friendly to the students. A standard tool used is a Chatbot, which is a software application that simulated

maintaining a conversation with the user through text messages at an early stage. Still, actual Chatbots implement Deep Learning (DL) and Machine Learning (ML) models to support the appropriation of acquiring knowledge autonomously. For instance, Chatbots are commonly utilized by users who cannot attend classes in person or need additional time out of the regular schedules set for the classes. Nevertheless, ChatGPT, one of the most used Chatbots nowadays, has demonstrated that the information provided during the conversation could not be accurate or sometimes incorrect. This lack of veracity damages the learning process between professors and students. Thus, it is necessary to develop tools incorporating artificial intelligence models where information is selected and controlled by professors or educational institutions to guarantee that the base of the knowledge transmitted to the students is adequate.

Silibot is a Chatbot designed, developed, and trained by the CMUA research group associated with the University of Los Andes that exploits artificial intelligence to support and facilitate the transmission of concepts related to semiconductors and integrated circuit areas. To complement the information associated with those areas, Silibot conducts the user in the design and layout implementation of a CMOS inverter with the open-source tools and the sky130 process design kit (PDK) provided by Google. With the design of the inverter in a commercial PDK, the users can enhance their understanding of the semiconductor and integrated circuit areas through several concepts associated with stages of the design and manufacturing of integrated circuit flows.

State-of-the-art

Before presenting Silibot and its conversational approach design, it is necessary to define several concepts associated with AI, chatbots, and the possible platform that could be used to implement the chatbots.

How a Chatbot works

With several technological advances in computer science, engineers developed different methods, each time more complex, targeting new intelligent algorithms based on ML, DL, and its derivatives to alleviate and optimize high-complexity human tasks. ML is derived from the AI field, and through experience and previous learning, it processes large amounts of data to generate discrete or continuous predictions [3].

Three different algorithms could be implemented in ML, supervised learning algorithms, non-supervised learning algorithms, and reinforcement learning. The first algorithm needs human intervention to define the correct and incorrect answers by defining labels during the training. The non-supervised learning algorithm learns without human intervention, whereas the reinforcement learning algorithm generates its training database considering the errors committed. The latter algorithm is commonly known as reward and punishment training [3].

DL, derived from ML, avoids extracting data characteristics and eliminates the external pre-processing information step since it uses local neural networks to construct high-complexity models [4].

To potentiate the machine's understanding of informal languages through the conversational approach [5], Natural Language Processing (NLP), derived from the union of ML and DL, allows machines to understand requests implemented in an informal structure. Once the machine receives the request from the user, NLP standardizes internally the text from the user to extract the literal meaning for adequate understanding and then provides the desired answer [6].

Still, with the current limitations associated with data comprehension, NLP uses Natural Language Understanding (NLU) algorithms to obtain the users' literal sense once NLP standardizes the text. Fig 1. presents a diagram illustrating the relation between the above-mentioned concepts.

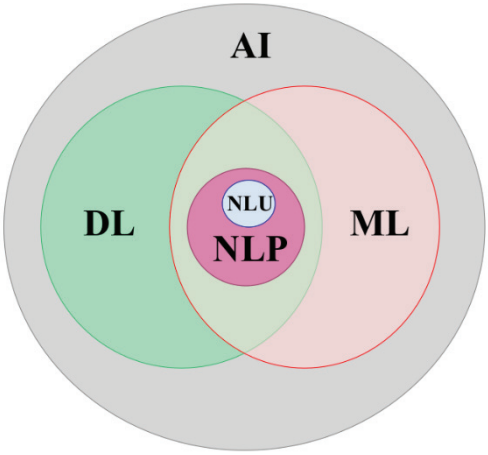

Fig 1. Relation between Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), Natural Language Understanding (NLU), and Natural Language Processing (NLP).

An application derived from NLP and NLU is chatbots, which are conversational agents developed to intuitively attend to users' requests. Chatbots target to execute more natural, fluid, effective, and accurate communications with the users, emulating a discussion with a human. Several types of chatbots are text box chatbots, virtual assistants, and physical robots. Text box chatbots interact with the users through input and output texts, whereas virtual assistants implement virtual personification using broadcast media. Finally, physical robots control several peripherals to exchange information with the user to enhance the conversation [7].

The chatbots mentioned above manage different amounts of data that depend on the particular emphasis given. For instance, it is possible to find chatbots associated with the banking and financial sector; some applications encourage and teach the user to implement healthier practices, while others accomplish entertainment tasks. Chatbots look forward to exchanging information with the user for later processing and consequently transmitting knowledge at different scales. Regardless of the scale, the information delivered by the application should be true and accurate, especially for chatbots with an emphasis on educational purposes.

Actual Bots for educational purposes

With the exponential growth of chatbots in several scenarios, it is possible to find many companies developing bots for different applications. A typical application is the raising development of language conversation chatbots to help users improve their learning. This is the case of Dialogflow, which creates an intelligent assistant that interacts and maintains a conversation with the users [5]. Another example is the development of bots covering many school subjects in several institutions in India during the COVID-19 pandemic to mitigate the negative impact on teaching and learning. Students can reach out to the bots on a friendly website 24 hours per day [8].

Specific bots could also be found in the literature covering distinct topics. For instance, Santander Industrial University in Colombia designed, developed, and trained a bot to address environmental subjects associated with the Santurbán wasteland. The bot supported the education of the kids that lived around the wasteland to protect and conserve it [9].

Finally, OpenAI is behind the recent and well-known conversational chatbot, ChatGPT, which uses automatic learning and large-scale language models. ChatGPT accomplishes several tasks, such as summarizing texts, extending information, translating documents, making predictions, or elaborating speeches with correct accuracy [10]. The information used to train

ChatGPT comes primarily from the Internet, which can sometimes be controlled since different sources provide the information. Doubts and mistrust exist regarding the texts generated by the tool [11]. Moreover, it is well known that ChatGPT demonstrates coherence in its answers, but sometimes the answers are not accurate and reliable, mainly when the questions asked belong to a well-defined context [10]. The latter occurs since ChatGPT looks to answer any question using general context information. Thus, Chat GPT has several challenges to overcome to be consolidated as an adequate complementary tool for education at different scales.

Platforms used to develop chatbots

Several platforms are dedicated to delivering intuitive tools to develop Chatbots for enhancing machine-human communication. Table 1. reviews some common platforms to generate conversational agents, such as Dialogflow ES, Dialogflow CX, Microsoft Azure Bot Service, IBM Watson, and Amazon Lex.

One of the most important criteria while selecting the development platform is that it implements applications with conversational emphasis. Among the platforms presented in Table 1, Dialogflow ES and Dialogflow CX are the most used platforms with this emphasis. Still, Dialogflow ES is very restricted regarding the conversational routes, does not incorporates a graphic interface, and does not use pre-testing tools. Therefore, we select Dialogflow CX to implement Silibot.

Table 1. Platform Comparison for Chatbots Development

	Dialogflow ES	Dialogflow CX	Azure Bot Service	IBM Watson	Amazon Lex
Text reception and answer	Yes	Yes	Yes	Yes	Yes
Conversational Ilimited turns	No	Yes	Yes	Yes	Yes
NLP	Yes	Yes	Yes	Yes	Yes
NLU	No	Yes	Yes	Yes	Yes
Integration with websites	Yes	Yes	Yes	Yes	No
Pre-testing tools	No	Yes	Yes	Yes	Yes
Approach	Small Projects. Conversational. Used in Educational. Environmental, Social, or Psychological areas	Small Projects. Conversational. Used in Educational. Environmental, Social, or Psychological areas	Large scale business projects. Recommended for Microsoft Environment.	Small Projects. No Conversational Focus in searching information in documents.	Large scale projects. Focus in business and travel areas.

Materials and methods

Proposed BOT

The definition of the Chatbot structure starts with identifying the cases, as shown in Fig. 2. It is possible to identify three different users interacting with the Chatbot: the professor, the class student, and people outside the class (strangers). The interaction between the users occurs through conversation. Thus, a conversational case targeting the application of semiconductor concepts in the design of integrated circuits is developed with the support of open-source tools and the sky130 PDK.

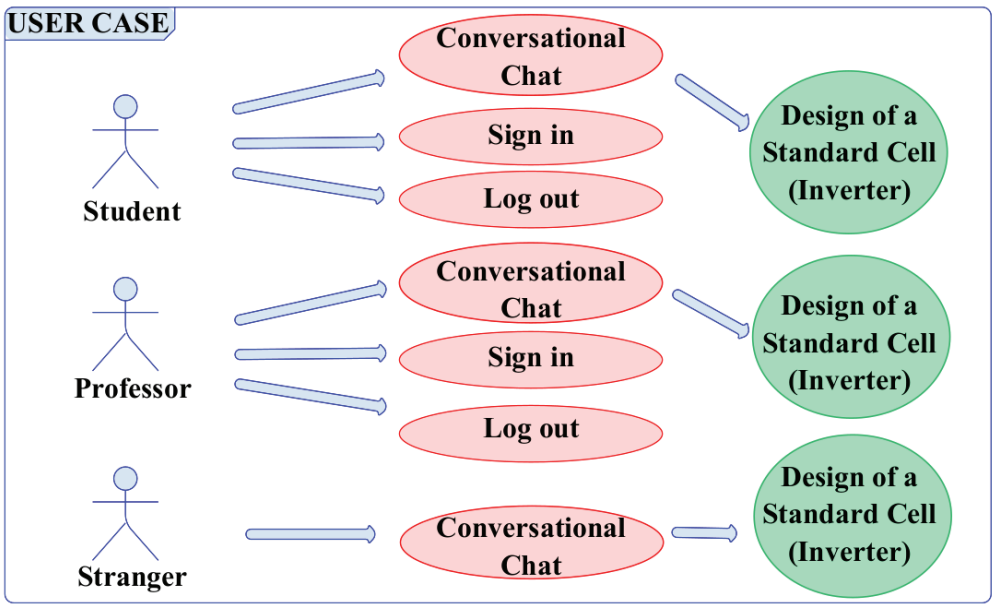

Fig. 2. Chatbot structure with the different users that can interact with the Chatbot.

Once we defined the Chatbot type as conversational, we implemented the conversational diagram in the Dialogflow CX tool based on the UML standard for state machines, as shown in Fig. 4. The main flow addresses the topic associated with integrated circuits, starting with the use of computers or cell phones, passing through the silicon wafer, and finishing with the design and layout extraction of a CMOS inverter in an open-source tool.

To increase the conversation's versatility, a bank of questions with unique answers is constructed and connected to specific parts of the main flow. With this bank, questions associated with the topic addressed by the user and not mentioned directly by him can broaden and complement the conversation between the user and Silibot to increase the transference of knowledge. Furthermore, these questions with unique answers allow the user to access rapid and appropriate responses to a specific topic without diving entirely into the main flow.

We trained the Chatbot with more than 30 attempts with multiple types of entities to identify specific words to enhance sentence comprehension and accuracy. For instance, the model could deliver a wrong answer when some users' requests use common words. Thus, the entities avoid the machine getting lost and increase understanding of the user's intentions. Moreover, we trained the entities with 30 sentences to balance data and avoid over-fitting, or under-fitting [3].

In the first instance, 30 sentences may seem a reduced value to train the Chatbot. Still, DialogflowCX incorporates the NLP technology, which provides many grammatical forms that allow the Chatbot to detect the users' intentions with higher accuracy and consequently enhance the detection of the requests.

Finally, the training model threshold was set by default to 0.3, this value results from the internal probability calculated by the neural networks. Since pretests confirmed that the detections completed by DialogflowCX were satisfactory, we decided to maintain the default probability. Thus, based on the previous results, it was possible to confirm that humans could test the Chatbox performance. Fig. 3a) presents an example of a conversation between a possible user and Silibot in the graphical interface developed in DialogflowCX. Fig. 3b) depicts the QR code to access Silibot.

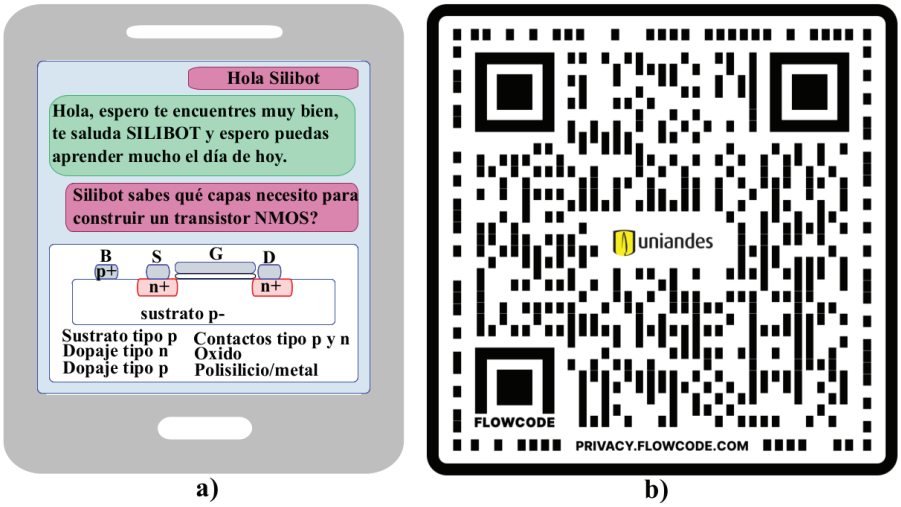

Fig. 3. a) illustrates an example of a conversation between the user and Silibot. The QR code to access Silibot is shown in b).

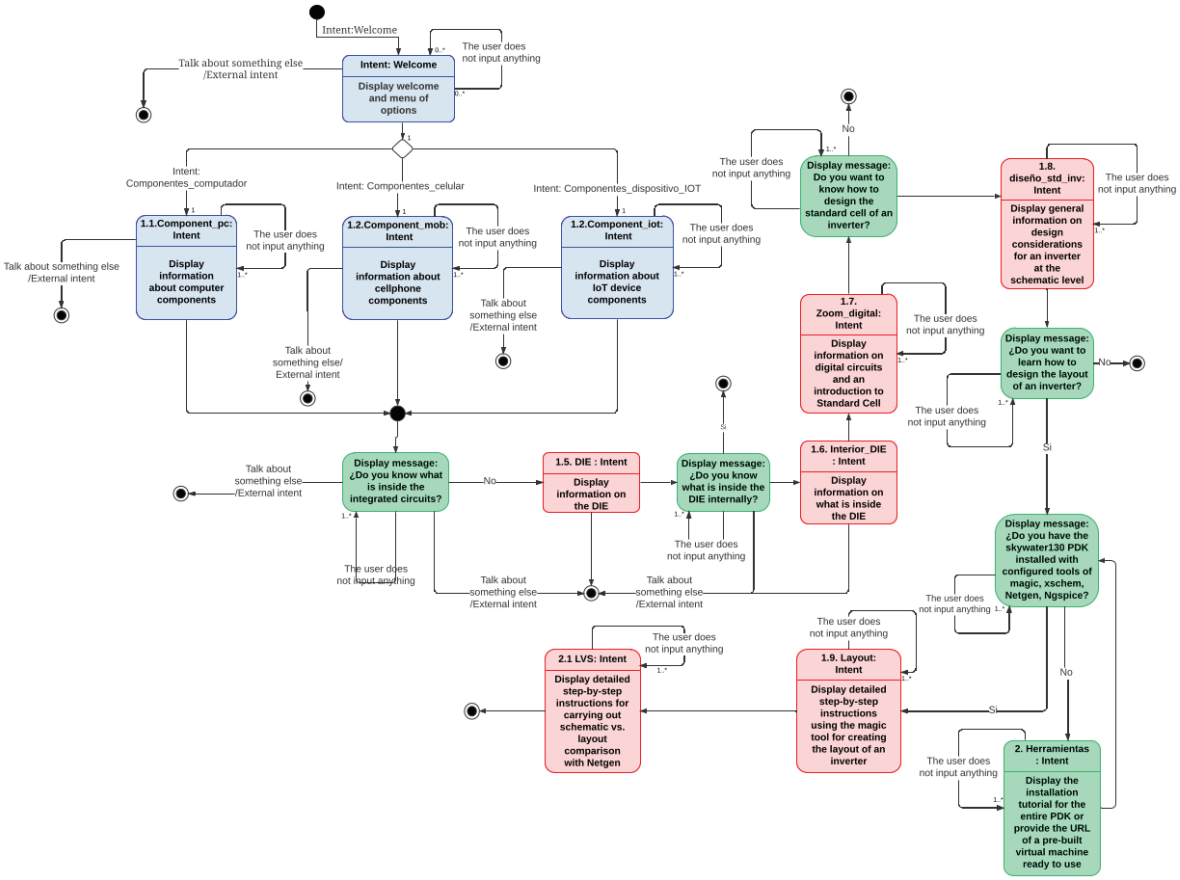

Fig. 4. Conversational diagram of the main flow in the Dialogflow CX tool based on the UML standard for state machines.

Results

Once we determined that the Chatbot was ready to be tested by humans, we located Silibot on a private website associated with the University of Los Andes. More than 258 data were collected to determine the Chatbot's performance metrics. Then, we implemented a multiclass matrix to extract those metrics since the matrix provides greater detail in the accuracy of the results and, at the same time, enables the corrections that should be done to enhance the performance.

Regarding the metrics, Silibot achieves an accuracy for correct predictions of 97.29 %, a total precision for correct data of 98.98 %, and 97.40 % for Recall, which determines the amount of positive data. Finally, the F1-Score determines a balance between precision and Recall, where the metric increases as negative and positive false decrease; its final value was 98.03 %.

Despite the Chatbot presenting performance metrics above 90 %, we extended the tests to identify the benefits of working with Silibot compared with ChatGPT. ChatGPT is the most used artificial intelligence browser to answer questions on many topics. We selected questions associated with a CMOS inverter's design and layout implementation using open-source tools with the sky130 PDK. We identified that the answers provided by ChatGPT were too general compared with the responses delivered by Silibot. The later results confirm the implementation of Silibot as a tool to support the educational material related to the design of integrated circuits.

Conclusions

We developed a Chatbot that provides accurate and well-defined information for educational purposes in semiconductors and integrated circuit design to enhance and complement the concepts provided during the classes and facilitate their transmission to the students. Regarding the performance of Silibot, we identified that the obtained metrics are satisfactory. Silibot achieves an accuracy of 97.29 %, a precision of 98.98 %, a Recall of 97.40 %, and an F1-Score of 98.03 %. Although ChatGPT answers correctly to most of the questions asked, the answers are not accurate when the question is associated with a specific area, such as integrated circuits, where the information is limited. Those undesired results encourage the development of specific tools with better performances, such as Silibot to transmit knowledge correctly. Finally, this tool will be extended to cover additional topics in semiconductors and integrated circuit design. It could also be extended to other educational areas and significantly impact education.

References

[1] U. N. ECLAC, "The sociodemographic impacts of the covid-19 pandemic in latin america and the caribbean," Fourth session of a Regional Conference on Population and Development in Latin America and the Caribbean., pp. 1–154, 2022.

[2] U. N. D. P. U. R. B. of Asia and the Pacific, "The-social-economic-impact-of-covid-19-in-the-asia-pacific-region," pp. 1–36, 2020.

[3] A. G´eron, Hands-on machine learning with Scikit-Learn, Keras, and TensorFlow. " O'Reilly Media, Inc.", 2022. [4] I. Goodfellow, Y. Bengio, and A. Courville, Deep learning. MIT press, 2016.

[5] A. F. Muhammad, D. Susanto, A. Alimudin, F. Adila, M. H. Assidiqi, and S. Nabhan, "Developing english conversation chatbot using dialogflow," in 2020 International Electronics Symposium (IES). IEEE, 2020, pp. 468–475.

[6] C. Kidd and B. Saxena. (2021) Nlp vs nlu: What's the difference? [Online]. Available: https://www.bmc.com/blogs/nlu-vs-nlp-natural-language-understanding-processing/

[7] G. Brustenga, M. F.-A. Guillerm, and N. Molas-Castells, "Briefing paper: chatbots in education," Barcelona, 2018.

[8] J. J. Sophia and T. P. Jacob, “Edubot-a chatbot for education in covid-19 pandemic and vqabot comparison,” in 2021 Second International Conference on Electronics and Sustainable Communication Systems (ICESC). IEEE, 2021, pp. 1707–1714.

[9] J. A. Lopez Cubides, “Dise ˜no, desarrollo y entrenamiento de un bot para una plataforma transmedia del p ´aramo de santurb ´an,” Ph.D. dissertation, Universidad Industrial de Santander.

[10] O. Tapalova and N. Zhiyenbayeva, “Artificial intelligence in education: Aied for personalised learning pathways,” Electronic Journal of e-Learning, vol. 20, no. 5, pp. 639–653, 2022.

[11] J. Franganillo and J. Guallar, “Chatgpt escribe un poema al estilo de lorca: el resultado muestra sus debilidades,” The Conversation, 2023, 6 febrero., 2023.

A Semiconductor and IC Teaching BOT for Accurate Knowledge Democratization

Juan Andrés Lopez Cubides [1], Fredy Segura-Quijano [1], Juan Sebastian Moya Baquero [1 2]
[1] CMUA - Universidad de Los Andes,[2] Onchip – Universidad Industrial de Santander
ja.lopezc12@uniandes.edu.co, fsegura@uniandes.edu.co, juan2178217@correo.uis.edu.co

Introduction

The pandemic of 2020 impacted different areas of society, such as health, the economy, and education. In addition, inequity to Internet access, to consumer electronic devices, and economic inequality increase the educational gap between developed and developing countries. Still, technological advances allow the possibility of mitigating the negative impacts by developing different tools to preserve the quality of education. Artificial Intelligence is a tool that has risen exponentially in the last years, primarily when it is used as an information browser. However, this tool must be more mature to guarantee the correct transmission of knowledge, especially in fields needing more available information.

We present Silibot, a Chatbot that uses artificial intelligence models to support autonomous learning in semiconductor and integrated circuits fields. It is a tool developed to reduce inequity regarding access to education and complement the professors' work during the classes.

Materials and Methods

With several technological advances in computer science, engineers developed different methods, each time more complex, targeting new intelligent algorithms based on ML, DL, and its derivatives to alleviate and optimize high-complexity human tasks. ML is derived from the AI field, and through experience and previous learning, it processes large amounts of data to generate discrete or continuous predictions.

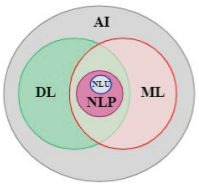

Fig. 1. Relation between Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), Natural Language Understanding (NLU), and Natural Language Processing (NLP).

To potentiate the machine's understanding of informal languages through the conversational approach, Natural Language Processing (NLP), derived from the union of ML and DL, allows machines to understand requests implemented in an informal structure. Once the machine receives the request from the user, NLP standardizes internally the text from the user to extract the literal meaning for adequate understanding and then provides the desired answer. Still, with the current limitations associated with data comprehension, NLP uses Natural Language Understanding (NLU) algorithms to obtain the users' literal sense once NLP standardizes the text. Fig. 1 presents a diagram illustrating the relation between the above-mentioned concepts.

TABLE I
PLATFORM COMPARISON FOR CHATBOTS DEVELOPMENT

	Dialogflow ES	Dialogflow CX	Azure Bot Service	IBM Watson	Amazon Lex
Text reception and answer	Yes	Yes	Yes	Yes	Yes
Conversational ilimited turns	No	Yes	Yes	Yes	Yes
NLP	Yes	Yes	Yes	Yes	Yes
NLU	No	Yes	Yes	Yes	Yes
Integration with websites	Yes	Yes	Yes	Yes	No
Pre-testing tools	No	Yes	Yes	Yes	Yes
Approach	Small Projects. Conversational. Used in Educational. Environmental, Social, or Psychological areas	Small Projects. Conversational. Used in Educational. Environmental, Social, or Psychological areas	Large scale business projects. Recommended for Microsoft Environment.	Small Projects. No Conversational Focus in searching information in documents.	Large scale projects. Focus in business and travel areas.

Several platforms are dedicated to delivering intuitive tools to develop Chatbots for enhancing machine-human communication. Table 1 reviews some common platforms to generate conversational agents.

Results and Discussion

Once we determined that the Chatbot was ready to be tested by humans, we located Silibot on a private website associated with the University of Los Andes. More than 258 data were collected to determine the Chatbot's performance metrics. Then, we implemented a multiclass matrix to extract those metrics since the matrix provides greater detail in the accuracy of the results and, at the same time, enables the corrections that should be done to enhance the performance.

Regarding the metrics, Silibot achieves an accuracy for correct predictions of 97.29 \%, a total precision for correct data of 98.98 \%, and 97.40 \% for Recall, which determines the amount of positive data. Finally, the F1-Score determines a balance between precision and Recall, where the metric increases as negative and positive false decrease; its final value was 98.03 \%.

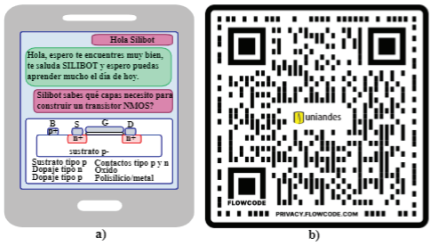

Fig. 2 a) illustrates an example of a conversation between the user and Silibot. The QR code to access Silibot is shown in b).

Despite the Chatbot presenting performance metrics above 90\%, we extended the tests to identify the benefits of working with Silibot compared with ChatGPT. ChatGPT is the most used artificial intelligence browser to answer questions on many topics. We selected questions associated with a CMOS inverter's design and layout implementation using open-source tools with the sky130 PDK. We identified that the answers provided by ChatGPT were too general compared with the responses delivered by Silibot. The later results confirm the implementation of Silibot as a tool to support the educational material related to the design of integrated circuits.

Conclusions / Next Steps

We developed a Chatbot that provides accurate and well-defined information for educational purposes in semiconductors and integrated circuit design to enhance and complement the concepts provided during the classes and facilitate their transmission to the students. Regarding the performance of Silibot, we identified that the obtained metrics are satisfactory. Silibot achieves an accuracy of 97.29\%, a precision of 98.98\%, a Recall of 97.40\%, and an F1-Score of 98.03\%. Although ChatGPT answers correctly to most of the questions asked, the answers are not accurate when the question is associated with a specific area, such as integrated circuits, where the information is limited. Those undesired results encourage the development of specific tools with better performances, such as Silibot to transmit knowledge correctly. Finally, this tool will be extended to cover additional topics in semiconductors and integrated circuit design. It could also be extended to other educational areas and significantly impact education.