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La Editorial Tecnológica de Costa Rica es una dependencia especializada del Instituto Tecnológico de Costa Rica. Desde su creación, en 1978, se ha dedicado a la edición y publicación de obras en ciencia y tecnología. Las obras que se han editado abarcan distintos ámbitos respondiendo a la orientación general de la Institución.

Hasta el momento se han editado obras que abarcan distintos campos del conocimiento científico-tecnológico y han constituido aportes para los diferentes sectores de la comunidad nacional e internacional.

La principal motivación de la Editorial es recoger y difundir los conocimientos relevantes en ciencia y tecnología, llevándolos a los sectores de la comunidad que los requieren.

La revista *Tecnología en Marcha* es publicada por la Editorial Tecnológica de Costa Rica, con periodicidad trimestral. Su principal temática es la difusión de resultados de investigación en áreas de Ingeniería. El contenido de la revista está dirigido a investigadores, especialistas, docentes y estudiantes universitarios de todo el mundo.

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Contenidos

Presentación

Presentation

Esteban Arias-Méndez[1]

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1 IEEE LAEDC 2023 General Co-Chair
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IEEE Latin American Electron Devices Conference (LAEDC) 2023 welcome you to this fifth edition. LAEDC is the flagship conference for EDS in Region 9 and offers an enriching opportunity to learn about many of the fields related to Electron Devices and novel technologies. This special issue is focused on the short papers related to EDS topics presented at the conference.

At LAEDC 2023 we celebrated different events and sessions. The EDS R9 Summer School about "Design, Characterization, and Fabrication of Sensors and Integrated Circuits" at INAOE in Puebla, México, with 18 International and national speakers and more than 80 international student participants from 9 countries. We also had a WIE/YP panel session, a MOS-AK workshop, an EDS Mini Colloquium, a Humanitarian Technology Panel Session, the EDS Region 9 Chapters Summit 2023 (SRC meeting), and a series of free workshops open to public in an event called "Ingeniería abierta para la ciudadanía" held at the Zocalo of Puebla.

For this 2023 edition we had 81 submissions received, 47 accepted papers presented, 16 posters, 105 participants from 21 countries.

We hope you enjoy the selected short-papers below.

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.

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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.

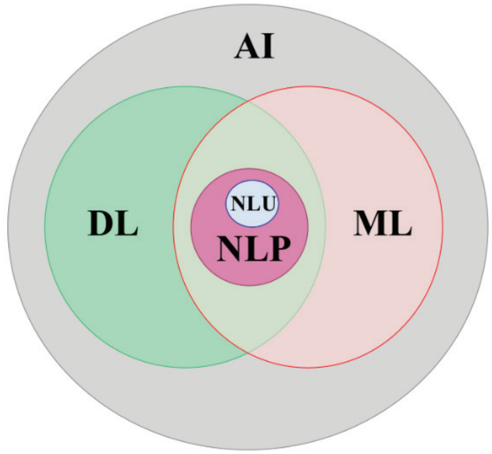

Fig 1. Relation between Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), Natural Language Understanding (NLU), and Natural Language Processing (NLP).

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.

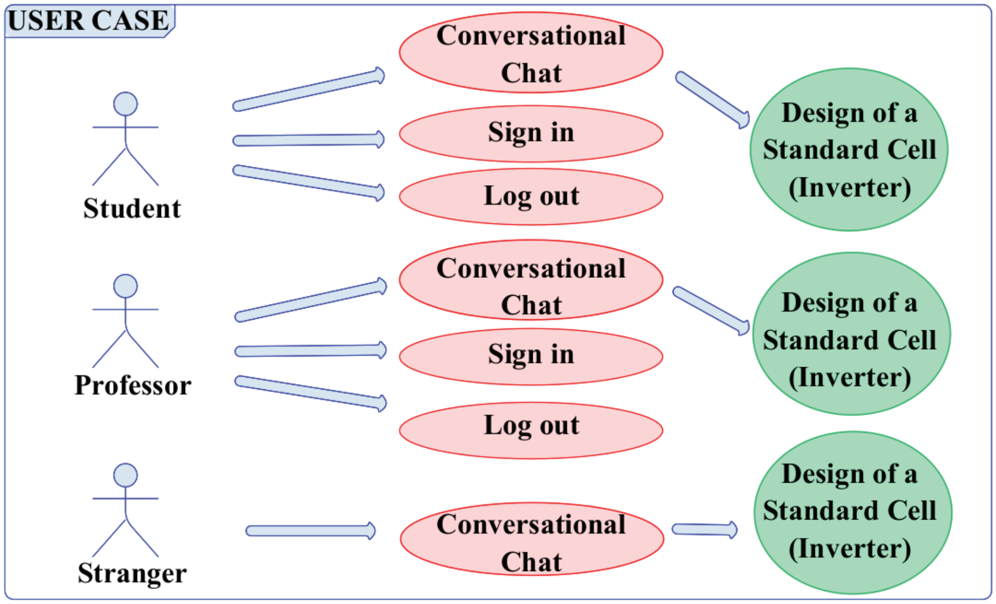

Fig. 2. Chatbot structure with the different users that can interact with the Chatbot.

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.

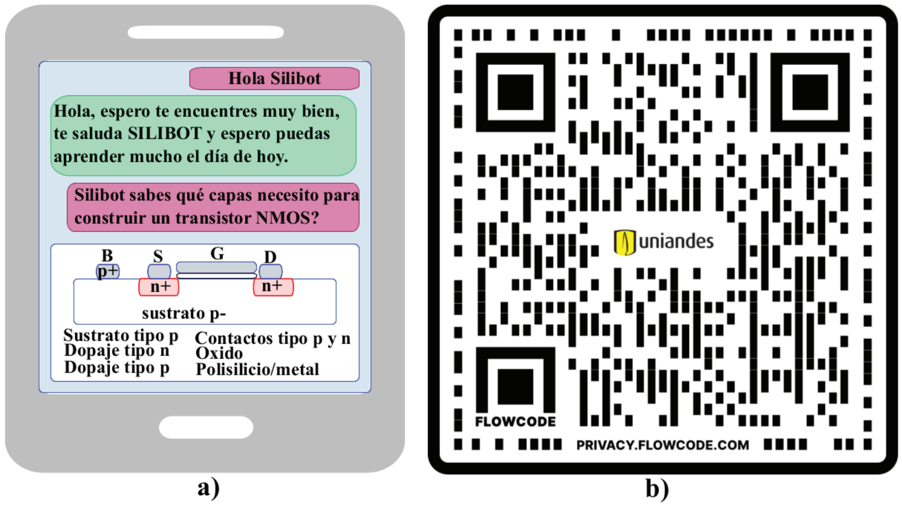

Fig. 3. a) illustrates an example of a conversation between the user and Silibot. The QR code to access Silibot is shown in b).

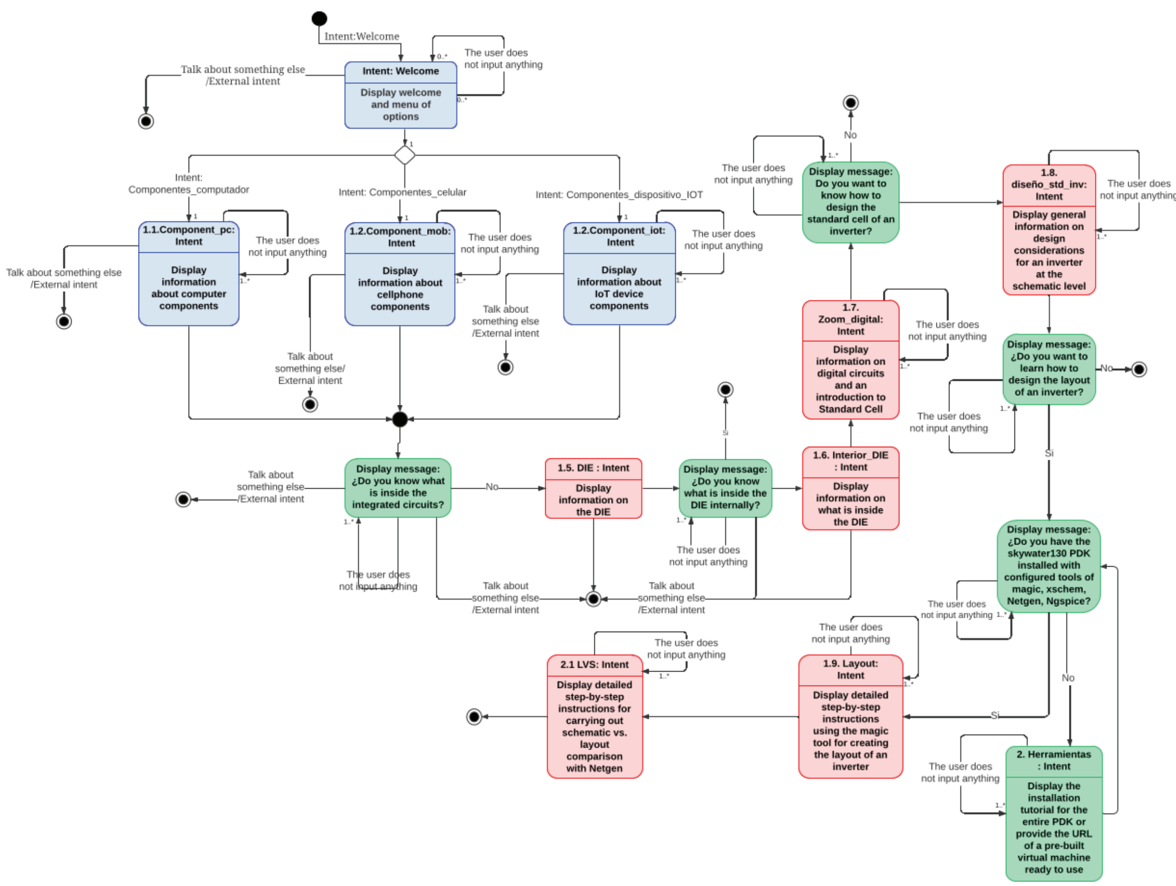

Fig. 4. Conversational diagram of the main flow in the Dialogflow CX tool based on the UML standard for state machines.

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.

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Universidad de los Andes

LAEDC 2023

A Semiconductor and IC Teaching BOT for Accurate Knowledge Democratization

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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.

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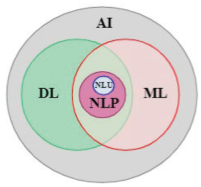

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Results and Discussion

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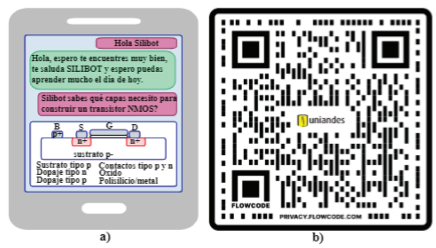

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Conclusions / Next Steps

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.

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Sistemas de ventilación automatizados para el control de la calidad del aire en industrias y áreas de trabajo que involucren alimentos

Automated airing systems for air quality control in industries and work areas that involve food

Gerald Castillo Picado[1], Johel Sanabria Salas[2]

Castillo Picado, G; Sanabria Salas, J. Sistemas de ventilación automatizados para el control de la calidad del aire en industrias y áreas de trabajo que involucren alimentos. *Tecnología en Marcha*. Vol. 37, special issue. June, 2024. IEEE Latin American Electron Devices Conference (LAEDC). Pág. 15-23.

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Palabras clave

Automatización; sensores; confort; túnel de aire forzado; reducción de costos; ventiladores; cortinas de aire.

Resumen

Los sistemas de control automatizado de aire son una tecnología avanzada que permite a las industrias gestionar y controlar la calidad del aire en su entorno. Estos sistemas utilizan una combinación de sensores, controladores y software inteligente para tomar decisiones de manera automática. Su capacidad para medir la calidad del aire, la humedad, la temperatura y la presencia de insectos es especialmente útil en entornos industriales que pueden ser pesados para los trabajadores debido a factores ambientales, entre las ventajas que ofrecen estos sistemas se encuentran la mejora de la salud, la comodidad y la seguridad de los trabajadores. La automatización de estas funciones también reduce los costos de energía y aumenta la eficiencia de los procesos de producción. Además, estos sistemas pueden ser personalizados para adaptarse a las necesidades específicas de cada industria, lo que es fundamental para el buen desarrollo del proceso de salud, ambiental y de confort.

Keywords

Automation; sensors; comfort; forced air tunnel; costs reduction; fans; air curtains.

Abstract

Automated air control systems for industry are advanced technologies that allow the management and control of air quality in industrial environments, which can sometimes be very heavy due to different aspects of the environment. These systems are made up of sensors, controllers and intelligent software that will allow decisions to be made automatically, they are special for measuring air quality, the amount of humidity, regulating the temperature of the place and avoiding the presence of insects, these Systems have multiple advantages, such as improving the health, comfort and safety of workers, doing this automatically generates a reduction in energy costs and the efficiency of production processes, in addition, they can be customized to adapt to the specific needs of each industry, being a very important point for a good development of the health, environmental and comfort process.

Introducción

Los sistemas de control automatizado de aire para la industria representan una solución innovadora y eficiente para garantizar un ambiente de trabajo saludable y seguro, y al mismo tiempo mejorar los procesos de producción. Gracias a la incorporación de tecnologías avanzadas como sensores, controladores y software inteligente, estos sistemas permiten medir y controlar de manera automática factores como la calidad del aire, la humedad, la temperatura y la presencia de insectos.

La calidad del aire es un factor clave en cualquier entorno industrial, ya que puede afectar significativamente la salud y el bienestar de los trabajadores. Un ambiente contaminado puede causar problemas respiratorios, irritación en los ojos y la piel, y en casos extremos, enfermedades graves. Los sistemas de control automatizado de aire permiten mantener un ambiente limpio y saludable, reduciendo así los riesgos para la salud de los trabajadores.

Además, estos sistemas pueden ayudar a aumentar la eficiencia energética de los procesos de producción, ya que permiten regular automáticamente la temperatura y la humedad del ambiente en función de las necesidades específicas de cada industria. Esto se traduce en una reducción de los costos de energía y en una mejora de la productividad, ya que los trabajadores pueden desempeñar sus tareas en un ambiente más cómodo y adecuado.

Por otro lado, estos sistemas también pueden personalizarse para adaptarse a las necesidades específicas de cada industria, lo que es fundamental para garantizar un buen desarrollo del proceso de salud, ambiental y de confort. Esto significa que los sistemas de control automatizado de aire pueden ser adaptados a las necesidades particulares de cada empresa, teniendo en cuenta factores como el tipo de producción, el tamaño del espacio y las condiciones ambientales.

Materiales y métodos

La realización de este proyecto va dirigido a mejorar herramientas de trabajo que permita tener unas mejores condiciones para sus alimentos y sus empleados, con el cual van a tener muchas ventajas a la hora de exportar sus productos y conseguir nuevos clientes, se eligió una empresa agrícola, esto debido a que esta no siempre tiene las posibilidades de realizar estos trabajos y que en la actualidad se encuentra en un abandono tecnológico, por lo cual el impacto que se va a generar es mayor y se va a notar de una mejor manera.

Se debe trabajar un proyecto que represente claramente el impacto económico, social y ambiental que se van a notar en la empresa, esto debido a que la empresa tiene que estar anuente de todos los cambios que se van a realizar, ya que si se aplica un proyecto que sea muy caro el comprador puede negarse a realizarlo, por eso se va a buscar la opción más económica y que cumpla con todas las características necesarias, que no afecte el sonido del lugar y que no tenga problemas con el ambiente alrededor ya que son las plantaciones

El proceso de empaquetado del chayote se realiza en una empacadora, la cual es un galerón cerrado donde el calor se mantiene y los materiales con los que se elaboró hacen que la temperatura aumente, además de los olores que son producidos por los fertilizantes utilizados en la producción del producto, esto se ve afectado en la salud y confort de los empleados. En la siguiente imagen podemos ver las condiciones en la que se trabaja donde existe una gran humedad y algunos olores que hacen que sean incomodos para el empleado y también podemos ver que el almacenamiento de los chayotes tiene que estar una caja encima de la otra por la falta de espacio y esto hace que la temperatura aumente, haciendo que el producto pierda sus propiedades.

Figura 1. Empresa chayotera de la zona.

El problema que es más perjudicial para esta empresa es la perdida de productos por la temperatura que está presente en el local donde se empaca (temperatura promedio de 26 grados Celsius según la empresa), el ministerio de agricultura y ganadería recomiendan mantener este producto entre las temperaturas de 13 y 21ºC, donde muestra las pérdidas de nutrientes que pasan a elevadas temperaturas, en un estudio elaborado por la empresa Scielo en México dice " Los frutos de chayote no presentaron cambio significativos es su composición al almacenarlos a temperatura ambiente (20 ±2 °C) y a baja temperatura (10 ±1 °C, 85 % HR), además contienen menor humedad (5.1 a 6.1%)" , en la siguiente imagen podemos ver como esta empresa hizo pruebas a diferentes temperaturas y como se dañó el producto

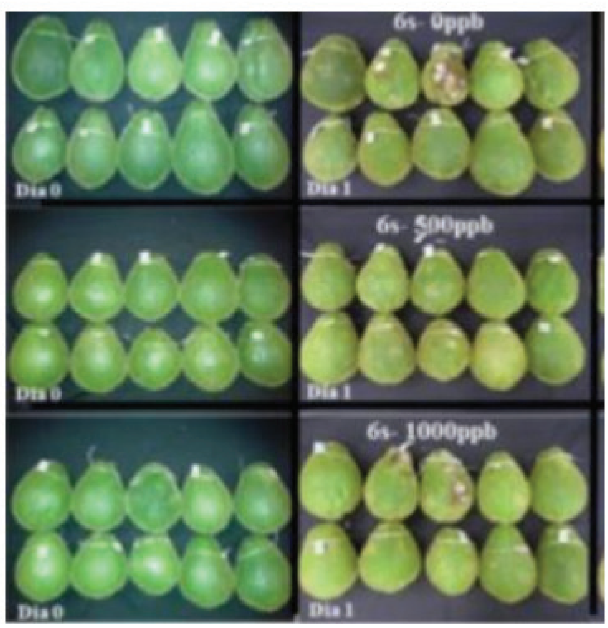

Figura 2. Daño en el producto por mala conservación. Fuente (Scielo)

Otro problema es la presencia de insectos debido a la temperatura y a los fertilizantes utilizados para eliminar las plagas hace que el local se llene de insectos que incomodan a los empleados, esto puede ser poco aseado y desagradable, por lo tanto, hay que encontrar la manera de mitigar la entrada de estos insectos

Para plantear la solución al problema se tiene que buscar la manera que todos los problemas queden erradicados con un mismo proyecto, dice Soler y Palau que "que una solución para el sector alimenticio cuenta con niveles de cuidado y de mucha atención de las condiciones en su interior, sobre todo si se trata de productos expuestos dentro de los procesos". Como primer punto se buscó la información necesaria de la empresa, las dimensiones del local que serían 25x20 m, una altura aproxima de 10 m y que tiene una cantidad de empleados de 25, estos datos van a servir para realizar el cálculo del caudal presente en la empresa, este cálculo consta de 3 pasos:

Paso 1. Cálculo de volumen: $25x20x10 = 5000\ m3$ $5000m3 = 176573.3\ ft3$

Paso 2. Cambios por minuto: para una fábrica se tiene 10 cambios por hora lo que representa 6 minutos por cambio

Paso 3. Calculo de CFM necesarios: $\frac{176573.3 \text{ ft3}}{6 \text{ min/cambio}} = 29428.88\ CFM$

La ventaja de un sistema de ventilación automatizado es que para todas las industrias se puede tener una respuesta diferente, pero que sea más beneficiosa, además como vamos a implementar un sistema controlado por sensores y por un sistema completamente automatizado

Para solucionar el problema se va a optar por el método del túnel de aire forzado que es muy utilizado para la industria alimenticia para poder mantener los alimentos en temperaturas adecuadas, esto para que no pierdan sus nutrientes, en la siguiente imagen podemos ver un ejemplo de este método

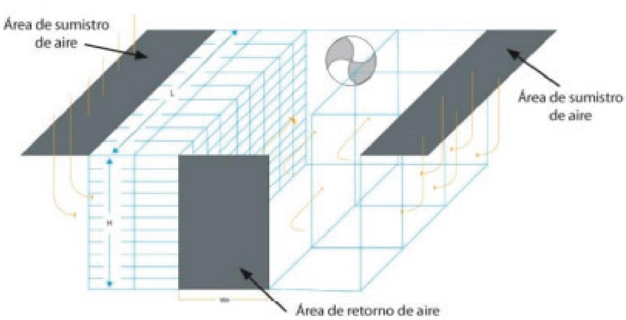

Figura 3. Túnel de aire forzado. Fuente (Mundo HVCAR)

Según HVCAR "El preenfriamiento por aire forzado es un método muy utilizado para enfriar frutas, vegetales o flores cortadas. Esta técnica consiste en pasar altos volúmenes de aire fresco a alta presión a través del producto, extrayendo de una forma rápida y uniforme el calor contenido en el producto."

En nuestro caso a este túnel va ir a un lado del depósito, ya que el aire tiene mucha presión, por lo cual los empleados no van a poder tener un ambiente agradable por el ruido que provoca el sistema, y en otro lado del depósito se va a colocar un sistema propio para la ventilación de los malos olores y los insectos, que para ese último se plateo hacer una cortina de aire que según Soler y Palau es "Las cortinas de aire son la solución de ventilación idóneas para evitar las pérdidas de calor a través de ventanas o puertas de grandes dimensiones. Estos equipos crean una barrera invisible separando el ambiente exterior del interior de una estancia o recinto con el fin de evitar las pérdidas de calor a través de ventanas o puertas de grandes dimensiones” , este cambio de presión no les va a permitir la entrada al lugar donde se almacena el producto.

Para la automatización de este proyecto se van a colocar sensores de temperatura y humedad que permitan tener regulado el calor en el recinto, además de unos sensores de movimiento en las puestas, para que cuando se siente la presencia de algún movimiento se active la cortina de viento impidiendo la entrada de algún insecto, con el tema de los malos olores se van a instalar un sistema con temporizadores para que distribuya el aire por todo el lugar evitando los malos olores, la automatización en la ventilación de un lugar puede proporcionar varias formas de reducción de costos. Se pueden lograr ahorros significativos en costos de energía al utilizar un sistema de ventilación automático que controle de manera precisa la temperatura y los horarios de funcionamiento en función de la ocupación del lugar. La automatización también permite monitorear el rendimiento del sistema y eliminar errores humanos que pueden afectar el rendimiento y disminuir los costos de energía por que el sistema se va a utilizar solo cuando se necesita, no todo el tiempo.

Esta solución se planteó en el software de diseño de REVIT, que se especializa en temas industriales de ventilación, la solución se presenta en la próxima imagen

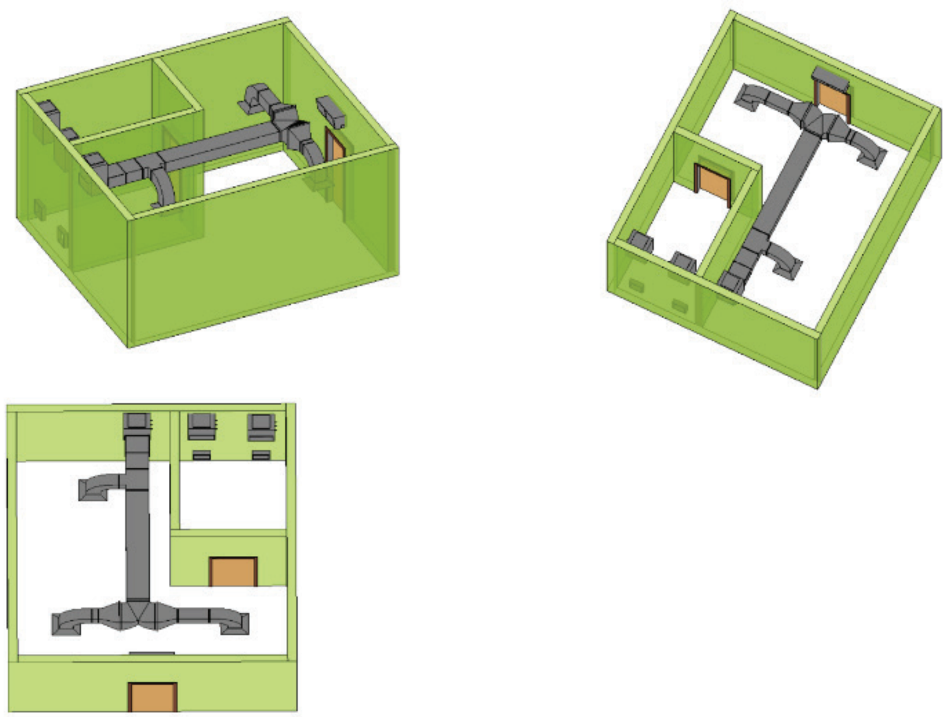

Figura 4. Solución para la empresa productora.

Resultados

Podemos observar en la figura 4 que se colocaron los diferentes puntos de distribución de aire en el lugar separados estratégicamente para que la distribución del aire les permita llegar a cualquier lugar, haciendo que todos los empleados tengan un buen confort en su zona de trabajo, además el cuarto de almacenamiento es donde se va a encontrar el producto, este se mantendrá en constante evaluación previniendo su descomposición y por último la puerta está controlada por una cortina de aire que permite un ambiente libre de insectos.

Al aplicar un sistema de control automático para la correcta distribución del aire en el recinto genero un impacto de gran nivel en la empresa, ya que los trabajadores al tener un ambiente más adecuado para trabajar van a aumentar su desempeño.

Los diferentes dispositivos instalados generaron un impacto positivo en la empresa, las cortinas de aire para controlar insectos fue un éxito debido a que la cantidad de estos animales se vio reducida en un gran porcentaje, además con este se previenen de enfermedades, protegiendo al personal de paros innecesarios.

Por otro lado, el cálculo realizado para estimar el caudal dentro del local permitió hacer la instalación de los dispositivos adecuados para el transporte de ese aire, tenemos que el caudal es de 29428.88 CFM, para mover esa cantidad de aire se necesita:

Cuadro 1. Materiales necesarios.

Túnel	Caudal	Zona de trabajo	Caudal
2 ventiladores	7500 CFM	1 ventilador	22500 CFM
2 extractores	7500 CFM	1 extractor	22500 CFM
		3 rejillas	7500 CFM
		3 codos	
		2 bifurcaciones en T	
		3 reducciones	

Para el túnel de viento se van a necesitar 2 ventiladores y 2 extractores, estos se van a encargar de darle un movimiento al aire, para mantener fresco el producto, para la zona de trabajo se va a necesitar un ventilador, una cortina de aire, 3 rejillas y un extractor.

Lo más importante es poder mantener el alimento fresco, las ventas van a aumentar, debido a que el producto va a estar en mejores condiciones, ya que está siendo tratado en un espacio donde se va a mantener fresco durante todo el tiempo, gracias a los sensores que fueron instalados para controlar los productos, estos van a hacer trabajar al sistema cuando sea conveniente.

El tener un control automático genera una reducción de gastos a nivel de electricidad debido a que el funcionamiento del equipo solo es cuando el material lo necesita y no se desperdicia energía por tenerlo encendido todo el día, no olvidemos que es una empresa productora agrícola que no tiene el dinero necesario para hacer grandes inversiones, con esto se logró darle una solución a su problema de manera sencilla y económica, apoyándose en los dispositivos electrónicos.

Conclusiones

En conclusión, los sistemas de control automatizado de aire para la industria son una solución innovadora y eficiente para garantizar un ambiente de trabajo saludable y seguro, y al mismo tiempo mejorar los procesos de producción. Su capacidad para medir y controlar de manera automática factores como la calidad del aire, la humedad, la temperatura y la presencia de insectos, los convierte en una herramienta fundamental para cualquier empresa que busque mejorar las condiciones de trabajo de sus empleados.

Entre las principales ventajas de estos sistemas se encuentran la mejora de la salud, la confortabilidad y la seguridad de los trabajadores, la reducción de los costos de energía y la eficiencia de los procesos de producción. Además, su capacidad para personalizarse y adaptarse a las necesidades específicas de cada industria los convierte en una herramienta versátil y altamente efectiva.

Se recomienda que las empresas consideren la implementación de sistemas de control automatizado de aire como parte de sus esfuerzos por mejorar las condiciones de trabajo de sus empleados y reducir los costos de energía. Es importante que se realice una evaluación cuidadosa de las necesidades específicas de cada industria antes de seleccionar el sistema adecuado. También se debe considerar la formación del personal en la operación y mantenimiento del sistema, así como el seguimiento y la actualización periódica del software y los equipos.

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Automated airing systems for air quality control in industries and work areas that involve food.

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Introduction

Automated air control systems for the industry represent an innovative and efficient solution to guarantee a healthy and safe work environment, and at the same time improve production processes. Thanks to the incorporation of advanced technologies such as sensors, controllers and intelligent software, these systems allow the automatic measurement and control of factors such as air quality, humidity, temperature and the presence of insects.

Materials and Methods

Figure 1. Chayote company in the area. Own source

The problem that is most harmful for this company is the loss of products due to the temperature that is present in the place where it is packed (average temperature of 26 degrees Celsius according to the company), the Ministry of Agriculture and Livestock recommends keeping this product between temperatures of 13 and 21°C, where it shows the losses of nutrients that occur at high temperatures, in a study prepared by the company Scielo in Mexico says "The chayote fruits did not present significant changes in their composition when stored at room temperature (20 ±2 °C) and at low temperatures (10 ±1 °C, 85% RH), they also contain less humidity (5.1 to 6.1%)", in the following image we can see how this company did tests at different temperatures and how the product was damaged

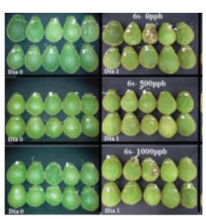

Figure 2. Damage to the product due to poor conservation. Source (Sky)

Another problem is the presence of insects due to the temperature and the fertilizers used to eliminate the pests, which causes the premises to fill with insects that make the employees uncomfortable, this can be not very clean and unpleasant, therefore, a way must be found to mitigate the entry of these insects In order to propose the solution to the problem, a way must be found so that all the problems are eradicated with the same project.

Calculation of the flow present in the company, this calculation consists of 3 steps:

Step 1. Volume calculation: $25x20x10$ = 5000 $m3$ 5000$m3$ = 176573.3 $ft3$
Step 2. Changes per minute: for a factory there are 10 changes per hour, which represents 6 minutes per change.
Step 3. Calculation of CFM needed: (176573.3 ft3)/(6 min/change) = 29428.88 CFM

Results and Discussion

A strategically located air distribution system has been implemented in a workplace to provide comfort for employees. A storage room has been installed that is constantly evaluated to prevent product deterioration. An air curtain has been used at the door to maintain an insect free environment. The automatic air control system has had a positive impact on the company, improving worker performance. Different devices have been installed, such as fans, extractors and air curtains, to achieve proper air distribution. The main goal is to keep food fresh, which will drive sales out of the business. In addition, automatic control has generated energy savings by operating only when needed. In general, a simple and cheap solution has been found to improve working conditions and keep products in good condition.

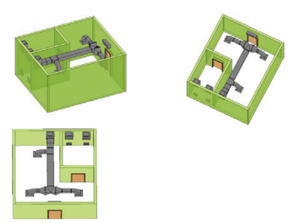

Figure 3 . Solution for the production company. Own source

Conclusions / Next Steps

Automated air control systems for industry are an efficient and innovative solution to improve working conditions and optimize production processes. These systems can automatically measure and control factors such as air quality, humidity, temperature, and the presence of insects. By implementing them, companies can benefit from improvements in the health, comfort and safety of workers, as well as reduced energy costs and improved production efficiency. It is important that companies make a careful assessment of their specific needs before selecting an automated air control system.

Implementation of holographic displays to increase realism in virtual reality through 3D images that simulate being in the environment

Implementación de pantallas holográficas para aumentar el realismo en la realidad virtual a través de imágenes 3D que simulan estar en el entorno

Diego Arturo Álvarez Esquivel[1], Nicole Tatiana Parra Valverde[2]

Álvarez Esquivel, D.A; Parra Valverde, N.T. Implementation of holographic displays to increase realism in virtual reality through 3D images that simulate being in the environment. *Tecnología en Marcha*. Vol. 37, special issue. June, 2024. IEEE Latin American Electron Devices Conference (LAEDC). Pág. 24-29.

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Keywords

Virtual reality; holography; 3D images; displays; innovation.

Abstract

This paper presents a study on the use of holographic displays in virtual reality. It highlights the significant advances that virtual reality has experienced in recent years and emphasizes the importance of improving realism in the immersive experience. The potential of holographic displays to enhance the quality of virtual reality by generating 3D images that resemble real physical objects is discussed. The current limitations of electro holographic recording due to the pixelated structures used are mentioned. A model for generating digital holograms using holographic displays is described, based on image superposition techniques and convolution with a point spread function. It is concluded that holographic displays have the potential to revolutionize virtual reality by providing high-quality 3D images and increased interactivity.

Palabras clave

Realidad virtual; holografía; imágenes 3D; pantallas; innovación .

Resumen

Este artículo presenta un estudio sobre el uso de pantallas holográficas en la realidad virtual. Se destacan los avances significativos que ha experimentado la realidad virtual en los últimos años y se enfatiza en la importancia de mejorar el realismo en la experiencia de inmersión. Se discute el potencial de las pantallas holográficas para elevar la calidad de la realidad virtual al generar imágenes 3D que parecen objetos físicos reales. Se mencionan las limitaciones actuales de la grabación electro holográfica debido a las estructuras pixeladas utilizadas. Se describe un modelo de generación de hologramas digitales utilizando pantallas holográficas, basado en técnicas de superposición de imágenes y convolución con una función de punto de propagación. Se concluye que las pantallas holográficas tienen el potencial de revolucionar la realidad virtual al brindar imágenes 3D de alta calidad y mayor interactividad.

Introduction

Virtual reality (VR) has been a constantly evolving technology in recent years and has had a great impact on different fields, such as education, industry, entertainment, and health [1]. Despite technological advances, one of the main challenges in VR has been to increase realism in the immersive experience in virtual environments.

Holographic displays are one of the most promising technologies to enhance the virtual reality experience. Unlike traditional flat screens, which display 2D images, holographic displays are capable of generating 3D images that appear to float in the air, as if they were real physical objects. This means that users can move around the images and view them from different angles, increasing the sense of presence and realism in the virtual environment.

Conventional holographic displays are capable of providing full parallax viewing and excellent resolution on the order of thousands of lines/mm. However, the electro-holographic recording has not yet achieved this same resolution due to the limitations of the pixel structures used in this process. These structures are not small enough compared to the wavelength of visible monochromatic light, which limits the number of possible viewing angles. Fortunately, recent advances in high-efficiency liquid crystal devices have provided new tools and possibilities for electro holographic reconstruction from digital holograms. Several approaches for electro-holographic reconstruction have been reported, with holographic reconstruction using liquid crystal devices as one of the most common methods. [2]

The implementation of holographic displays in virtual reality is still at an early stage, but this technology is expected to advance rapidly in the coming years. With high-resolution, wide field-of-view holographic displays, users will be able to experience more realistic and immersive virtual environments than ever before. In addition, holographic technology is also expected to be used in other fields, such as advertising, medicine, and education.

In this poster, we will explore the implementation of a model similar to that proposed by Xing Yang, HongBo Zhan, and Qiong-Hua Wang.[3] for digital hologram generation using a computational technique of superposition of images projected on a single projection screen, convolved with a point spread function (PSF) to generate the complex amplitude in the holographic plane. However, instead of using a conventional projection screen, a holographic screen is used to generate 3D images that appear to float in the air, as if they were real physical objects.

Materials and methods

In this poster, we will explore the implementation of a model similar to that proposed by Xing Yang, HongBo Zhan, and Qiong-Hua Wang.[3] for digital hologram generation using a computational technique of superposition of images projected on a single projection screen, convolved with a point spread function (PSF) to generate the complex amplitude in the holographic plane. However, instead of using a conventional projection screen, a holographic screen is used to generate 3D images that appear to float in the air, as if they were real physical objects.

Experimental configuration

The experiment will be conducted in a laboratory environment specifically designed for virtual reality research. The experimental setup will consist of a VR room that will provide an immersive space and allow free movement of the user.

The central component of the display system in the VR room will be a high-resolution LEDS-illuminated holographic display placed around the user to generate holograms within the viewing area. As in the experiment of Xing Yang, HongBo Zhan, and Qiong-Hua Wang it is necessary to use two or more holographic displays that function as projection planes to capture the projected rays from the 3D points and form the images according to the required projection angle according to the user's position.

In addition to the holographic display, other devices will be used. A position tracking system as used in the Valve Index will be implemented to track the user's movements in real-time and provide accurate information about the user's location in the virtual space. An eye-tracking system is employed to capture the user's eye movements and enable intuitive interactions with the holograms.

Hologram generation

Hologram generation will be based on a holographic calculation process that consists of the calculation of the complex amplitude distribution in the holographic displays through the convolution of each projected image and its Point Distribution Function (PSF). This step is fundamental to achieving the generation of holograms in real-time. For this step, the model proposed in the experiment of Xing Yang, HongBo Zhan, and Qiong-Hua Wang could be used.

The 3D object used in the experiment will be a virtual representation of an interactive VR environment. Advanced 3D modeling and rendering techniques will be used to create virtual objects and realistic scenes. These projected images will be combined on the holographic plane to form three-dimensional holograms. Accurate and synchronized generation of these images would be essential to achieve a consistent and high-quality holographic representation.

Real-time interaction and visualization

Custom visualization software will be developed to enable real-time interaction and visualization of the generated holograms. The software will be integrated with the position tracking system and eye tracking system to update the holograms according to the user's movements and gaze direction.

Real-time rendering techniques will be implemented to improve the visual quality of the holograms and provide an immersive experience. Lighting, shading, and reflection effects will be used to simulate the interaction of light with virtual objects in the virtual reality environment.

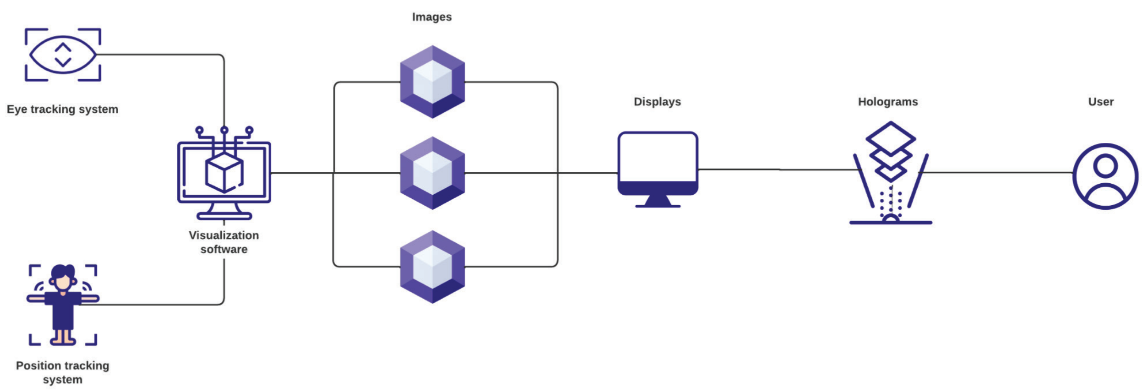

Figure 1. System concept diagram.

System evaluation

Evaluation of the holographic visualization system in the virtual reality room will be conducted in a comprehensive manner to gain a full understanding of its performance and quality. To this end, participants with different levels of virtual reality experience will be recruited to perform specific tasks within the holographic environment and provide feedback on various aspects of the system.

During the evaluations, objective and subjective data will be collected to obtain a complete and accurate assessment. In terms of objective data, performance metrics such as participants' response times in performing specific tasks and eye-tracking accuracy while interacting with the holograms will be recorded. These metrics will provide quantitative information on the efficiency and accuracy of the visualization system.

In addition to objective data, qualitative methods will be used to collect subjective information about the usability, sense of presence, and depth perception of the generated holograms. Questionnaires, interviews, and subjective evaluation scales will be used for participants to express their opinions, sensations, and experiences with the holographic system. This subjective data will be valuable in understanding user satisfaction, immersion in the virtual environment, and the perceived quality of the holograms.

The comprehensive evaluation of the system will identify strengths, weaknesses, and areas for improvement. The data collected during the evaluations will be analyzed and used to make adjustments and optimizations to the holographic display system based on the results and recommendations. The ultimate goal is to improve the visual quality, interaction, and immersive experience in the virtual reality room with the holographic display.

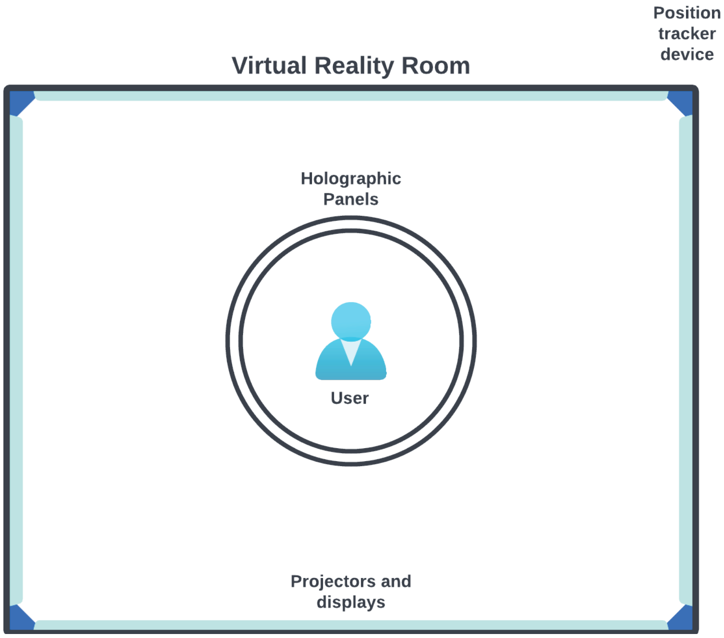

Figure 2. Sketch of the VR room using the holographic system.

Results and discussion

Currently, the project is in its initial phase and the results we expect to see in our system are the real-time values of the system in operation.

Conclusions

The integration of the holographic visualization system in virtual reality rooms can have a substantial technological impact by enabling the generation and projection of holograms within the viewing area. This not only enriches the immersive experience for users but also opens up new possibilities for interaction with the virtual environment. By combining key aspects such as real-time hologram generation and high-quality visualization, the system aims to deliver a realistic and convincing holographic experience. In addition, the comprehensive evaluation of the system through objective and subjective data will provide valuable information to improve visual quality, interaction, and immersion in future implementations, which could further boost the development of holographic technologies in the field of virtual reality.

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Implementation of holographic displays to increase realism in virtual reality through 3D images that simulate being in the environment.

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Introduction

Virtual reality (VR) has significantly impacted various industries by providing immersive experiences. However, enhancing realism in virtual environments remains a key challenge. This research focuses on holographic displays as a potential solution to overcome this limitation. Holographic displays generate 3D images that appear as if they were real physical objects floating in space, offering a more engaging and realistic experience for users.

Uses of virtual reality devices

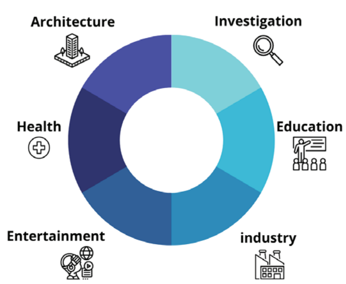

Fig 1. Virtual Reality Devices Applications – Own authory

Materials and Methods

The model is implemented to generate digital holograms using a holographic display in a virtual reality environment. The process involves calculating the complex amplitude distribution in holographic displays by convolving projected images with their Point Distribution Function (PSF). A 3D virtual representation and advanced modeling and rendering techniques are used to create realistic three-dimensional holograms. Real-time interaction and visualization are achieved through customized software and position tracking and eye-tracking systems. In addition, a comprehensive evaluation of the system is conducted in the virtual reality room, collecting objective and subjective data to assess its performance, usability, sense of presence and depth perception.

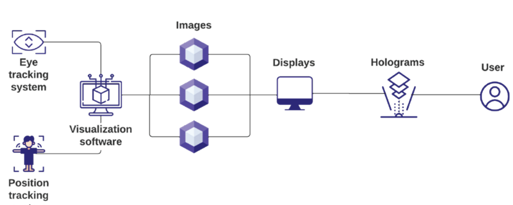

Fig 2. Concept Diagram – Own Authory

The results of the evaluation are used to identify areas for improvement and adjustments and optimizations are made to the holographic visualization system. The main objective of this study is to improve the visual quality, interaction and immersive experience in the virtual reality room through the use of the holographic display. It seeks to provide a more realistic and immersive virtual environment for users, taking advantage of the capabilities of holographic technology and real-time rendering techniques.

Discussion

Currently, the project is in its initial phase and the results we expect to see in our system are the real-time values of the system in operation.

Conclusions

The integration of the holographic visualization system in virtual reality rooms can have a substantial technological impact by enabling the generation and projection of holograms within the viewing area. This not only enriches the immersive experience for users but also opens new possibilities for interaction with the virtual environment. By combining key aspects such as real-time hologram generation and high-quality visualization, the system aims to deliver a realistic and convincing holographic experience. In addition, the comprehensive evaluation of the system through objective and subjective data will provide valuable information to improve visual quality, interaction, and immersion in future implementations, which could further boost the development of holographic technologies in the field of virtual reality.

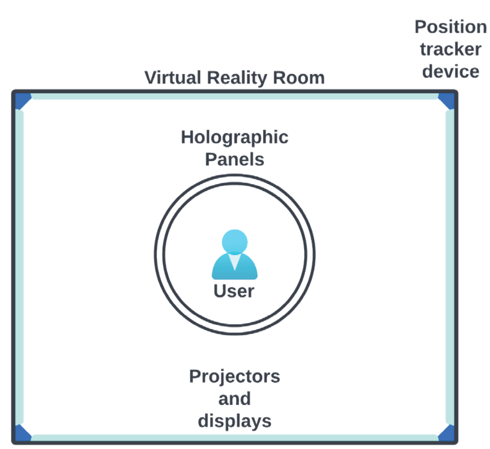

Fig 3. Design Diagram – Own Authory

IEEE Advancing Technology for Humanity
2023 IEEE Latin American Electron Devices Conference (LAEDC)
Electron Devices Society

Automatización de selección y comprobación de tamaños de materiales para sistemas de envasado

Automation of selection and verification of material sizes for packaging systems

Pablo Javier Rodriguez-Ugalde[1]

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Palabras clave
Automatización; codificadores; decodificadores; sensores; circuitos; señales digitales.

Resumen
Los sistemas de automatización en la selección y comprobación de materiales son sistemas los cuales funcionan por medio de tecnología avanzada, por medio de este tipo de sistemas se permite dentro de la industria el ahorrar en mano de obra y obviar errores humanos dentro de estos tipos de procesos mejorando de esta manera su producción y seguridad laboral. Por medio de la ayuda de sistemas de señales y lógica digital se emplea e implementa un método de automatización basado en sensores con el fin de seleccionar y comprobar los tamaños de distintos materiales dentro de la industria, específicamente para el embazado, se expondrán distintitos términos importantes para una mejor comprensión de las distintas partes que componen un sistema como este además de su aplicación. Además, se cuenta con una demostración visual por medio de software donde se podrá apreciar de una forma más detallada el proceso y los resultados de un sistema de este tipo junto con las recomendaciones y conclusiones pertinentes.

Keywords
Automation; encoders; decoders; sensors; circuits; digital signals.

Abstract
Automation systems in material selection and verification are advanced technology-based systems that allow for labor cost savings and elimination of human errors in these types of processes, improving production and occupational safety within the industry. By employing signal systems and digital logic, an automation method based on sensors is implemented to select and verify different materials' sizes, specifically for packaging. Various important terms for a better understanding of the different parts that make up such a system and its application will be presented. Additionally, a visual demonstration through software will show the process and results of such a system in more detail, along with relevant recommendations and conclusions.

Introducción
En la actualidad, la automatización es un componente clave en la industria moderna, permitiendo una mayor eficiencia, precisión y rentabilidad en los procesos de producción. Uno de los aspectos críticos en la industria es la selección de materiales o productos, lo cual puede ser un proceso laborioso y propenso a errores humanos. Sin embargo, con los avances en la tecnología digital y la integración de sensores en los sistemas de automatización, se ha logrado desarrollar sistemas de selección automatizados altamente eficientes y confiables.

En este contexto, el presente se enfoca en el uso de sistemas digitales para la automatización de la selección en la industria mediante el uso de sensores. Estos sensores son dispositivos que capturan datos de manera precisa y en tiempo real, permitiendo tomar decisiones automáticas en función de los criterios establecidos. Estos sistemas de selección automatizada han demostrado ser una solución efectiva para mejorar la velocidad, precisión y calidad de la selección de materiales o productos en la industria.

En esta sección del artículo se debe introducir los conceptos necesarios para identificar el problema o situación a resolver. Además, especificar el objetivo de la investigación. La automatización de la selección en la industria no solo ofrece ahorro de tiempo y esfuerzo, sino que también tiene un impacto positivo en términos energéticos y ambientales. La eliminación de la necesidad de intervención humana constante permite optimizar el consumo de energía y reducir los costos asociados. Al utilizar sistemas automatizados basados en sensores, se pueden evitar errores humanos y minimizar la generación de residuos al seleccionar de manera precisa y eficiente los objetos o materiales requeridos.

Además, la automatización de la selección en la industria también mejora la eficiencia en la gestión de recursos. Los sistemas digitales automatizados pueden analizar y seleccionar los objetos o materiales en función de criterios predefinidos, lo que reduce la posibilidad de errores y desperdicios en comparación con la selección manual. Esto contribuye a una gestión más eficiente de los recursos, lo que es beneficioso tanto desde el punto de vista económico como ambiental.

Materiales y métodos

Automatización industrial

La automatización industrial se puede definir como el desarrollo de técnicas con las cuales se puede establecer un manejo adecuado de la información recolectada de procesos industriales con el fin de la resolución de problemas en función de la toma de decisiones antes y durante el desarrollo del proceso productivo, las mismas pueden incorporar herramientas informáticas y de control con el fin de llevar a cabo de forma autónoma y óptima procesos según la perspectiva ingenieril y siguiendo los objetivos estratégicos de la empresa [1].

Según el tipo de proyecto de automatización a implementar en la empresa el mismo puede clasificarse según diferentes criterios, como lo pueden ser el grado de participación de la acción humana en el proceso productivo, la metodología para manejo de la información, y el tipo de herramientas tecnológicas utilizadas para diseñar e implementar el sistema de automatización industrial.

Para clasificar el grado de acción humana aplicado en el proceso productivo con un sistema de automatización se pueden utilizar dos conceptos, la automatización parcial o total; en el primer tipo de automatización la acción humana forma parte integral del proceso ya que ciertos accionamientos o movimientos deben ser llevados a cabo por una personas con asistencia de un sistema de producción controlado por alguna herramienta eléctrica o electrónica; en el caso de un proceso con automatización total la participación humana es no esencial en el proceso ya que el sistema posee las capacidades necesarias para llevar a cabo acciones sin necesidad de una persona que realice accionamientos o inicie movimientos en la máquina [2].

En referencia a la metodología utilizada manejo de la información del sistema automatizado de producción se puede realizar una clasificación con los términos de lazo abierto y lazo a cerrado, donde el sistema de control de lazo abierto es aquel en el cual el que la salida del proceso no incide en la etapa de control del sistema, en la mayoría de los casos estos sistemas funcionan siguiendo una regla de tiempos, por otra parte se tiene el tipo de sistema donde la salida si incide en el etapa de control (lazo cerrado), en la cual se necesitan de sensores en diferentes partes del proceso de producción con el fin de retroalimentar el sistema de control de la máquina [3].

Al analizar las herramientas tecnológicas utilizadas en el sistema de control automático se puede realizar una clasificación con los conceptos de lógica cableada y lógica programada, en la lógica cableada se realiza una conexión de elementos de control para llevar a cabo una acción sobre un proceso automático el circuito en sí posee una forma de conexión la cual permite establecer una función lógica según las necesidades del sistema, este tipo de automatización hace uso de compuertas lógicas que manejan la información de las señales de entrada para presentar una señal a la salida (lógica digital), este mismo proceso se puede desarrollar con relés, contactores, sensores, fines de carrera, etc. Para la lógica programada se tienen dispositivos flexibles y complejos denominados PLC (Programmable Logic Controller), es cual es un tipo de "computadora", la cual recibe las señales de entrada y mediante un código específico cargado en su memoria, puede realizar ciertas acciones [4].

Electrónica digital

La electrónica digital se puede entender como una de las ramas de la electrónica encargada del procesamiento de señales binarias (1 y 0), donde el estado de una señal puede ser encendido o apagado, arriba o abajo, sí o no, etc; de esta forma el sistema electrónico digital puede recibir señales de entrada y generar señales de salida en función de las condiciones del sistema siguiendo una lógica booleana; de esta forma se puede procesar mucha información en tiempo real, con una precisión muy alta y a gran velocidad.

Algunos de los componentes principales utilizados en los sistemas de automatización digital son, las compuertas lógicas, los flip-flop, los registros y microprocesadores, ya que los mismos se encargan de realizar operaciones de suma, multiplicación, comparación etc, con las señales que se procesan.

Circuito lógico

El circuito lógico es el sistema conformado por la interconexión de componente electrónicos como lo son las compuertas lógicas, los flip-flop, los registros, contadores, etc, dependiendo de la configuración específica con la que se construyó el sistema las diferentes combinaciones de entrada generan diferentes salidas al realizar operaciones de suma o multiplicación de señales binarias.

Arduino

Un Arduino es una placa de circuito impreso (PCB), de hardware y software libre que incorpora un microcontrolador reprogramable y una serie de pines-hembra, que internamente están conectadas a las patillas del microcontrolador y permiten que conectarse a sensores y actuadores [5]. Existen distintas pacas de Arduino.

Compuertas lógicas

Las compuertas lógicas son componentes electrónicos los cuales permiten realizar operaciones lógicas elementales al recibir señales binarias de entrada.

Decodificadores

Un decodificador es un circuito lógico que acepta un número de entradas representado en binario y activa una salida que corresponde a ese número en otro sistema de numeración tiene n salidas y 2n entradas [6]. En la siguiente figura se muestra el diagrama de un decodificador.

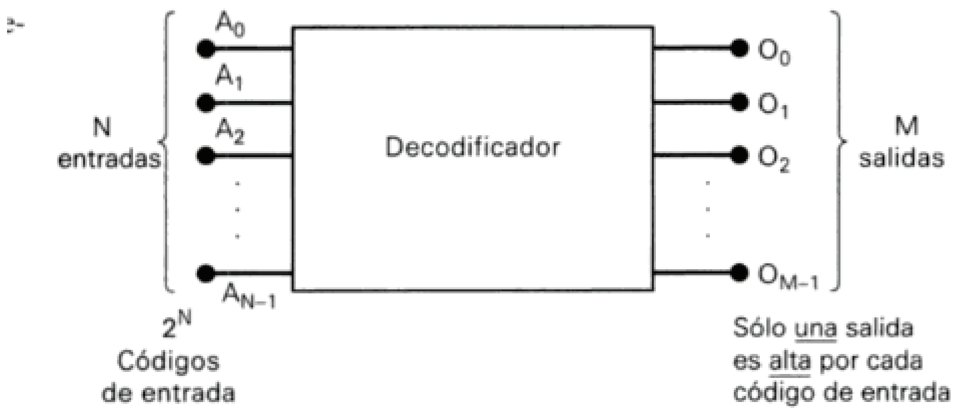

Figura 1. Diagrama general de un decodificador. Fuente: [6].

Codificadores

Un codificador es un circuito lógico que tiene 2n entradas y n salidas, las salidas se generan un código binario que corresponde a la señal de entrada [1]. En la figura 2(a) se muestra el símbolo de un codificador de 4 entradas y dos salidas y en figura 2(b) la configuración interna del mismo.

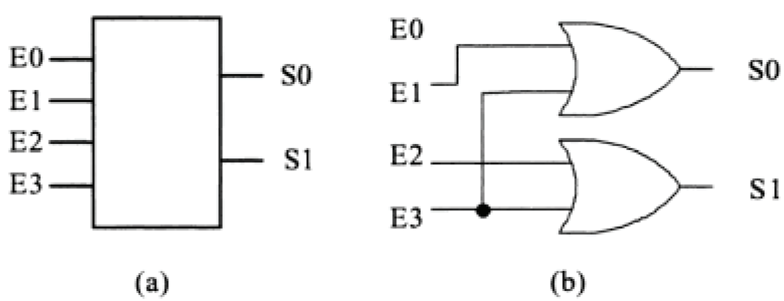

Figura 2. Símbolo de codificador 4:2 y estructura interna del mismo. Fuente: [1].

Resultados

Descripción de la solución propuesta

Es un sistema de llenado de botellas de 4 capacidades 250mL, 500mL, 750mL y 1000mL, que consta en tres partes. El panel de control que es donde escoge la capacidad de la botella que se va a llenar. La sección de comparación, que verifica si la botella en la banda tiene la misma capacidad que se seleccionó en el panel de control. Por último, se tiene la sección de llenado que es donde la botella se llena. (Esta simulación se basa en el llenado de botellas pero el sistema por sensores y señales digitales puede ser aplicado dentro de la industria de envasados a conveniencia, de igual manera, para efectos prácticos se limitó a el uso de 4 entradas representadas en los cuatro distintos tamaños de las botellas, pero usando la misma lógica se puede ampliar el número de entradas distintas, variando el código dentro de los arduinos.

Panel principal y sistema de comparación de envases

Para ilustrar el funcionamiento del sistema propuesto para el control y comparación de botellas se realizó una simulación en Arduino con ayuda de la plataforma de Tinkercad, en la figura 4, se puede observar el diagrama del circuito armado en esta plataforma. Para simular los Sensores 1, 2, 3 y 4 se utilizó un SPST de conmutadores DIP x 4 estos darán la señal del tipo de botella que pasara a la parte del llenado y trasladara esta información al codificador el cual esta implementado por medio de un Arduino uno y Código, en esa misma protoboard se implementaron tres leds los cuales representaran las salidas SS1, SS2 y Enable. Para representar las señales provenientes del panel del control se agregaron cuatro botones representados en la protoboard de abajo a la derecha en la figura 3, dicha señal da entrada al Arduino uno que se encuentra debajo, este Arduino tiene un Código el cual permite hacer el trabajo de un codificador 4:2 con prioridad en el bit de menor peso (LSB) y un decodificador 2:4, las señales recibidas por los botones ingresan al Arduino, este realiza la función del codificador y en representación de las salidas de este se colocaron dos leds de color rojo representando C1 y C2 respectivamente, además este Arduino como se mencionó antes toma esas dos salidas las ingresa pero esta vez como valores de entrada para el decodificador y este luego de decodificar los valores envía las salidas a la proto de su izquierda donde por medio de cuatro leds se representara el botón presionado para la botella seleccionada.

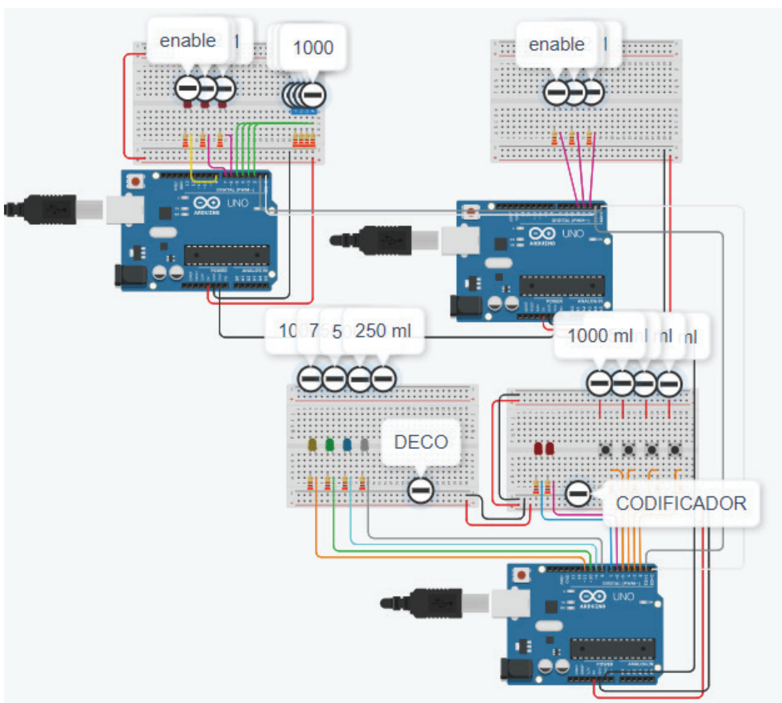

Figura 3. Circuito en Tinkercad del sistema de comparación de botellas.

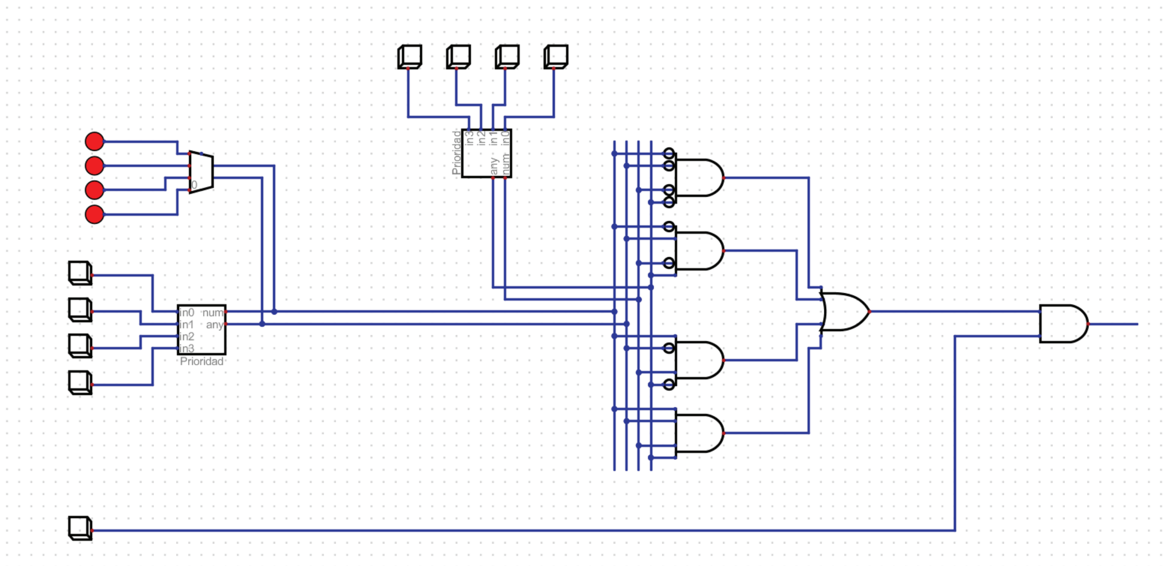

Figura 4. Diagrama del panel principal y sistema de comparación de embaces realizado en DIGITAL.

Descripción general del panel principal

Funcionamiento del codificador y decodificador

En el primer parte del proyecto de control digital se tiene la propuesta de un panel principal conformado por un codificador 4:2 con prioridad en el bit de menor peso (LSB), un decodificador 2:4 y un botón de seguridad los cuales van a dar inicio al sistema para la selección de comparación de botellas, el codificador cuenta con cuatro botones los cuales van a dar entrada a el tipo de botella, en base a esta entrada se tendrán dos salidas C1 y C2, dichas salidas avanzaran a la siguiente fase y también a la entrada del decodificador y este por medio de los LEDs mostrara la salida y esta deberá coincidir con el botón que se seleccionó. Una vez se comprobó que la entrada y la salida por el LED coinciden se puede presionar el botón de seguridad.

Sistema de comparación de botellas

Para la segunda parte se va a contar con un codificador 4:2 con prioridad en el bit de mayor peso (MSB) el cual recibirá entradas por medio de sensores los que se encargaran de identificar el tamaño de las botellas, esta señal será codificada y enviada por las salidas SS1 y SS2, en la continuación del sistema de comparación e botellas se recibirán las dos señales del sistema de control (C1 y C2) y las dos señales de salida del codificador anterior (SS1 y SS2) para así entrar a el comparador creado a base de compuertas, dicho comparador se encargara de verificar que tanto las señales de control como las recibidas por el codificador de los sensores son iguales y de ser así permitir que el sistema siga, lo cal nos lleva a la comprobación final de esta parte del sistema el cual sería el compara por medio de una compuerta AND la salida del Sistema de comparación de botellas y el del botón de seguridad del Sistema de control y de esta forma si recibe ambas señales en positivo continue con la siguiente parte del sistema el cual sería el proceso de llenado.

Cuadro 1. Codificador 4:2 con prioridad en el bit de menor peso (LSB) implementado en la sala de control para seleccionar la presentación de la botella.

Combinación	C 1	C 2	LED 1	LED 2	LED 3	LED 4	Presentación (mL)
0	0	0	1	0	0	0	250
1	0	1	0	1	0	0	500
2	1	0	0	0	1	0	750
3	1	1	0	0	0	1	1000

Cuadro 2. Decodificador 2:4 implementado en la sala de control para visualizar mediante leds la presentación de la botella seleccionada.

Combinación	B 4	B 3	B 2	B 1	C 1	C 2	Presentación (mL)
0	x	x	x	1	0	0	250
1	x	x	1	0	0	1	500
2	x	1	0	0	1	0	750
3	1	0	0	0	1	1	1000
	MSB			LSB			

Cuadro 3. Codificador 4:2 con prioridad en el bit de mayor peso (MSB) implementado en el comparador de botellas.

Combinación	SEN 4	SEN 3	SEN 2	SEN 1	SS 1	SS 2	Presentación (mL)
0	0	0	0	1	0	0	250
1	0	0	1	x	0	1	500
2	0	1	x	x	1	0	750
3	1	x	x	x	1	1	1000
	MSB			LSB			

Cuadro 4. Tabla de la verdad comparador.

Combinación	C 1	C 2	SS 1	SS 2	F
0	0	0	0	0	1
1	0	0	0	1	0
2	0	0	1	0	0
3	0	0	1	1	0
4	0	1	0	0	0
5	0	1	0	1	1
6	0	1	1	0	0
7	0	1	1	1	0
8	1	0	0	0	0
9	1	0	0	1	0
10	1	0	1	0	1
11	1	0	1	1	0
12	1	1	0	0	0
13	1	1	0	1	0
14	1	1	1	0	0
15	1	1	1	1	1

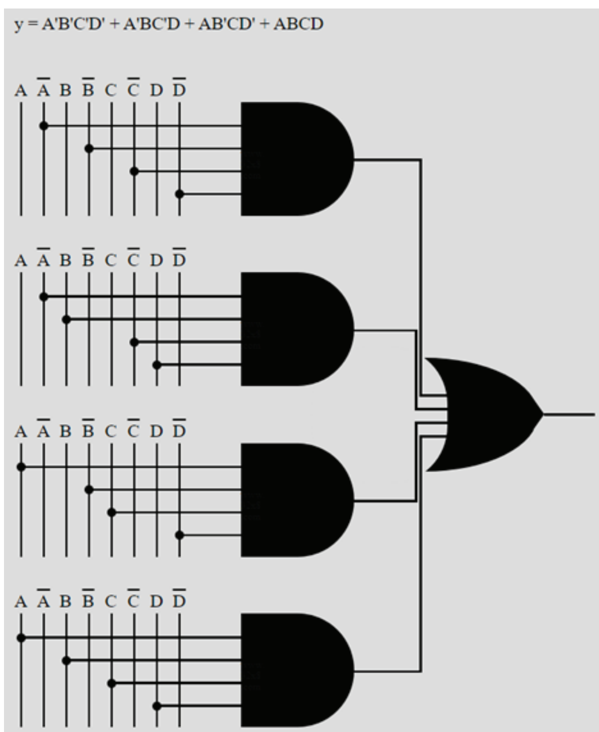

Figura 4. Implementación del comparador. Fuente: [7].

Cuadro 5. Tabla de la verdad de compuerta AND.

Combinación	S1	S2	F
0	0	0	0
1	0	1	0
2	1	0	0
3	1	1	1

Cuadro 6. Tabla de la verdad de compuerta OR.

Combinación	S1	S2	F
0	0	0	0
1	0	1	1
2	1	0	1
3	1	1	1

Recomendaciones

- Implementar microcontroladores más robustos, o en el mejor de los casos PLC´s. Arduino Uno es limitado para el tamaño de este proyecto.
- Suponiendo que se usa Arduino Uno, implementar otro protocolo de comunicación de datos, por ejemplo; SPI, I2C o wireless.

Conclusiones

- Por medio de los resultados anteriores se concluye que los sistemas de automatización para la selección y comprobación de materiales basado en sensores por medio de la identificación de los diferentes tamaños en la industria de embazado es una manera efectiva de eliminar mano de obra y error humano dentro de una empresa ya que por medio de los sistemas digitales y el hardware electrónico pertinente se consigue la sustitución.
- Se comprobó que el uso de Arduino no es la manera mas eficiente de realizar el sistema propuesto ya que existen limitantes a la hora del análisis de información y las conexiones necesarias, pero existen sistemas y métodos los cuales se recomiendan en la sustitución de este, para obtener una mejora en la eficiencia del sistema.

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Automation of Selection and Verification of Material Sizes for Packaging Systems

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Introduction

Automation is a key component in modern industry, allowing greater efficiency, precision and profitability in production processes. One of the critical aspects in the industry is the selection of materials or products, which can be a laborious process and probably human errors. However, with advances in digital technology and the integration of sensors in automation systems, highly efficient and reliable automated selection systems have been developed.

Automation of sorting in the industry not only saves time and effort, but also has a positive impact in energy and environmental terms. Eliminating the need for constant human intervention makes it possible to optimize energy consumption and reduce associated costs. By using sensor-based automated systems, human errors can be avoided and waste generation minimized by accurately and efficiently selecting the required objects or materials.

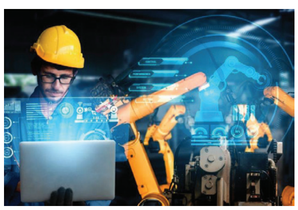

Figure 1. industrial automation illustration. Fuente: (Logistic world, 2023)

Materials and Methods

Industrial Automation

Depending on the type of automation project to be implemented in the company, it can be classified according to different criteria, such as the degree of participation of human action in the production process, the information management methodology, and the type of tools. technologies used to design and implement the industrial automation system.

Some of the main components used in digital automation systems are logic gates, flip-flop, registers and microprocessors, since they are in charge of carrying out operations of addition, multiplication, comparison, etc., with the signals that are process.

- Arduino
- Logic Gates
- Encoders Decoders
- Logic Circuits

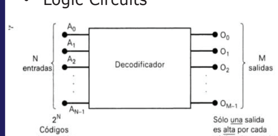

Figure 2. Diagrama general de un decodificador. Fuente: (Tocci & Widmer, 2003)

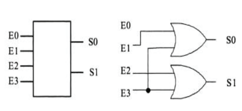

Figure 3. Símbolo de codificador 4:2 y estructura interna del mismo. Fuente: (Blanco, 2003)

Results and Discussion

To illustrate the operation of the proposed system for the control and comparison of bottles, a simulation was carried out in Arduino with the help of the Tinkercad platform. To simulate Sensors 1, 2, 3 and 4, an SPST of DIP switches x 4 was obtained, these will give the signal of the type of bottle that will go to the filling part and will transfer this information to the encoder which is implemented by means of an Arduino. one and Code, in that same breadboard three leds were implemented which will represent the outputs SS1, SS2 and Enable. To represent the signals coming from the control panel, four buttons represented on the breadboard at the bottom right in figure 3 were added, said signal gives input to the Arduino one that is below, this Arduino has a Code which allows to do the job of a 4:2 encoder with priority in the least weight bit (LSB) and a 2:4 decoder, the signals received by the buttons enter the Arduino, this performs the function of the encoder and representing its outputs were placed two red leds representing C1 and C2 respectively, also this Arduino as mentioned before takes these two outputs, enters them but this time as input values for the decoder and after decoding the values it sends the outputs to the proto on its left where by means of four leds the button pressed for the selected bottle will be represented.

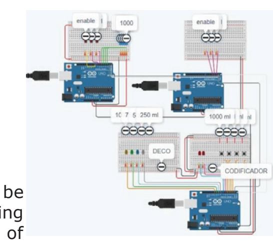

Figure 4. Circuit in Tinkercad of the bottle comparison system. Source: self made

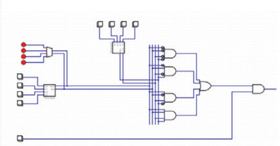

Figure 5. Diagram of the main panel and package comparison system made in DIGITAL. Source: own realization.

Conclusions / Next Steps

Recommendations

• Implement more robust microcontrollers, or at best PLC's. Arduino Uno is limited for the size of this project.

• Assuming that the Arduino Uno is used, implement another data communication protocol, for example; SPI, I2C or wireless.

Conclusions

• By means of the previous results it is concluded that the automation systems for the selection and verification of materials based on sensors by means of the identification of the different sizes in the packaging industry is an effective way to eliminate labor and human error. within a company since by means of digital systems and the relevant electronic hardware substitution is achieved.

• It was found that the use of Arduino is not the most efficient way to carry out the proposed system since there are limitations when it comes to analyzing information and the necessary connections, but there are systems and methods which are recommended to replace it, to obtain an improvement in the efficiency of the system.

2023 IEEE Latin American Electron Devices Conference (LAEDC)

Instrumental test of patch antennas manufactured for C-Band applications

Prueba instrumental de antenas de parche fabricadas para aplicaciones en la banda C

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Keywords

Antennas; communication technology; electronic equipment; engineering education; experimental methods.

Abstract

In free space, the calculated wavelength of a 5,2 GHz signal is 57,7 mm, this gives us an idea of the volume required to be occupied by a patch type antenna intended for C-band applications and some of the limitations of relying on a traditional manufacturing process. Considering the interest of competing in the current technological market, it is important to obtain experimental results of the performance of the product that can be obtained with the suggested minimum of resources. Patch antenna prototypes require experimental verifications regardless of the manufacturing process that was carried out, so this work presents a clear methodology that includes calculations, design parameters such as characteristic impedance, acid-based manufacturing, experimental setup with a signal generator and a spectrum analyzer, tests with their respective measurements considering quantitative and qualitative approaches, compatibility with commercial C-band equipment and evaluation of results, providing an experimental comparison of different prototypes of designs based on simple patch antennas and array antennas.

Palabras clave

Antenas; tecnología de comunicación; equipos electrónicos; educación en ingeniería; métodos experimentales.

Resumen

En el espacio libre, la longitud de onda calculada de una señal de 5,2 GHz es de 57,7 mm. Esto nos da una idea del volumen requerido para ser ocupado por una antena tipo parche destinada a aplicaciones en la banda C, y algunas de las limitaciones de depender de un proceso de fabricación tradicional. Considerando el interés de competir en el mercado tecnológico actual, es importante obtener resultados experimentales del rendimiento del producto que se puede obtener con el mínimo de recursos sugerido. Los prototipos de antenas de parche requieren verificaciones experimentales independientemente del proceso de fabricación que se haya llevado a cabo, por lo que este trabajo presenta una metodología clara que incluye cálculos, parámetros de diseño como la impedancia característica, fabricación basada en ácido, configuración experimental con un generador de señales y un analizador de espectro, pruebas con sus respectivas mediciones considerando enfoques cuantitativos y cualitativos, compatibilidad con equipos comerciales de la banda C y evaluación de resultados, proporcionando una comparación experimental de diferentes prototipos de diseños basados en antenas de parche simples y antenas de matriz.

Introduction

Nowadays, digital communications require greater bandwidths and operating bands in the order of GHz. Fortunately, this allows the use of compact antennas, even the ones that take advantage of designs that improves the gain and width of the basic antenna by applying stacked patch topology with printed circuit boards or PCBs [1]. Mass production ensures profitability in this type of product, but there are also prototyping stages that can require less complex and expensive methods: alternatives that may be attractive to researchers and engineers from

Central American countries. The research questions arise, what models and design rules must be respected as a minimum for the basic functional designs of patch antennas? what kind of experimental results can be obtained with this type of products?

Methodology

The applied methodology consists of the typical steps to follow for any electronic or telecommunications prototype:

a) Calculation and theoretical design.
b) Verification of the design using software simulators.
c) Manufacture of prototypes.
d) Experimental results: experimental set-up and commercial compatibility tests.

Calculation and theoretical design

The basic design of a patch antenna like the one in Figure 1 consists of calculating its width *W* and length *L*, slots methods with x_0 and y_0 dimensions are used for impedance matching.

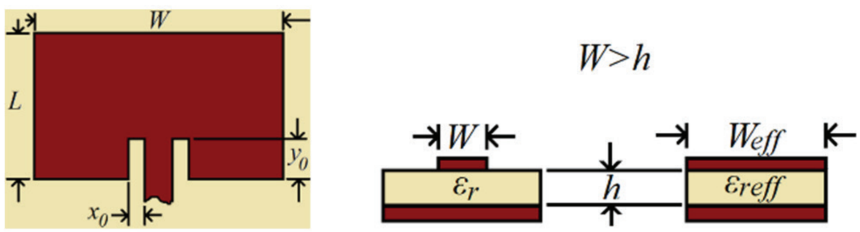

Figure 1. Patch antenna with an inset feed and its planar waveguide model.

Two models are considered here for the design: transmission line model and cavity model [2], [3]. For an efficient radiator, a practical *W* that leads to good radiation efficiencies [2] is given by (1) where *fr* is the resonance frequency, *c* is the free-space velocity of light and ε_r is the relative dielectric constant of the substrate, considered 4.5 for FR4.

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (1)$$

By the cavity model shown in Figure 1, the effective width W_{eff} and the effective relative dielectric constant ε_{reff} are calculated for its planar waveguide model. The constant ε_{reff} can be calculated by (2), where *h* is the height of the substrate, considered 1.6 mm for the local PCBs. The patch length *L*, suggested that $1 < W/L < 2$ [3], is given by (3). Figure 2 summarizes the sizing that would be obtained at different f_r.

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-1/2} \quad (2)$$

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} \tag{3}$$

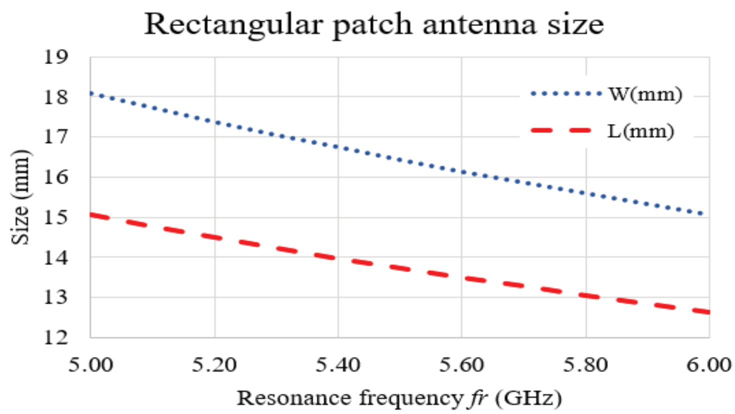

Figure 2. Calculated rectangular patch antenna sizing for h = 1.6 mm and ε_r = 4.5.

For inset feed, the input characteristic impedance of the patch antenna Z_{in} should match to the microstrip line characteristic impedance that feeds the patch. If we don't take into account mutual effects between slots and only a real resonant input impedance R_{in}, we can calculate it from the slots conductance G_1 and G_2 [2] as shown in (4) where λ_0 is the wavelength and k_0 is the phase constant ($k_0 = 2\pi/\lambda_0$), both in free space and at the resonant frequency.

$$Z_{in} = R_{in} = \frac{1}{(G_1 + G_2)} = \frac{1440\lambda_0}{W(24 - (k_0 h)^2)} \tag{4}$$

So, the inset feed point distance y_0 is obtained by (5) and Z_c is the characteristic impedance of the microstrip that will feed the patch antenna.

$$y_0 = \frac{L}{\pi} arccos\left(\sqrt{\frac{Z_c}{R_{in}}}\right) \tag{5}$$

From the single patch antenna, patch antenna arrays can be formed. This array can be fed by microstrips and λ/4 impedance microstrip transformers or even connecting one patch in series with another using microstrips [4].

Software design verification and microstrip line

Software-aided design is also considered for the fabrication of patch antennas. One of the software considered is: Matlab R2022b Update 4 (9.13.0.2166757), 64-bit (win64), January 11, 2023. The simple patch antenna design suggested by this software tool, to be operated at 5.2 GHz, consists of $W = L$ = 26 mm, that is $W = L \approx \lambda_0/2$; this leads to y_0 = 8 mm for a Z_c = 50 Ω, but the effects of the substrate FR4 are not considered yet.

Evaluating (2) using, for example, W = 15 mm leads to ε_{reff} = 3.91 but with a W = 30 mm leads to ε_{reff} = 4.11. In both cases, the effective relative dielectric constant is not affected as much by the value of these W. Wavelength has a larger impact as a function of the dielectric constant: at 5.2 GHz in free space λ_0 = 57.7 mm but λ = 28.5±0.5 mm when we use the previous W and ε_{reff}. In fact, re-evaluating (4) and (5) using the W values of 15 mm or 30 mm and ε_{reff}, keeping $W = L$, gives y_0 = 3.75±0.3 mm for Z_c = 50 Ω. The calculator included in the software KiCad ((c)1992-2022 KiCad Developers Team, version 6.0.6) indicates that a 3 mm width microstrip would be appropriate to obtain a characteristic impedance Z_c = 50 Ω at 5.2 GHz.

Prototyping

The use of local commercial PCBs with FR4 substrate, provides a low-cost but compatible alternative even to mmWave antennas [1]. Although a CNC machine allows a more reliable process, is not useful for removing considerable amounts of copper, so the prototype patch antennas were manufactured with the help of a solution of muriatic acid with hydrogen peroxide to remove copper from the PCB. The limitations of this process consist mainly in the fact that too narrow microstrip cannot be manufactured and a micrometer precision cannot be achieved. The manufactured prototype patch antennas appear in Figure 3 and Figure 4, their dimensions appear in the Table 1.

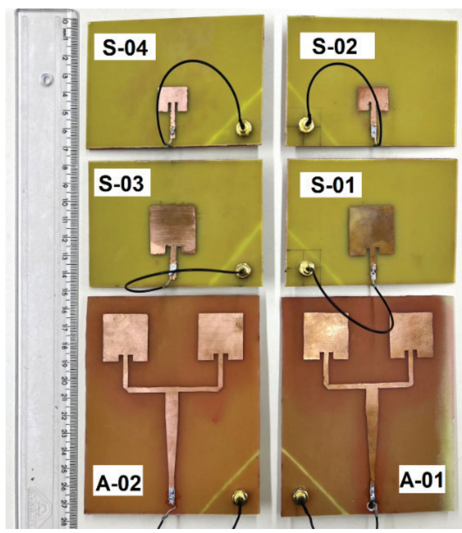

Figure 3. Manufactured patch antennas, simple (S-01, S-02, S-03, S-04) and in arrangement of two (A-01, A-02).

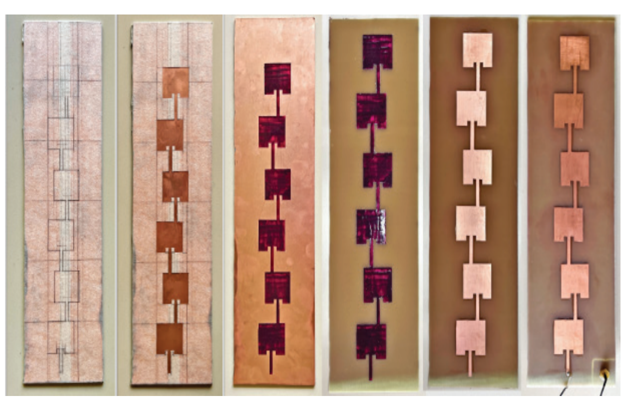

Figure 4. Manufacturing sequence shown for the A-03 patch antenna array (from left to right): drawing, cutting of the adhesive tape for the mold, varnish on the mold and remove the rest of the tape, use of the acid, remove the varnish.

Table 1. Prototype antenna sizes.

Antenna design	Measured patch dimensions				Number of patches
	W(mm)	L(mm)	x_0(mm)	y_0(mm)	
S-04, S-02	16.5	13.5	1.5	5	1
S-03, S-01	26	26	3	4	1
A-02, A-01	26	26	2.5	3.5	2
A-03	26	26	3	4	6

Experimental results

Experimental set-up

The methodology consists in design, simulation, manufacturing, tests, measurements and comparison of experimental measurements [5], [6], [7], [8]. The results of the tests in this work may be considered mostly from a qualitative approach as they are not carried out in an anechoic chamber. The Figure 5 and Figure 6 visually explain the set-up.

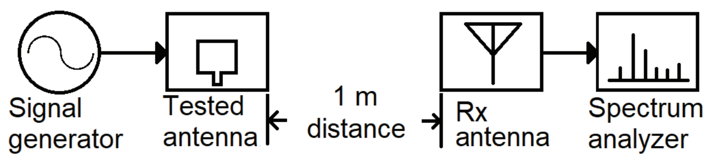

Figure 5. Scheme of the experimental set-up for the frequency sweep and the radiation pattern.

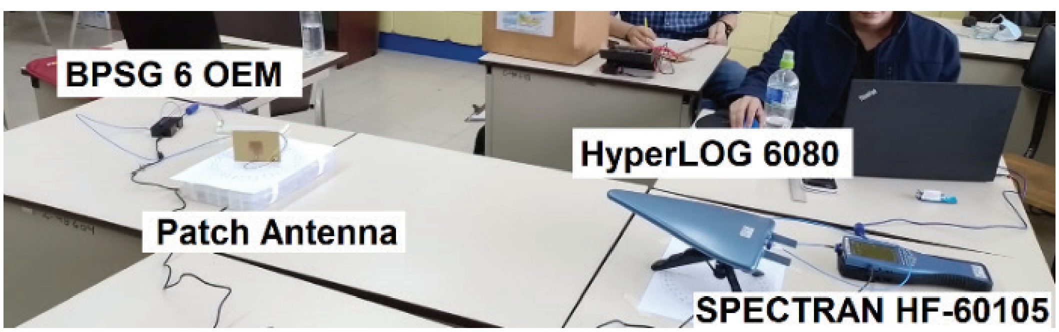

Figure 6. Experimental set up of measurements for the frequency sweep and the radiation pattern.

To empirically verify a functional distance between antennas for the tests, the AARONIA signal generator BPSG 6 OEM is used with a 5.2 GHz carrier and AM tones around 250 Hz, transmitting an AM signal through the S-03 antenna. This signal is received, demodulated, and the tones reproduced through the speaker of the AARONIA spectrum analyzer SPECTRAN HF-60105. By this way it is verified that the intensity of the signal transmitted is within the sensitivity of the spectrum analyzer. All these tests done at 5 dBm by the signal generator.

For the frequency sweep test, the patch antennas are pointed directly at the HyperLOG 6080 antenna of the spectrum analyzer. Using digital data logging, thousands of samples are taken to plot each of the curves shown in Figure 7 and Figure 8.

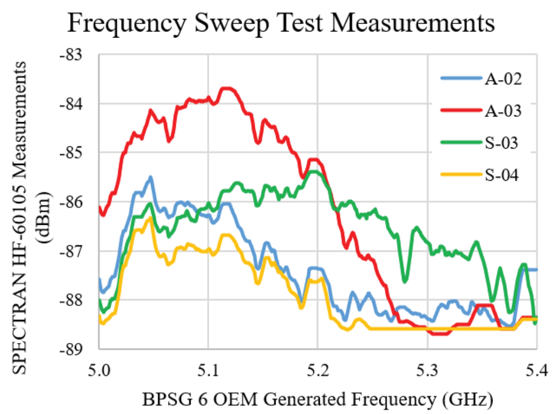

Figure 7. Frequency sweep measurements for each patch antenna.

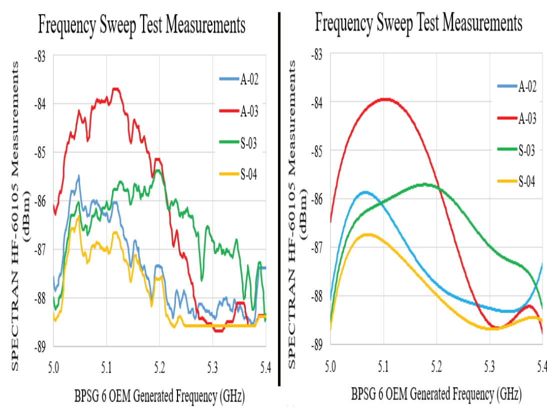

Figure 8. Frequency sweep 6th order polynomial regression for each antenna.

For the radiation patterns test, the reference axes in Figure 9 are used. Each radiation pattern measured is plotted in Figure 10, Figure 11, Figure 12 and Figure 13, as the result of overlaying the different radiation patterns obtained by each of the more than 50 frequencies per patch antenna. Each circle in the grid of radiation patterns represents a step of 10 dBm, with the center being -90 dBm and the outermost circle -40 dBm.

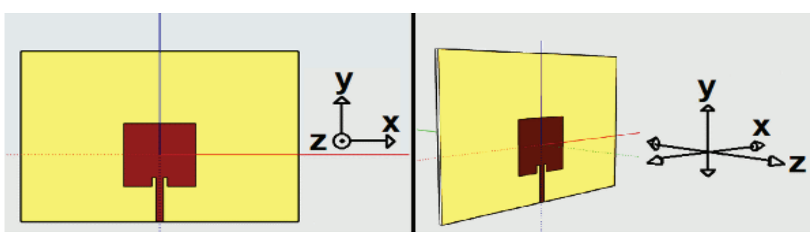

Figure 9. Reference of the x, y, z axes assigned to the patch antennas.

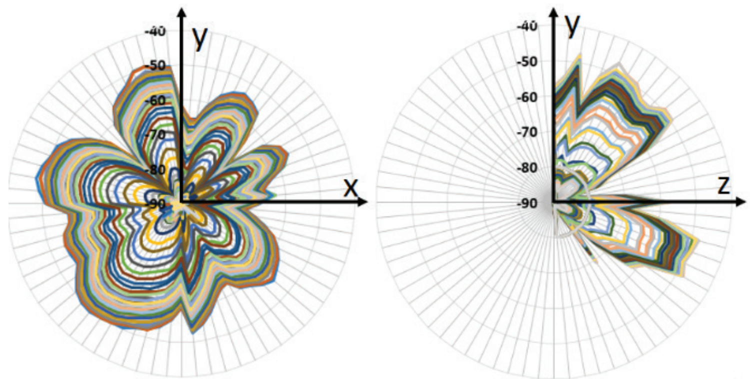

Figure 10. Measured and plotted radiation pattern of the S-04 antenna: from 5.137 GHz to 5.143 GHz. Higher gains at 5.14 GHz.

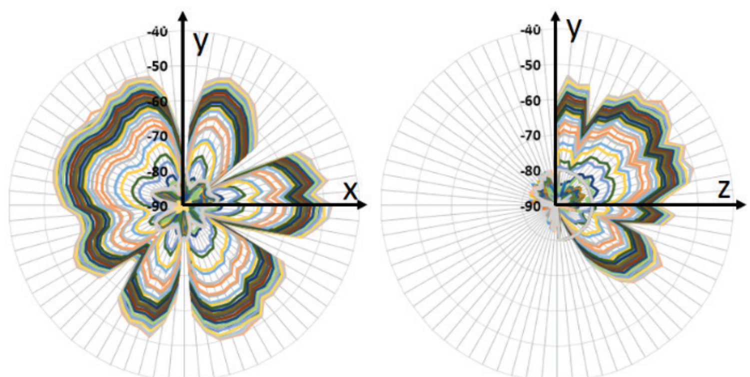

Figure 11. Measured and plotted radiation pattern of the S-03 antenna: from 5.197 GHz to 5.203 GHz. Higher gains at 5.2 GHz.

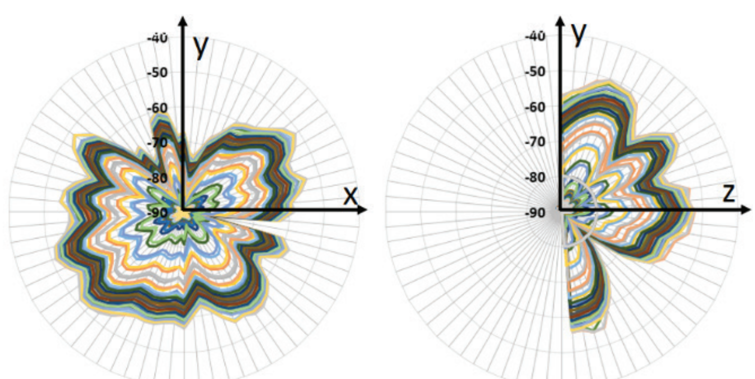

Figure 12. Measured and plotted radiation pattern of the A-02 antenna: from 5.052 GHz to 5.058 GHz. Higher gains at 5.055 GHz.

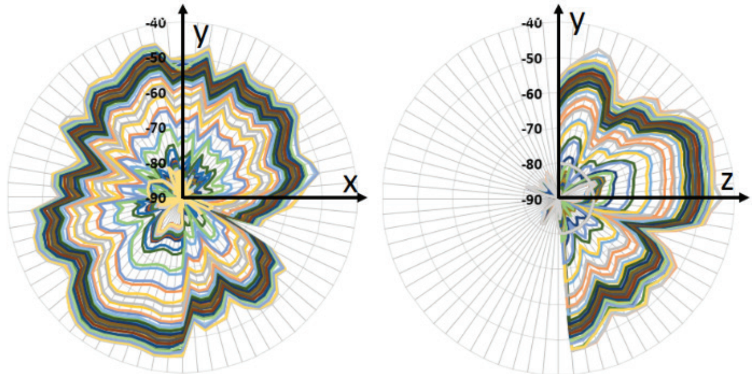

Figure 13. Measured and plotted radiation pattern of the A-03 antenna: from 5.112 GHz to 5.118 GHz. Higher gains at 5.115 GHz.

Experimental commercial compatibility

Additional antennas are used for these tests: An Ubiquiti sector antenna model LAP-120 (LiteBeam 5 AC AP, 16 dBi, 120 deg) named as LAP-01 and an Ubiquiti parabolic antenna model LBE-5AC-GEN2 (5GHz airMAX AC LiteBeam Gen2, Radio up 450+Mbps) named as LBM-01. For the experimental set-up the distance between LAP-01 and LBM-01 is 2.8 m. The tested patch antenna is set to be 3.1 m from the LAP-01 and 1.7 m from the LBM-01.

The results of using the tested patch antennas as receivers or Rx mode appears in Table 2 and shown in Figure 14, where the tested patch antenna is connected to the spectrum analyzer and it is set to a central frequency of 5.2 GHz and span of 30 MHz.

The detection of the signal by LAP-01 has even been verified when the patch antennas operate in transmission or Tx mode, that is, connected to the frequency generator as shown in Figure 15.

Table 2. Gains measured by the spectrum analyzer.

Tested Antenna Rx mode	Measurements made by the spectrum analyzer	
	LAP-01 and LBM-01 Linked	LAP-01 and LBM-01 both switched off
S-04	-60.4 ± 1.2 dBm	-86.0 ± 4.8 dBm
S-03	-65.1 ± 1.4 dBm	-88.2 ± 3.6 dBm
A-02	-67.5 ± 1.4 dBm	-87.8 ± 6.0 dBm
A-03	-74.1 ± 3.8 dBm	-89.3 ± 2.2 dBm

Figure 14. Screen capture of the measured spectrum with S-04 in Rx mode with the LAP-01 and LBM-01 linked (up) and then both switched off (down).

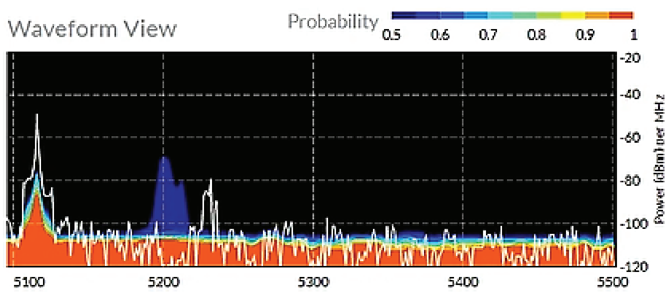

Figure 15. Screen capture of the measured spectrum by the Airview tool of the LAP-01 with S-04 in Tx mode. 5115 MHz and 5 dBm by the signal generator.

Conclusions

During design and calculations, it is noted how doubling the width of the microstrip has the effect of varying a few micrometers over the calculated slots, this helps to explain how patch antennas work well despite the handcrafted process. According to the radiation patterns, the A-03 prototype (the array of six patch antennas connected in series) as a transmitter has the highest gain in dBm between 5.0 GHz and 5.4 GHz.

The design and manufacture of patch antennas for applications in about 5.2 GHz, whether simple or in array, can be done in a practical way with satisfactory experimental results. A clear and simple methodology can be used even in training programs and encourage the local electronics industry to aim at the manufacture of faster, more competitive radio frequency devices compatible with the current market. Tests with digital modulation that include bit error rates can be a later work since the range and behavior of the prototype patch antennas are known.

Acknowledgments

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EIPRO Equipos, Ingeniería y Prototipado Electrónico, S. de R. L.

LAEDC 2023

Instrumental test of patch antennas manufactured for C-Band applications

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Introduction

Nowadays, digital communications require higher bandwidths and operating bands in the order of GHz. Fortunately, this allows the use of compact antennas, even the ones that take advantage of designs that improves the gain and width of the basic antenna by applying stacked patch topology with printed circuit boards or PCBs. Mass production ensures profitability in this type of product, but there are also prototyping process that can be less complex and less expensive : alternatives that may be attractive to researchers and engineers from Central American countries. So the research questions arise, what models and design rules must be respected as a minimum for the basic functional designs of patch antennas?, what kind of experimental results can be obtained with this type of products?

Equipment and Materials

- Spectrum Analyzer SPECTRAN HF-60105, Aaronia.
- Antenna HyperLOG 6080, Aaronia.
- Signal generator BPSG 6 OEM, Aaronia.
- Antenna LiteBeam, 16 dBi, Ubiquiti.
- Antenna LBE-5AC-GEN2, 5GHz airMAX AC LiteBeam Gen2, Ubiquiti.
- Double layer PCBs 70x100 mm.
- Double layer PCBs 300x200 mm.
- Hydrochloric acid.
- Hydrogen peroxide.
- Acetone, varnish.
- SMA Connectors, 50 ohm.

Methods and Setup

The basic design of a patch antenna like the one in Fig. 1 consists of calculating its width W and length L, slots methods with x_0 and y_0 dimensions are used for impedance matching.

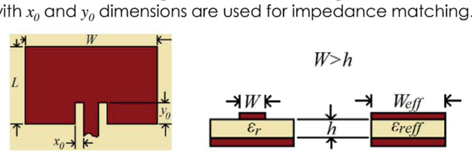

Fig. 1. Patch antenna with an inset feed and its planar waveguide model.

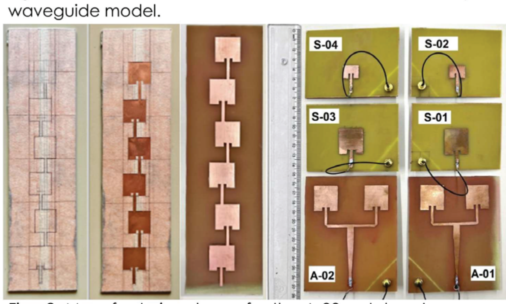

Fig. 2. Manufacturing shown for the A-03 patch antenna array prototype (left) and the others prototypes (right).

Manufacturing these antennas consists of drawing, cutting of the adhesive tape for the mold, varnish on the mold and remove the rest of the tape, use of the acid, removing the varnish (Fig. 2). This is how we proceed to do the tests of frequency sweep and the radiation pattern (Fig. 3).

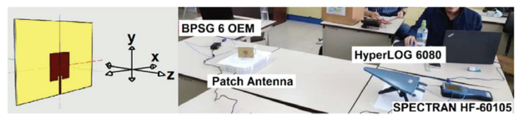

Fig. 3. Experimental set up of measurements for the frequency sweep and the radiation pattern.

Results and Discussion

The results of the tests in this work should be considered mostly from a qualitative approach as they are not carried out in an anechoic chamber.

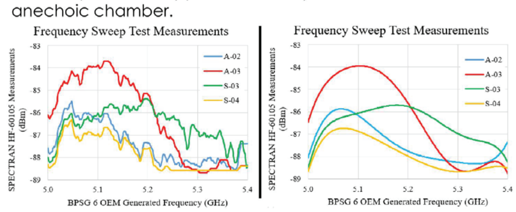

Fig. 4. Frequency sweep measurements for each patch antenna.

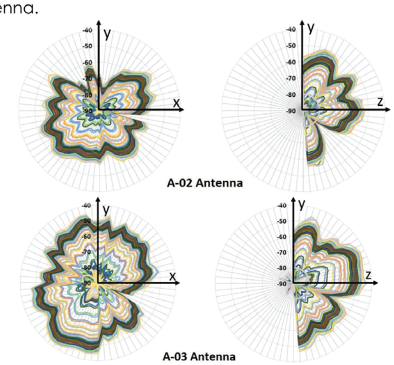

Fig. 5. Measured (dBm) and plotted radiation pattern of the A-02 antenna and the A-03 antenna, both around 5,1 GHz.

Conclusions / Next Steps

The design and manufacture of patch antennas for applications in about 5 GHz, whether simple or in array, can be done in a practical way with satisfactory experimental results. A clear and simple methodology can be used even in training programs and encourage the local electronics industry to aim at the manufacture of faster, more competitive radio frequency devices compatible with the current market. Tests with digital modulation that include bit error rates can be a later work since the range and behavior of the prototype patch antennas are known.

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Thermal conductivity of GeSn alloys: a CMOS candidate for energy harvesting applications

Conductividad térmica de aleaciones de GeSn: Candidato CMOS para aplicaciones de recolección de energía

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Keywords

Thermoelectrics; GeSn; thermal conductivity; 3-omega method; characterization; thin films.

Abstract

The thermal conductivity, κ, of thin GeSn semiconductors with Sn concentration of 12 at.% was studied by the 3-omega method. Accent is put on room temperature characterization where a small lattice conductivity of 4.5W/m-K was extracted. Similar performance was found but using the Raman thermometry optical method indicating the reliability of the measurements and showing GeSn alloys as promising materials for thermoelectric applications.

Palabras clave

Termoeléctrico; GeSn; conductividad térmica; método 3-omega; caracterización; películas delgadas.

Resumen

La conductividad térmica, , the semiconductores delgados de GeSn con concentraciones de Sn del 12% fue estudiada usando el método 3-omega. Especial atención se pone en la caracterización a temperatura ambiente en donde se extrajo una pequeña conductividad de la red de 4.5W/m-K. Un comportamiento similar fue encontrado pero usando el método óptico de Termometría Raman indicando la confiabilidad de las mediciones y mostrando que las aleaciones de GeSn son materiales prometedores para aplicaciones termoeléctricas

Introduction

In thermoelectric materials the conversion between thermal and electrical energy takes place. This process involves heat transport through both electrons and phonons. The efficiency of this process is defined by the figure of merit ZT which relates the thermal conductivity, electrical conductivity, and Seebeck coefficient of the material for a specific temperature. To obtain a high ZT, large Seebeck coefficient and electrical conductivity are required as well as a low thermal conductivity.

$Ge_{1-x}Sn_x$ binary alloys have recently got increasing attention due to their photonic and electronic applications, and its compatibility with the CMOS technology. The thermal conductivity (κ) of this material was only recently investigated for different Sn concentrations by using optical Raman thermometry (~4W/m-K for $Ge_{0.88}Sn_{0.12}$) [1] showing its relevance for thermoelectric applications at room temperature. In this work, a study of the thermal conductivity of GeSn alloys was performed but using the electrical 3-omega method. Layers of different thicknesses and similar Sn concentration.

Experimental methods

Growth, Characterization, and Device Fabrication

The $Ge_{1-x}Sn_x$ layers were grown by chemical vapor deposition (CVD) on a Ge post-deposition annealed (GePDA) buffer on Si(100) wafers. The composition and thickness of the samples were determined by fitting the Rutherford backscattering (RBS) spectrum. A set of 5 samples with similar GePDA (around 350nm) and Sn concentration (~ 12 at.%) with different GeSn thicknesses were chosen for the measurements.

A 200 nm layer of SiO_2 was deposited for electrical isolation on the $Ge_{0.88}Sn_{0.12}$ surface. Afterward, by optical lithography and lift-off a 50nm-Cr/250nm-Au strip was deposited. The metal strip acts simultaneously as heater and thermometer, as shown in the inset in Fig.2. Devices with different dimensions for the heater stripe were fabricated with width (2*b*) and length (*l*) values of 10, 15, 20 µm and 1000, 1500 µm, respectively.

Three-Omega Method

The thermal conductivity can be extracted using the 3ω–method [2]. By applying a current with frequency ω on a conductor (e.g. our heater stripe) the power dissipation generates heat waves with a 2ω oscillatory component. The heat induces a variation of the conductor resistance so that the voltage drop, adding a 3ω oscillatory component. Finally, the temperature oscillation ($\delta T_{2\omega}$) is expressed in terms of both 1ω-voltage ($V_{1\omega}$) and 3ω-voltage ($V_{3\omega}$):

$$\delta T_{2\omega} = \frac{2}{\alpha} \frac{Re(V_{3\omega})}{Re(V_{1\omega})} \tag{1}$$

where α is the temperature coefficient of the heater.

This $\delta T_{2\omega}$ can also be obtained by modeling a semi-infinite substrate with several thin layers and a finite-width stripe heater as in [2] including the explicit constant value derived in [3]:

$$\delta T_{2\omega} = \frac{P_{2\omega}}{l} \left\{ \frac{1}{\pi\kappa} \left[\frac{3}{2} - \gamma - i\frac{\pi}{4} - \frac{1}{2}\ln\left(\frac{2\omega b^2}{D}\right) \right] + \sum \frac{\tau_n}{2b\kappa_n} \right\} \tag{2}$$

where γ is the Euler gamma (γ = 0.5772…), *D* is the thermal diffusivity of the substrate, τ is the thickness of the thin layers, and *P* is the input power.

The first term corresponds to the temperature variation $\delta T_{2\omega}$ in the substrate while the sum of terms represents each of the thin layers. This theoretical equation leads to the so-called differential 3ω-method, which is basically the subtraction of measurements to take the Si substrate and Ge buffer out of the final calculation. In this case, the δT_A of a Si/GePDA/SiO_2 is subtracted from the δT_B of a Si/GePDA/GeSn/SiO_2 to isolate the GeSn δT_{diff} of interest and finally calculate the value of interest:

$$\delta T_{diff} = \delta T_B - \delta T_A = \frac{P_{2\omega}\, \tau_{GeSn}}{2lb\kappa_{GeSn}} \tag{3}$$

Finally, equating δT in (1) and (2) leads to,

$$V_{3\omega} = \alpha \frac{V_{1\omega}^3}{\sqrt{2}lR} \left\{ \frac{1}{\pi\kappa} \left[\frac{3}{2} - \gamma - i\frac{\pi}{4} - \frac{1}{2}\ln\left(\frac{2\omega b^2}{D}\right) \right] + \sum \frac{\tau_n}{2b\kappa_n} \right\} \tag{4}$$

A lock-in amplifier supplies the 1ω AC voltage using one of the two pairs of the device contacts and the other two are used for measuring the 3rd harmonic component of the input voltage frequency that corresponds to the $V_{3\omega}$ (see inset in Fig. 2). Three measurements were made on the samples: frequency scan, voltage scan, and resistance. For the frequency scan measurement ω is variated at a fixed $V_{1\omega}$. For the voltage scan measurement, the $V_{1\omega}$ is variated at fixed ω. In both $V_{3\omega}$ is extracted. Finally, for the resistance measurement $V_{1\omega}$ is variated at a certain ω and the current is measured.

Results

Fig.1a clearly shows the linear dependency with ln(ω) for the in-phase component and a constant behavior for the out-of-phase component of $V_{3\omega,}$ as is expected according to equation (4). Also, as a validation of the method the $V_{1\omega}$ was variated from 0 to 5V at 1KHz (voltage scan measurement) to show the cubic dependency between $V_{3\omega}$ and $V_{1\omega}$. In Fig.1b this dependency is shown by fitting the natural logarithm of both voltages resulting in a value of ~3.17.

The temperature coefficient of resistance for the stripe, α in (1), was obtained by increasing the temperature from 50K to 350K and fitting the resistance at different temperatures for a linear approximation of the value. Using two different devices a value of ~0.00224 K^{-1} at 300K was obtained as shown in Fig.1c. The validated 3ω method was then used to extract the thermal conductivity of GeSn layers with different thicknesses.

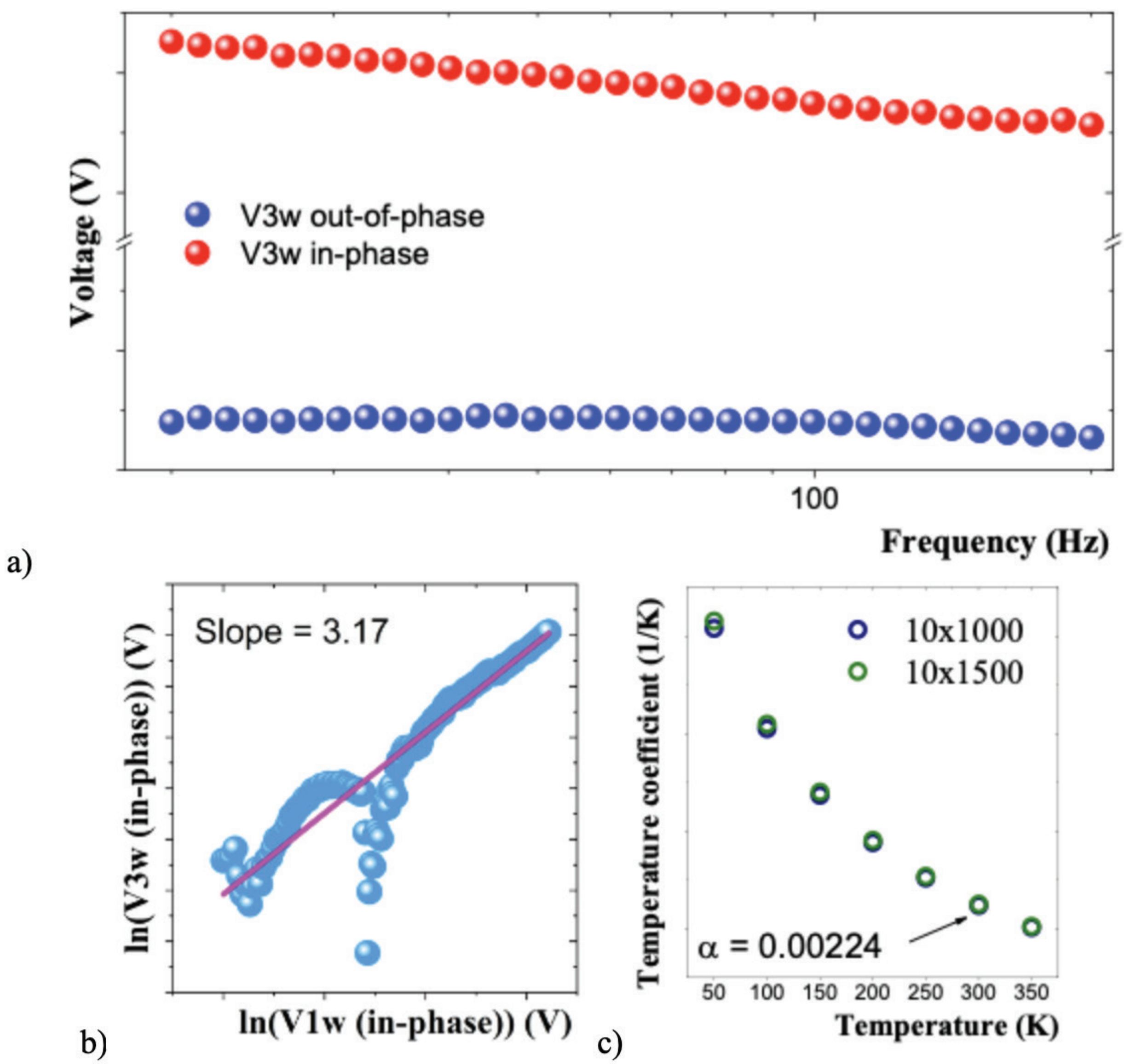

Figure 1. a) Real and imaginary parts of the $V_{3\omega}$ as a function of frequency, b) The cubic dependency of the $V_{3\omega}$ with the $V_{1\omega}$ is shown by linearly fitting the logarithm of both values. c) Temperature coefficient (α) at different temperatures for two devices with different stripe geometries (2*b* x *l*)

Fig.2 shows a thermal conductivity for different GeSn thicknesses. For thinner samples (40nm) the lower thermal conductivity value is associated with the increase of the phonon scattering at the $Ge_{0.88}Sn_{0.12}$ / Ge PDA interface and possibly due to very high compressive strain in the GeSn lattice. After a certain thickness, above the critical thickness for strain relaxation, the conductivity is almost constant. However, the defect density in the thin Ge PDA (350 nm) can contribute to increased scattering and lower the k. For this reason a very thick GeSn layer (700 nm) grown on high-quality 1500 nm Ge substrate was measured to confirm the results. Sets of devices for every sample were measured showing the same behavior. While the layers are not intentionally doped (~ p-type $1x10^{17}cm^{-3}$) it allows us to neglect the electrons contribution to the thermal conductivity. The measured κ represents the GeSn lattice thermal conductivity.

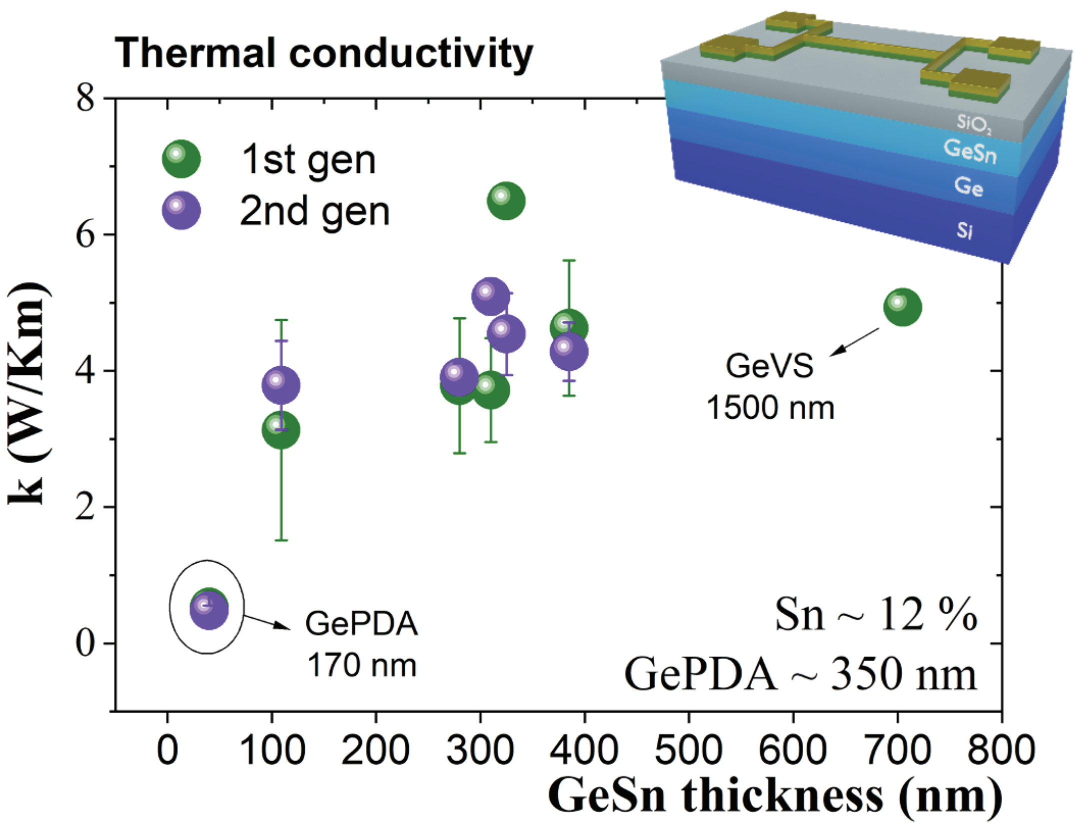

Figure 2. Thermal conductivity for different GeSn layer thicknesses for two generations of measurements.

Conclusions

The electrical 3ω-method was used to extract the κ of $Ge_{0.88}Sn_{0.12}$ alloys at different thicknesses. A constant behavior was shown for thicknesses above 100nm. The constant tendency spreads near a very low value of 4W/m-K, in agreement with previously published data [1] for the same Sn concentration. As outlook, samples with different Sn concentrations will be presented to confirm the decrease of the with the Sn content. New devices are being prepared to measure also the Seebeck coefficient.

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[1] D. Spirito, N. von den Driesch, C. L. Manganelli, M. H. Zoellner, A. A. Corley-Wiciak, Z. Ikonic, T. Stoica, D. Grützmacher, D. Buca, and G. Capellini, "Thermoelectric Efficiency of Epitaxial GeSn Alloys for Integrated Si-Based Applications: Assessing the Lattice Thermal Conductivity by Raman Thermometry", ACS Applied Energy Materials 2021 4 (7), 2021, pp. 7385-7392

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Cinvestav JÜLICH Forschungszentrum LAEDC2023

Thermal conductivity of GeSn alloys: a CMOS candidate for energy harvesting applications

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* jhonny.tiscareno@cinvestav.mx

Introduction

In thermoelectric materials the conversion between thermal and electrical energy takes place. The efficiency of this process is defined by the figure of merit ZT which relates the thermal conductivity (κ), electrical conductivity (σ), and Seebeck coefficient (S) of the material for a specific temperature. To obtain a high ZT, large S and σ are required as well as a low κ.

$$ZT = \frac{\sigma S^2}{\kappa} T$$

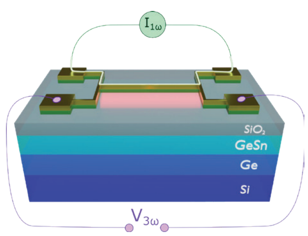
Figure of merit

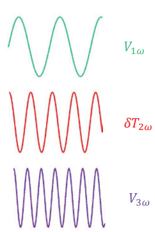
GeSn sample grown by CVD.
Si subs. + Ge buffer (PDA) + GeSn

$Ge_{1-x}Sn_x$ binary alloys are novel group IV semiconductors fully compatible with Si-based technology which are promising candidates for thermoelectric applications at room temperature.

For this work, the thermal conductivity of thin GeSn (~12% Sn) layers was measured by the electrical 3ω-method to demonstrate that for such Sn concentrations the κ significatively decreases compared to that of pure Ge (~64 W/Km).

Materials and Methods





$$\delta T_{2\omega} = \frac{2\,Re(V_{3\omega})}{\alpha\,Re(V_{1\omega})}$$

Experimental

$2b$: stripe width
l: stripe length
ω: frequency
D: subs. thickness
τ: thin layer thickness
P: applied power

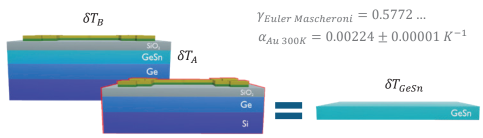
Substrate / Thin layers

$$\delta T_{2\omega} = \frac{P_{2\omega}}{l}\left\{\frac{1}{\pi\kappa}\left[\frac{3}{2} - \gamma + i\frac{\pi}{4} - \frac{1}{2}\ln\left(\frac{2\omega b^2}{D}\right)\right] + \sum \frac{\tau_n}{2b\kappa_n}\right\}$$

Theoretical

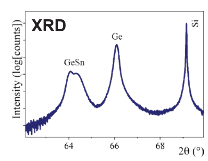
$\gamma_{Euler\ Mascheroni} = 0.5772 \ldots$

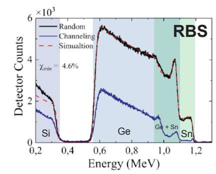
$\alpha_{Au\ 300K} = 0.00224 \pm 0.00001\ K^{-1}$

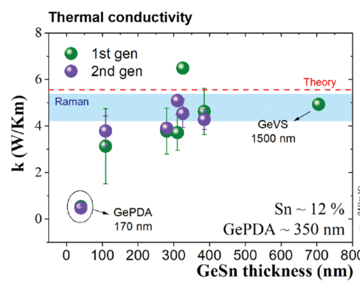


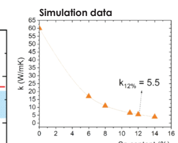
$$\delta T_{GeSn} = \delta T_B - \delta T_A = \frac{P_{2\omega}}{l}\left\{\frac{\tau_{GeSn}}{2b\kappa_{GeSn}}\right\}$$

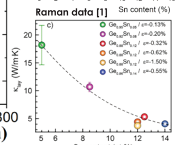
Results and Discussion









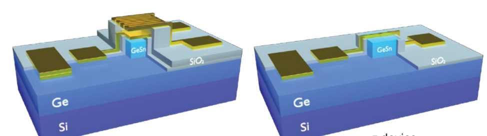


1. "Thermoelectric Efficiency of Epitaxial GeSn Alloys for Integrated Si-Based Applications: Assessing the Lattice Thermal Conductivity by Raman Thermometry", D. Spirito, N. von den Driesch, C. L. Manganelli, M. H. Zoellner, A. A. Corley-Wiciak, Z. Ikonic, T. Stoica, D. Grützmacher, D. Buca, and G. Capellini, ACS Applied Energy Materials 2021 4 (7), 7385-7392 https://pubs.acs.org/doi/10.1021/acsaem.1c01576

For thinner samples (40nm), the low thermal conductivity value is associated with the increase of the phonon scattering at the GeSn/Ge(PDA) interface and possibly due to very high compressive strain in the GeSn lattice. After a certain thickness, above the critical thickness for strain relaxation, the conductivity is almost constant. However, the defect density in the thin Ge(PDA) (350 nm) can also contribute to increase the scattering and decrease the κ. For this reason, a very thick GeSn layer (700 nm) grown on high-quality 1500 nm Ge substrate was measured to confirm the results

Conclusions / Next Steps

The electrical 3ω-method was used to extract the κ of GeSn (~12% Sn) alloys at different thicknesses. A constant behavior was shown for thicknesses above 100nm. The constant tendency spreads near a very low value of 4 W/Km, in agreement with previously published data [1] for the same Sn concentration. As outlook, samples with different Sn concentrations will be presented to confirm the decrease of the κ with the Sn content. New devices are being prepared to measure also the Seebeck coefficient and electrical conductivity.



S and κ device

σ device

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An industrial safety automation system using GSM technology

Un sistema de automatización de seguridad industrial con tecnología GSM

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Das, P.S; Pathak, M. An industrial safety automation system using GSM technology. *Tecnología en Marcha*. Vol. 37, special issue. June, 2024. IEEE Latin American Electron Devices Conference (LAEDC). Pág. 60-74.

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Keywords

Industrial automation; L.P.G. (Liquefied Petroleum Gas); gas sensor; temperature sensor; smoke sensor; GSM modem; relay drivers; relays; motor driver; DC motor.

Abstract

The primary aim of the proposed system is to develop a compact industrial security product based on emerging GSM technology. The project parallelly aims at providing an automized platform, enhancing the application diversity. The project basically focuses on developing the protection of dangerous gas leakages (basically methane, butane, propane, L.P.G. and Carbon mono-oxide gases) which are most common gases in the industrial sector. The system also focuses on smoke detection sensor along with temperature sensor. So as to minimize industrial hazard occurring due to gas leaks and sudden temperature divergences. The proposed system will be modelled to perform on both automatic and manual controls where the former will ensure security even when employees/workers might be absent inside an industry. Further the auto-mode would ensure relay drivers, relays, and alarm along with additional motor drivers that would systematically function coolers, emergency vents, and other emergency devices connected with the loads.

Palabras clave

Automatización industrial; L.P.G. (Gas de petróleo licuado); sensor de gas; sensor de temperatura; sensor de humo; módem GSM; controladores de relevos; relés; controlador de motor; motor de CC.

Resumen

El objetivo principal del sistema propuesto es desarrollar un producto de seguridad industrial compacto basado en la tecnología GSM emergente. Paralelamente, el proyecto tiene como objetivo proporcionar una plataforma automatizada, mejorando la diversidad de aplicaciones. El proyecto se centra básicamente en desarrollar la protección de fugas de gases peligrosos (básicamente metano, butano, propano, L.P.G. y monóxido de carbono) que son los gases más habituales en el sector industrial. El sistema también se enfoca en el sensor de detección de humo junto con el sensor de temperatura. Para minimizar el riesgo industrial que se produce debido a fugas de gas y divergencias repentinas de temperatura. El sistema propuesto se modelará para funcionar tanto en controles automáticos como manuales, donde el primero garantizará la seguridad incluso cuando los empleados/trabajadores estén ausentes dentro de una industria. Además, el modo automático garantizaría controladores de relés, relés y alarmas junto con controladores de motor adicionales que funcionarían sistemáticamente con enfriadores, ventilaciones de emergencia y otros dispositivos de emergencia conectados con las cargas.

Introduction

The automation systems based on GSM technology are becoming very much important in modern field of science, primarily in first world country [1]. Though industries are fascinated and looking for automization and digital security systems but due to high cost of product and implementation cost (i.e., not very much implemented in developing countries) automation is lacking far behind in these countries. The complexity encircling in designing an efficient as well as economic solution for a proficient Industrial security system is huge. But meeting up to the bullet objectives of this significant security and automized system will be sure to cater the industrial needs. This will aid the production system with a whole new dimension of security, providing a secured progress. Few solutions are available as a product in the market but they are either focusing on security or focusing on automation system [2]-[4]. Apart from mono type operation they are also addressing very functionalities. A system which can address the security and automation within affordable cost will be highly in demand.

Simulation Framework

The article describes a simulation framework that uses Proteus 7 Professional for circuit simulation and Keil CX51 C compiler software for embedded C programming. This approach provides a comprehensive solution for designing and testing embedded systems [5]-[6].

Proteus 7 Professional is a powerful tool for designing and simulating circuits. It provides a user-friendly interface and a wide range of simulation capabilities. The software allows users to create complex circuits with ease and simulate their behaviour in real-time. This enables engineers and researchers to test their designs and identify any potential issues before moving on to the implementation stage. Figure 1 shows the schematics view of circuit simulation using Proteus.

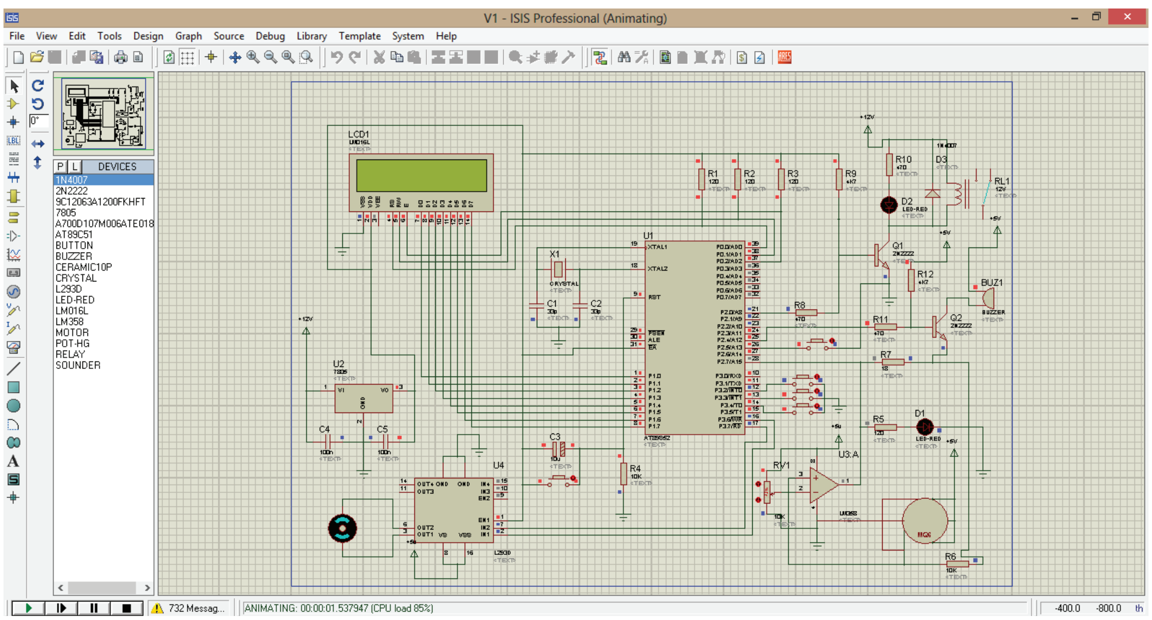


Figure 1. Simulating the proposed system using Proteus 7.0 Professional for comprehensive circuit analysis.

Keil software, on the other hand, is a popular integrated development environment (IDE) for embedded C programming. It provides a complete solution for developing, debugging, and testing software for microcontrollers. Keil software supports a wide range of microcontrollers and provides a rich set of features to simplify the development process.

By combining these two tools, we have designed and tested the complete embedded systems, including both the hardware and software components. This approach provides us a powerful solution for embedded system development, enabling us to create the proposed systems that meet the required design specifications.

The overall experiment which is performed with the help of software coding mentioned in APPENDIX-I.

Methodology and Working Principle

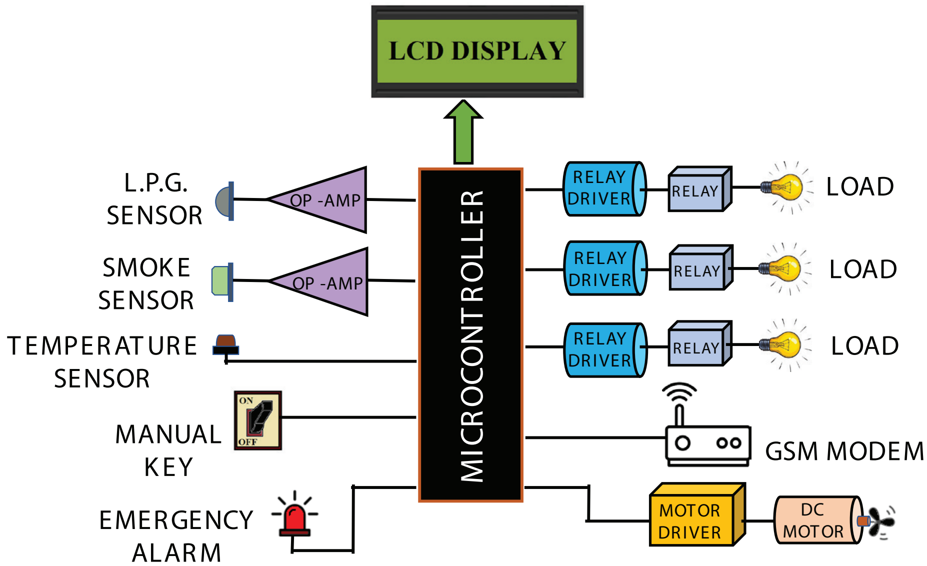


Figure 2. Methodology showing interface connections of different components required to build the proposed system.

The proposed system is mainly designed to protect workers, equipment, and property from harm, thereby minimizing the risk of injury, equipment damage, and property loss. The system uses various sensors, relays, and communication devices to detect and respond to hazardous conditions in the workplace. The working principle of an industrial automation safety system using a microcontroller, L.P.G. sensor, smoke detector, temperature sensor, relays, emergency alarm, and GSM modem is as follows:

- **Sensing hazardous conditions**: The L.P.G. sensor, smoke detector, and temperature sensor are used to detect the presence of hazardous conditions such as gas leaks, smoke, and high temperatures (temperature higher than the required condition).
- **Alerting personnel**: The alarm is used to alert personnel to the presence of a hazardous condition. The GSM modem can also be used to send SMS or email alerts to designated personnel or emergency services.
- **Activating relays**: When a hazardous condition is detected, the sensors activate the corresponding relays, which in turn trigger the safety mechanisms. For example, a gas leak could trigger the shutdown of the gas supply or ventilation system by activating the motors connected to it.
- **Monitoring and control**: The microcontroller monitor the status of the various sensors and relays, and can be programmed to perform certain actions in response to specific conditions.

Figure 2 shows the interfacing of different components required the built the proposed system.

System Description

The circuit for the proposed system is designed around easily available components in the market or through online. The primary components of the circuit are 8051 family microcontroller SST89E516RD2/ V516RD2, MQ6, DS18B20, LM358, L239D and SIM900 Modem. Initially we have started with AT89S52 but during the addition of features the memory space was exhausted, hence we have shifted SST microcontroller which is having 64K of flash memory as comparing to 8K of AT89S52. The most of the components excluding the relay and GSM modem requires regulated 5V hence we are using KA7805 (LMV805) for voltage regulation. 7805 has 3 pins. Pin 1 is regulated or unregulated input where we can give 5 V to 18 V. Pin 2 is ground and pin 3 is regulated output. Irrespective of input voltage at pin 1 (within the range) at pin 3 we always get +5V. To reduce any noise or repel in the power section, we have to use two 100nf capacitor which are connected across pin 1 and pin 2 and pin 3 of 7805.

A. Interfacing the Microcontroller, LCD and Voltage Regulator

The microcontroller that we are using is PDIP type. It has 40 pins. It is compatible fully with 8051 family with various advantage features and high program memory space. Pin 40 is which is connected to the pin 3 of 7805. Pin 20 is ground. Any microcontroller or microprocessor requires clock source to fetch instruction. The clock source can be a crystal oscillator, function generator and RC oscillator or even we can use a separate microcontroller to provide the clock pulse though we can use different clock source, crystals are more widely used as it is reliable, economic and easily available. Pin 18 and 19 of the microcontroller are XTAL 2 and XTAL 1 respectively. Here we have use a crystal of value 11.0592 MHz. According to data sheet it can work at 0 to 40 MHz at 5V and 0 to 33 MHz at 3V. But we have use 11.0592 MHz as we have to perform serial communication. In case of 8051 family 11.0592 is more precise when we have to perform serial communication as it will effect by less error. Parallel to the crystal that is at pin 18 and 19 we have connected 33pf capacitor (C1 and C2). According to data sheet the C1 and C2 can be anything in between 20 to 40 pf, but 33 is a common practice with 8051 family hence we have selected 33pf only.

The pin 9 of microcontroller is reset pin. Also, according to datasheet if we give logically high i.e. +5V at pin 9 for two machine cycles i.e., 12 x 2 = 24 clock pulse, the device will restart and for normal operation pin 9 must be pull down, hence we have connected a 10K resistance across pin 9 and ground as pull-down resistance. Pin 31 is pin. According to datasheet, if we have to use external program memory pin 31 must be connected to ground and to use the internal program memory it must be connected with . As we are using internal memory (pin 31) is connected with .

For display of various information, status of the devices and the sensor we are using a 16 x 2 LCD module. The module can display two lines and 16 characters per line. It consists of 16 pins. Pin 1 is ground, pin 2 is which is connected to pin 3 of 7805. Pin 3 is contrast control. It is used to provide a referral voltage to adjust the contrast of the display unit. In our circuit a 10K variable resistance is used as potential divider, the output of the variable resistance is connected to pin 3 of LCD. One terminal is connected to and the other terminal is connected to ground (GND).

Pin 4, pin 5 and pin 6 of the LCD are the most important pins, they are marked as RS, WR and EN. Pin 7 to pin 14 of the LCD is Data Bus which is marked as D0 to D7. Pin 15 and 16 are LED + and LED which is having no relation with programming. Instead, it is used to provide power supply to the LED used in the LCD to provide backlight. Hence, many simulations or circuit designing software (like Proteus) keep pin 15 and pin 16 hidden.

The D0 to D7 i.e., pin 7 to 14 is connected to pin 1 to pin 7 of microcontroller i.e., port 1. The RS, RW and EN pins connected to pin 39, 38 and 37, respectively i.e., PO.0; PO.1; PO.2. of the microcontroller.

Figure 3 shows the motherboard interface of the proposed system containing SST89E microcontroller, voltage regulator (KA7805) and LCD display.

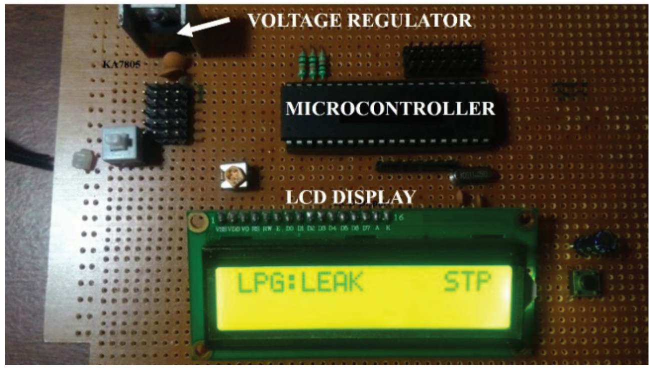


Figure 3. Motherboard interface of the proposed system containing SST89E microcontroller, voltage regulator (KA7805) and LCD display.

The 8051/8052 family with 40 pins PDIP package has 4 i/o ports P0, P1, P2 and P3. The internal resistance of P0, P1, P2 and P3. are activated but the internal pull-up of port 0 is not activated hence we must have to use external pull-ups with the i/o pins of port 0 if it is used. As RS, RW and EN is connected to 39, 38 and 37, we have to use 10K resistance as external pull-ups for these i/o pins.

B. Interfacing the GSM Modem with the Microcontroller

The microcontroller communicates through serial communication with TTL mode but the modem that we are using (SIM900), shown in Figure 4, has to be connected with RS232 protocol, hence we are using a TTL to RS232 converter circuit based on MAX232. The MAX232 is having 16 pins with DIP package. It has two channels i.e., pin 7 and pin 8 with pin 9 and pin 10; and pin 11 and pin 12 with pin 13 and pin 14. As we need only one channel for communication, we have used Pin 11, 12 (TTL) and pin13 and 14(RS232). The GSM modem SIM900 is used to establish remote communication with GSM technology. It is used to receive command in terms of SMS and hand it over to the microcontroller. The microcontroller is responsible to process the received SMS and identify the acceptance or rejection of the messages as command. If it has received predefined command as a message, it perform the required task.

For example – if it received #DEV 1: ON, it will switch ON the device. Similarly, if it has received #DEV 1: OFF, it will deactivate the 1st device.

Figure 4. SIM900 GSM Modem.

C. Interfacing the Sensor Circuits with the Microcontroller

The system is equipped with three different sensors namely-

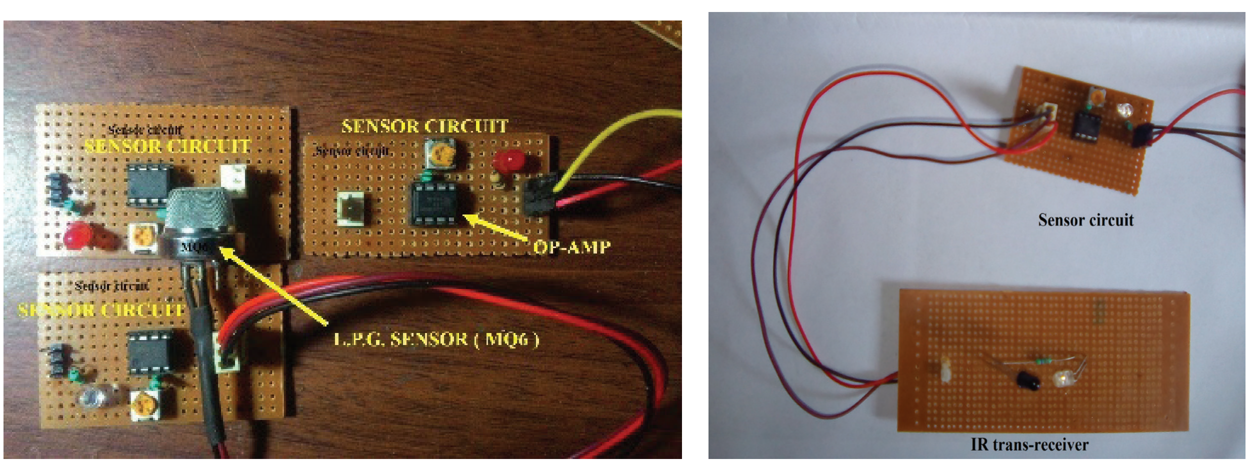
(i) the temperature sensor (DS18B20),

(ii) the L.P.G. sensor (MQ6), and

(iii) the smoke detector.

To detect the temperature, we are using digital temperature sensor DS18B20 from Dallas semiconductors. It has internal converter and it profiled the data with serial mode (1-Wire communication); hence it does not require any additional ADC. The DQ pin i.e., pin 2 is connected with pin 28 i.e., P2.7 of the microcontroller. To read the temperature, the microcontroller sends specific command to DS18B20 with the DQ pin and in reverse DS18B20 give the temperature to the microcontroller. Through DQ pin, pin 1 of the DS18B20 is ground and pin3 is (+5V). DS18B20 can be powered by parasite power supply also. But we are using 5V only.

To detect L.P.G. or inflammable gas like methane, propane or butane, we are using MQ6, shown in Figure 5(a). But the current pass through the MQ6 is not enough to directly interface with digital i/o pin of the microcontroller. Hence, a current to voltage converter is used as amplifier as well as digital converter. A popular dual op-amp IC LM358 is used for this purpose. LM358 is having dual comparator but we are using only the first comparator, pin 1 is the non-inverting output of the first comparator, pin 2 is the inverting input of the first comparator, and pin 3 is non-inverting input for the first comparator. Hence, MQ6 output is connected to pin 3 of LM358. Pin 4 is ground and Pin 8 is . LM358 can be powered with single power supply with a wide range. Here, we are using 5V as output of comparator is connected to the i/o pin of the microcontroller. The pin 2 is connected with a 10K variable resistance where one terminal is connected to ground. Using these variable resistance we can set the sensitivity level of the sensor by proving different threshold value.



(a) (b)

Figure 5. (a) L.P.G. sensor (MQ6) along with sensor circuits (b) IR trans-receiver (photo diode and IR LED) used as smoke detector along with its sensor circuits

The similar circuit is used for smoke detection where we have connected a pair IR trans-receiver (photo diode and IR LED) placed in angular position so that can detect the smoke with the help of optical reflection method, shown in Figure 5(b).

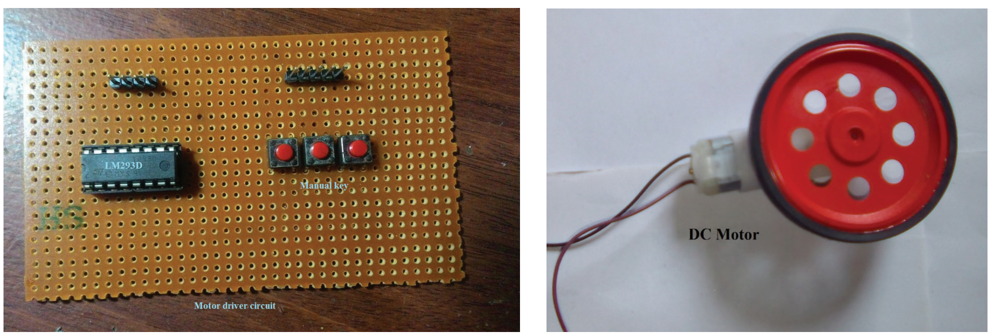
D. Interfacing the Driver Circuit along with the DC Motor with the Microcontroller

The system has the ability to control a DC motor with B- operator clockwise, anti-clockwise and stop, shown in Figure 6 (a) and 6 (b). L293D is having 16 pins with DIP package. Pin 1 is the enable pin for channel (1), if pin 1 is connected to the channel (1) will be activated. And a low at pin 1 will not effect on the control signal of the motor, irrespective of input control signal. Pin 2 and Pin 7 are the input for first channel. Pin 3 and pin 6 are the output of the first channel where we can connect a DC motor. Pin 4 and pin 5 are ground (GND).

Pin 8 of L293D is the power supply for the motor. The input at this pin is depended on the voltage required by the motor connected with L293D.

Pin 9 is the enable pin for channel (2). Pin 11 and pin 14 are the output for channel (2), and pin10 and pin15 are the input for channel (2).

Here in the proposed system, we have use channel (2) of L293D. The input signal to the driver is connected with pin 16 and pin1 7 i.e., P3.6 and P3.7. The motor can be controlled by the SMS as well as the manual switch. Three switches are connected with P3.3; P3.4 and P3.5 for stop, clockwise and anti-clockwise direction of the motor.



(a) (b)

Figure 6. (a) Motor driver circuit (b) DC motor with B-operation used in the proposed system.

When the system detect smoke or any inflammable gas, it activates a buzzer as alarm. The microcontroller cannot drive the buzzer directly. Hence a buzzer device circuit is designed around 2N2222, a 470 resistance and 10K pull up resistance. The controlling signal of the buzzer circuit is drawn from P3.2 of the microcontroller i.e., pin 12.

E. Interfacing the Relay Driver Circuits along with the Relays with the Microcontroller

To control the various devices, we have connected three relay driver circuits for demonstration purpose, shown in Figure 7. The relay device circuit are nothing but switch circuit designed around NPN switching transistor 2N2222 from Philips. The control signal for these three relay drivers is connected from pin 21, pin 22 and pin 23(i.e., P2.0, P2.1 and P2.2 of the microcontroller). Just like motor controlling system, we can control the device with help of SMS, at the same time we have three push to ON momentary or tactile switch to pin 24, pin 25 and pin 26 (i.e. P3.3; P3.4 and P3.5) of the microcontroller.

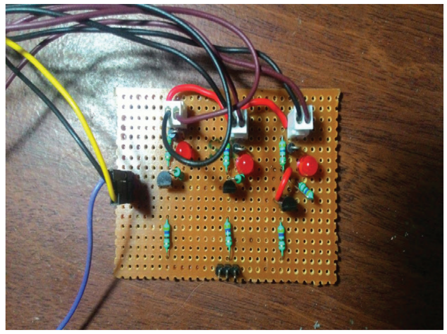


Figure 7. Relay driver circuit used in the proposed system.

The automization part of the prototype is programmed so that if the system temperature reaches upto or above it, the buzzer alarm of the system will get activated which indicates that the temperature must be pulled down for safety reasons. This temperature can be set up according to the required needs of various industrial as well as environmental conditions. Figure 8 shows the hardware prototype of the proposed system.

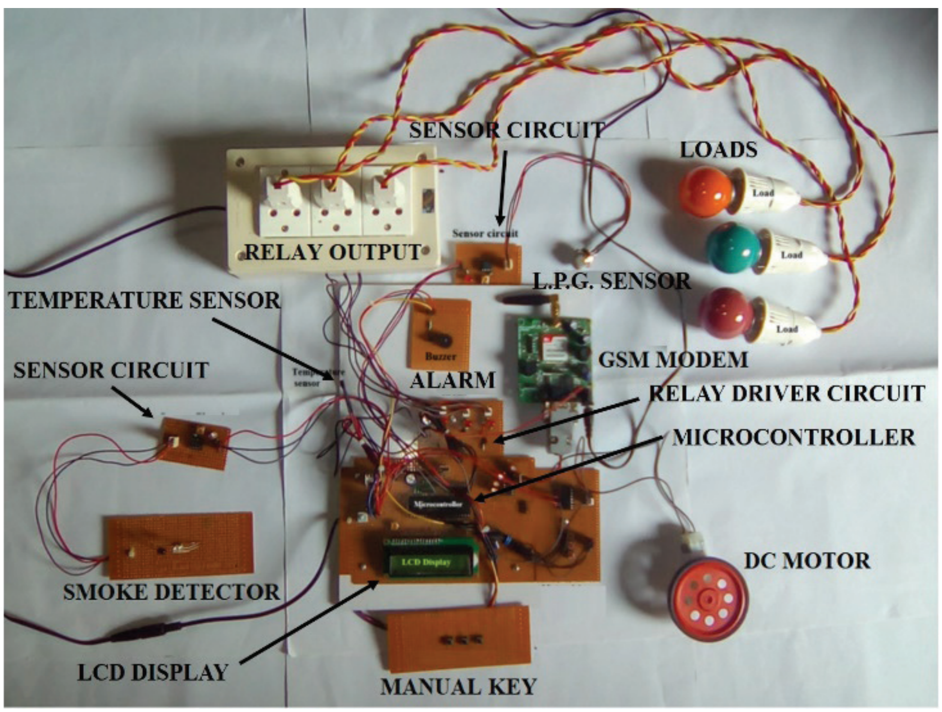


Figure 8. Hardware prototype of the proposed system along with system components.

Experimental Results/Outcomes

- Finally, the proposed system is being successfully designed for fulfilment of the desired needs in the industrial sectors in terms of safety, security and automation.
- Through in the prototype, only three sensors namely L.P.G. sensor, temperature sensor, and IR trans-receiver (photo diode and IR LED) smoke detector are used, there are provisions for addition of more sensors like the Carbon Monoxide sensors, and other harmful gas sensors for harmful gases produced in industries which plays a dangerous role in industrial sectors as well as to the environment near it.

- As the article entitled “A GSM Based Safety Automation System”, the safety automation in the system is provided only to the temperature sensor which can further be modified in driving of the DC motor or any load with respect to the temperature limit.

Figure 9 shows the hardware prototype of the proposed system in active mode along with system components.

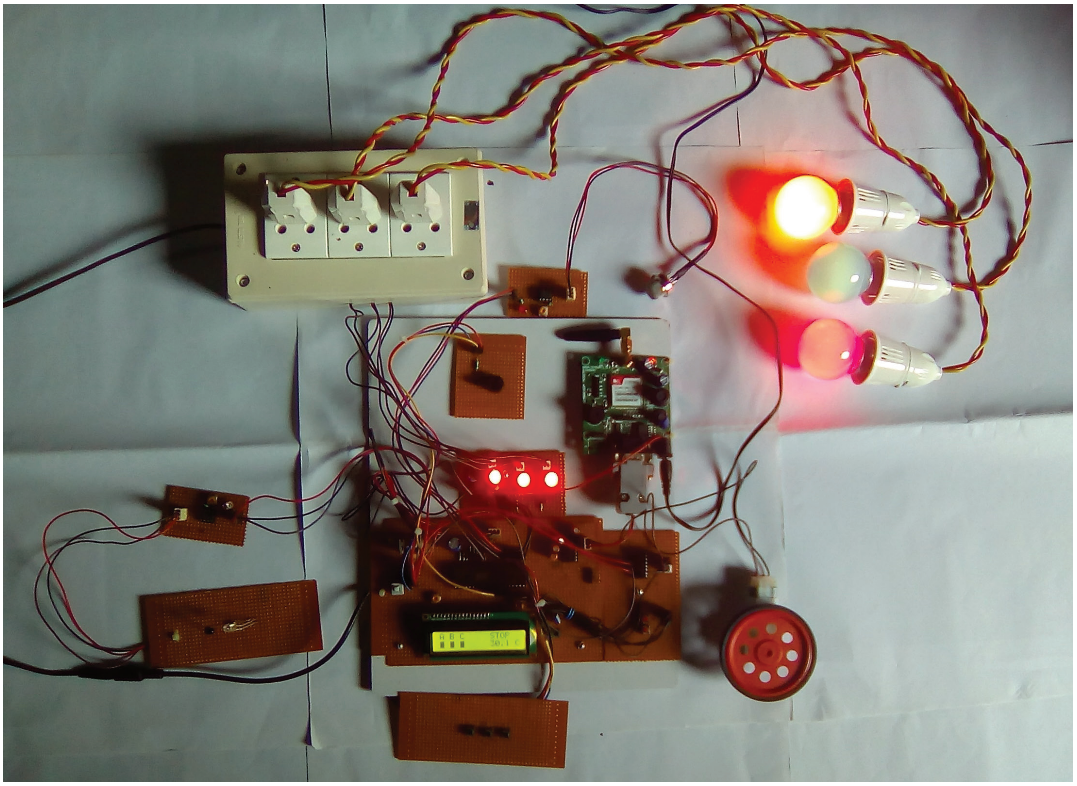


Figure 9. Hardware prototype of the proposed system in active mode along with system components.

Conclusion

- The article will help to implement or fulfil some of the important needs of modern industries in the field of safety, security and automation using easily available, cheap and economic components.
- At the beginning of designing this system, a lot of difficulties have been faced regarding circuit components, interfacing with different circuit components, GSM technology but with the help of datasheets, application of theoretical concepts, the problems got resolved one by one [7]-[9].
- Moreover, while designing the system, working on embedded C, Proteus 7 professional, Keil compiler played a major role. This project helped more of a practical implementation of using of embedded C, Proteus 7 professional, Keil compiler, GSM technology, interfacing of LCDs, interfacing of sensors, interfacing of relay drivers with microcontrollers, which would have been much difficult to understand while theoretical studies.
- Though the system is designed for industrial sectors it can further be implemented in commercial purposes using desired and required amounts of components based on environmental condition.

Lastly, in future this proposed system can be further developed with the advent of ideas and technologies of science.

Acknowledgment

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APPENDIX - I

The following embedded C codes have been used to design the proposed industrial safety automation system.

```
#include<reg51.h> // Include header file to work with 8051 Series Microcontroller
#define LCD Port P1   // LCD Port i.e. PIN 7 to pin 14 of LCD is Connected to P1(PIN 1 to 8 of 8051)
sbit RS=P0^0;    // RS pin LCD (PIN 4) is Connected to P0.0 of 8051 (PIN 39)
sbit RW=P0^1;  // RW pin LCD (PIN 5) is Connected to P0.1 of 8051 (PIN 38)
sbit EN=P0^2; // EN pin LCD (PIN 6) is Connected to P0.2 of 8051 (PIN 37)
sbit LPGSENSOR =P2^7;
sbit RELAY1=P2^0;
sbit BUZZER=P2^4;
sbit SW1=P2^5;
sbit STOP=P3^2;
sbit CLK=P3^3;
sbit CCLK=P3^4;
sbit M1_A=P3^6;
sbit M1_B=P3^7;
void delay (int t)  // This function will generate tms delay
```

```
{
 int i;     // Declare local variable i to use as counter
 while(t>0)    // Loop until t become ZERO
{
 i=1275; // Set the starting value of i with 1275
// In 8051 with 11.0592MHz Crystal, it consumes
// approxd 1ms to count from 0 to 1275 or vice-versa
while(i>0)i--;  // Decrease the value of i by -1 until it becomeZERO
t--; // Decrease the value of t by -1
}
}
void LCDCommand(char c) // This function will send a Command to LCD
{
RS=0;    // RS=0 means, we are writing Command on LCD
RW=0; // RW=0 means, we are using the LCD in Write Mode
LCDPort=c;  //Copy the Value of c(Command) to LCD Port (P1 in our Case)
EN=1;    // Set the EN pin High       -----+
delay (2); // Wait for 2ms        +-- Generate a High to Low Pulse
EN=0; // REset the EN pin Back to Low ----+
return ; // Return from the Function
}
void LCDData(char c)// This function will send a Data to LCD
{
 RS=1; // RS=1 means, we are writing Data on LCD
 RW=0; // RW=0 means, we are using the LCD in Write Mode
 LCDPort=c;  //Copy the Value of c(Command) to LCD Port (P1 in our Case)
 EN=1;   // Set the EN pin High-----+
 delay(2); // Wait for 2ms        +-- Generate a High to Low Pulse
 EN=0; // REset the EN pin Back to Low ----+
return ; // Return from the Function
}
void LCDInit()//This function will Initilized the LCD
{
LCDCommand(0x38); // 16x2 LCD, 8 Bit Mode
LCDCommand(0x06); // Display From Left to Right
LCDCommand(0x0c); // Display ON, Cursor Hide
LCDCommand(0x01); // Clear LCD
}
void LCDPuts(char *s) // This function will Display a string  on LCD
{
 int i; // Declare Local variable i to use as index
for(i=0;s[i]!='\0';i++) // Scan each and every character of the string
{
LCDData(s[i]); // and display every character one by one
```

```
}
}
void main() // The main function start here
{
int RELAY1_STATUS=0;
RELAY1=0;
BUZZER=0;
M1_A=0;
M1_B=0;
LCDInit(); // Initilizing the LCD
LCDPuts("GSM BASED");
LCDCommand(0xc0); // Move to the Second Line
LCDPuts("Industrial SYSTM");
delay(100); // Wait for 100ms
LCDCommand(0x01); // Clear LCD
LCDPuts("Developed By....");
LCDCommand(0xc0); // Move to Second Line
LCDPuts("Prachuryya Das  ");
delay(100); // Wait for 100ms
LCDCommand(0xc0); // Move to Second Line
LCDPuts("JEC - IN - 2015");
delay(100); // Wait for 100ms
LCDCommand(0x01); // Clear LCD
LCDCommand(0x8d);
LCDPuts("STP");
while(1)
{
 if(LPGSENSOR==1)
{
LCDCommand(0x80);
LCDPuts("LPG:LEAK ");
BUZZER=1;
}
Else
{
LCDCommand(0x80);
LCDPuts("LPG: CLEAR");
BUZZER=0;
}
if(SW1==0)
{
if(RELAY1_STATUS==0)
{
RELAY1=1;
```

```
RELAY1_STATUS=1;
LCDCommand(0xc0); // Starting of Second Line
LCDPuts("DEV1:ON ");
}
else
{
RELAY1=0;
RELAY1_STATUS=0;
LCDCommand(0xc0); // Starting of Second Line
LCDPuts("DEV1: OFF");
}
}
if(STOP==0)
{
M1_A=0;
M1_B=0;
LCDCommand(0x8d);
LCDPuts("STP");
}
if(CLK==0)
{
M1_A=0;
M1_B=1;
LCDCommand(0x8d);
LCDPuts("CLK");
}
if(CCLK==0)
{
M1_A=1;
M1_B=0;
LCDCommand(0x8d); LCDPuts("ACL");
}
}
}
```

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An Industrial Safety Automation System Using GSM Technology

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Abstract

The proposed system aims to develop a compact industrial security product based on emerging GSM technology. It focuses on protecting against dangerous gas leakages, smoke detection, and temperature divergences in industrial settings. The system operates in both automatic and manual modes, providing security even when employees are absent. By integrating security and automation features at an affordable cost, the proposed system addresses the needs of the industrial sector.

Introduction

Automation systems based on GSM technology are increasingly important in the modern scientific field, especially in first-world countries [1]. However, the high cost of products and implementation has hindered the widespread adoption of automation in developing countries. Designing an efficient and cost-effective solution for industrial security systems is a complex challenge. By meeting the objectives of a comprehensive security and automation system, industrial needs can be met, enhancing production with enhanced security measures. Existing solutions in the market typically focus on either security or automation, and they often lack versatility[2]-[3]. There is a high demand for an affordable system that can address both security and automation requirements, offering a valuable solution for industries.

Simulation Framework

- The article presents a simulation framework using Proteus 7 Professional for circuit simulation and Keil CX51 C compiler software for embedded C programming[4-5].

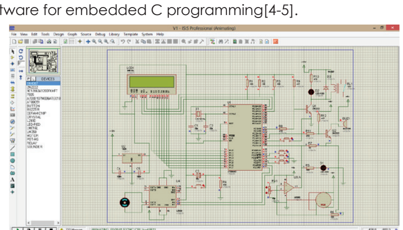

Figure 1. Simulating the proposed system using Proteus 7.0 Professional for comprehensive circuit analysis.

Methodology/Working Principle

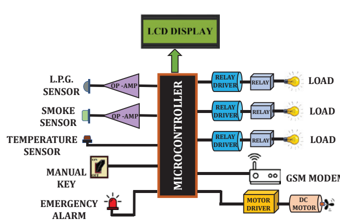

Figure 2. Methodology showing Interface Connections of different components required to build the proposed system.

- The proposed industrial automation safety system uses various sensors, including LPG, smoke, and temperature sensors, to detect hazards like gas leaks, smoke, and high temperatures.
- An alarm system alerts personnel when hazardous conditions are detected, while a GSM modem sends SMS or email alerts to designated individuals or emergency services.
- Safety mechanisms, such as shutting down gas supplies or activating ventilation systems, are triggered by relays. A microcontroller monitors sensor and relay statuses and executes programmed actions accordingly.

Results and Discussion

- The proposed system is designed to meet the needs of industrial sectors in terms of safety, security, and automation. The system includes three sensors: LPG sensor, temperature sensor, and an IR trans-receiver (consisting of a photo diode and an IR LED) smoke detector.
- There is provision for adding more sensors, such as Carbon Monoxide sensors and other harmful gas sensors, to detect dangerous gases produced in industries.
- These additional sensors are important for ensuring safety in industrial sectors and protecting the environment.
- The system can be modified to drive a DC motor or any load based on the temperature limit, enhancing its automation capabilities.

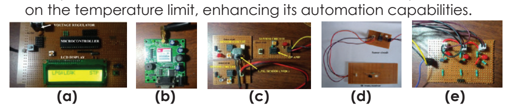

Figure 3. (a) Motherboard containing SST89E microcontroller, voltage regulator (KA7805) and LCD display **(b)** SIM900 GSM Modem **(c)** L.P.G. sensor (MQ6) with sensor circuits **(d)** IR trans-receiver as smoke detector along with sensor circuits **(e)** Relay driver circuit used in the proposed system.

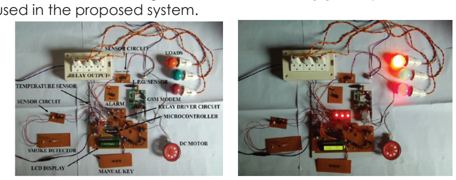

Figure 4. (a) Hardware prototype of the proposed system along with system components **(b)** Hardware prototype of the proposed system in active mode

Conclusions / Future Scope

- **Article focus:** Addressing safety, security, and automation needs in modern industries using affordable components.
- **Overcoming challenges:** Initial design faced difficulties with circuit components, interfacing, and GSM technology, but solutions were found through datasheets and theoretical knowledge.
- **Key tools:** Embedded C, Proteus 7 Professional, and Keil compiler enabled practical implementation of technologies like GSM, LCDs, sensors, and relay drivers with microcontrollers.
- **Adaptability:** While designed for industrial sectors, the system can be adjusted for commercial use by modifying components based on environmental conditions.
- **Future potential:** The proposed system offers opportunities for further development and enhancement by incorporating new ideas and technologies from the field of science.

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Design and development of flexible boards and their application to biomedical engineering

Diseño y desarrollo de placas flexibles y su aplicación en la ingeniería en biomédica

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Keywords

Fabrication; flexible circuits; incremental methodology; materials; wearable technology.

Abstract

Wearable devices in the healthcare industry require to be easy to use, comfortable to handle, and reliable in their operation. This article presents a study on the design and manufacture of flexible circuits and their applications in the field of biomedical engineering. The methodology used in this study is the incremental methodology, which implies a step-by- step approach of the design and fabrication process. The study focuses on the fabrication of a flexible circuit using conductive ink and a flexible substrate. The results showed that the Voltera V-ONE printer can be used to create these circuits with a high accuracy and precision. Various substrates were used for the testing process due to their different characteristic. The final circuit was tested and found to be functional for applications in biomedical engineering.

Palabras clave

Circuitos flexibles; fabricación; materiales; metodología incremental; tecnología vestible.

Resumen

Los dispositivos vestibles, o wearables, en la industria de la salud deben ser fáciles de usar, amigables con el usuario y confiables en su funcionamiento. Este artículo presenta un estudio sobre el diseño y la fabricación de circuitos flexibles y sus aplicaciones en el campo de la ingeniería biomédica. La metodología utilizada en este estudio es la metodología incremental, que implica un enfoque paso a paso del proceso de diseño y fabricación. El estudio se centra en la fabricación de un circuito flexible utilizando tinta conductora y un sustrato flexible. Los resultados mostraron que la impresora Voltera V-ONE puede utilizarse para crear estos circuitos con una gran exactitud y precisión. Se utilizaron varios sustratos para el proceso de prueba debido a sus diferentes características. El circuito final fue probado y resultó ser funcional para aplicaciones en ingeniería biomédica.

Introduction

Flexible circuits have emerged as a promising alternative to traditional rigid circuit boards due to their unique properties. In recent years, flexible circuits have been increasingly used in various applications including aerospace, automotive, and consumer electronics. However, the field of biomedical engineering has also been greatly impacted by this technology. The design and fabrication of flexible circuits for biomedical applications has proven to be challenging and requires specialized knowledge, materials, and equipment [1].

Another important aspect of flexible circuits is the conductive material. In traditional rigid circuit boards, copper is commonly used as the conductive material. However, copper is not suitable for flexible circuits as it can easily crack or break when the circuit is bent or stretched. Conductive ink is an alternative solution for flexible circuits. Conductive inks are typically made of metallic nanoparticles dispersed in a solvent and can be printed onto a flexible substrate using a variety of printing techniques [2].

The Voltera V-ONE printer is a novel tool that allows the creation of printed circuit boards in-house, providing a cost- effective and efficient solution for small scale prototyping. [3]. The Voltera V-ONE printer uses conductive ink to create printed circuit boards on different substrates. The printer allows for the creation of complex circuits with a high degree of accuracy and precision. It has been used in various applications, including robotics, aerospace, and consumer electronics [4].

Our study aimed to demonstrate the feasibility of using the Voltera V-ONE printer for the fabrication of functional flexible circuits. The circuit was then tested for its functionality, and the results were analyzed to get to know how it could be implemented in the biomedical engineering field.

State of the Art

To prepare for the creation of the flexible research, a literary review was done and consisted of 25 articles related to the different types of methods used for the manufacture of circuits, sensors, and the implementation of the internet of things (IoT). These topics are essential to understand how to create flexible circuits and their possible application in healthcare. Articles were chosen based on their relevance, number of citations and recent publication date.

The compilation of articles was carried out in the IEEE Xplore, IOP and MDPI libraries. The library in which the largest number of documents related to circuit fabrication, sensor integration and implementation of IoT was found in the IEEE Xplore library.

The articles that were published within the last 6 years were the ones considered for the review. Fig.1 shows the countries of origin for the articles. The country from which more number were found was India with 24%, this is due to its large population and the need for innovation to become a developed country. The countries where we found one or 2 articles, which are quite diverse and correspond to 60% of the articles found. The wide variety of origins reflects the interest around the world in the topic.

Table I shows a summary of the topics of interest. Sensor research articles indicate that ultrasonic sensors are the most widely used technology for obstacle detection systems. In terms of circuit fabrication, traditional circuit printing is still the most widely used method, but there is growing interest in additive printing in various materials for circuit fabrication. Additive printing involves building up layers of material to create a circuit, which offers greater flexibility in design and material selection.

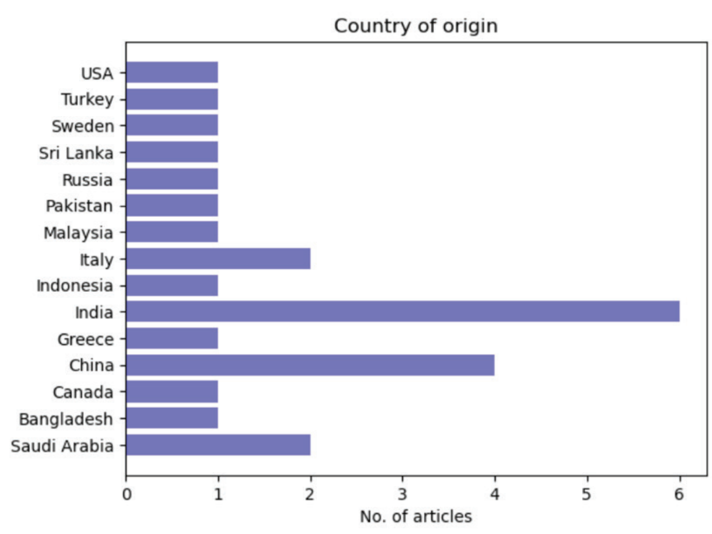

Fig 1. Country of origin of articles.

Table 1. Comparison of Topics of Interest

Topic	Summary
Sensors [5]–[20].	Most articles on obstacle detection systems use ultrasonic sensors as the main technology, closely followed by infrared sensors. Video analysis is presented as a less popular option.
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Internet of Things [11], [12] [27], [28]	IoT implementation has been mainly for data monitoring purposes followed by remote device control, and lastly for communication
Wearable design [29], [21], [5], [6], [7], [9], [10], [11], [12]	Some examples of wearbles are mostly different types of tools, a wearable pair of shoes with integrated sensors and IoT implementation using Bluetooth, a harness carrying the circuit on the chest and lastly a bracelet with movement detection and audio feedback.

Methodology

For this project the incremental methodology was used to create a prototype that could be implemented in a real environment. The incremental methodology, as seen in Fig.2, is based on creating a complete product at each stage of the project and improve the product within each cycle. The analysis takes in consideration what has been learned from previous increments. The design is based the literature review done previously. The code section integrates what is designed to make a complete and functional product for the research. Before creating a deliverable product, testing is done to understand where the objective was met, where it failed and, where it can improve [30].

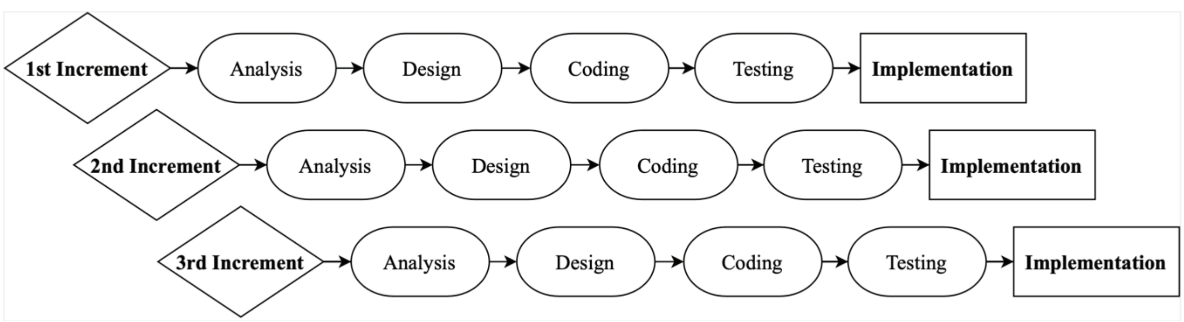

Figura 2. Incremental Methodology Diagram.

Results

In the first increment, the design of a functional circuit was pursued to recreate it in a flexible substrate. Based on the literature review, a prototype of an object detection system was designed, with the purpose of indicating the location of an obstacle in front of a person. The circuit design was done in Proteus. The circuit consists of a PIC18F45K22 micro- controller, two sensors (2 ultrasonic range finder). Two vibration motors controlled using a MOSFET transistor modulated by a PWM signal.

The left motor indicates that the object is on the left side of the person, the same for the right side. The intensity of the vibration indicates the proximity of the object to the sensor. A Bluetooth module for the use of IoT implementation. The coding for the system was done in the development tool for micro-controllers MikroC. The flow diagram of the code can be seen in Fig.3. The system was tested resulting in sensors operating correctly and a fast response from the motors.

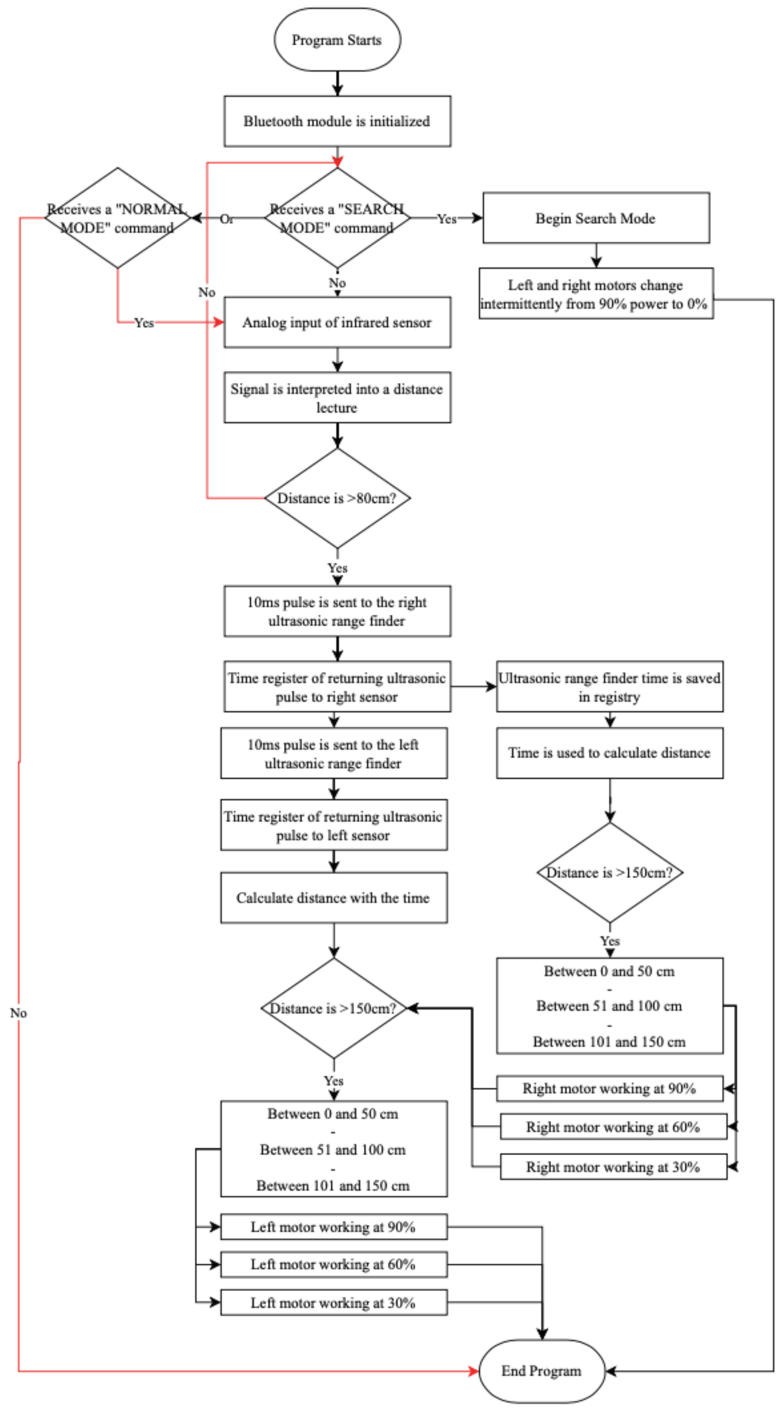

Figura 3. First Increment Code Diagram.

For the second increment, the Voltera V-ONE circuit printer was used. Proteus was used for the design, and board design was also elaborated for the routing of the circuit tracks. Several prints were made to test 3 different soldering methods.

Re-flow soldering using tin paste and a heat gun with air flow regulation and temperature control was successful. The result was a rigid board with the ability to remove and replace important components such as power supply, motors, sensors, and micro-controller. There was an issue with the brittleness of the solder joints. Movement and vibration from the motor was enough to break these solder joints.

On this increment, the circuit was divided into 4 modules due to the difficulty in soldering previously.

Circuits 1 and 2 are for motor control which is designed to have few connections. The tracks and soldering points are large and robust to avoid the fragility of previous circuits as this circuit will be directly exposed to vibrations from the vibration motors. Circuit 3 has the voltage regulation and power distribution.

Circuit 4 has the brain of the operation, the micro-controller PIC18F45K22 and the circuit of its oscillator crystal to have a time control to keep track of the time required for the operation of the system. The Bluetooth module is also found in this circuit.

The test for increment 3 consisted of the fabrication of a flexible circuit. It was necessary to change the substrate on which the conductive ink would be printed. The materials that were chosen for this purpose were polypropylene, which was found in the form of lamination sheets for the plastification of documents and PETG (Polyethylene Terephthalate Glycol) sheets, these materials are resistant to temperatures of approximately 80 °C.

Within the printing process one of the necessary steps to have a printed circuit is to heat the circuit for 50 minutes at 160 °C to adhere the ink to the substrate. In the case of polypropylene during the curing process the deformation due to the high temperature is minimal in comparison PETG.

For soldering we implemented the same method used with the circuit in rigid substrate. The problem in this case is the unevenly application of heat and deformation of the sheets of both polypropylene and PETG. A soldering iron with temperature regulation was needed, due to temperature exceeds 250 °C and the ink begins to lose adhesion. The welding was carried out by hand, to make quick welds and avoid deformation. The soldered circuit can be seen in Fig.4.

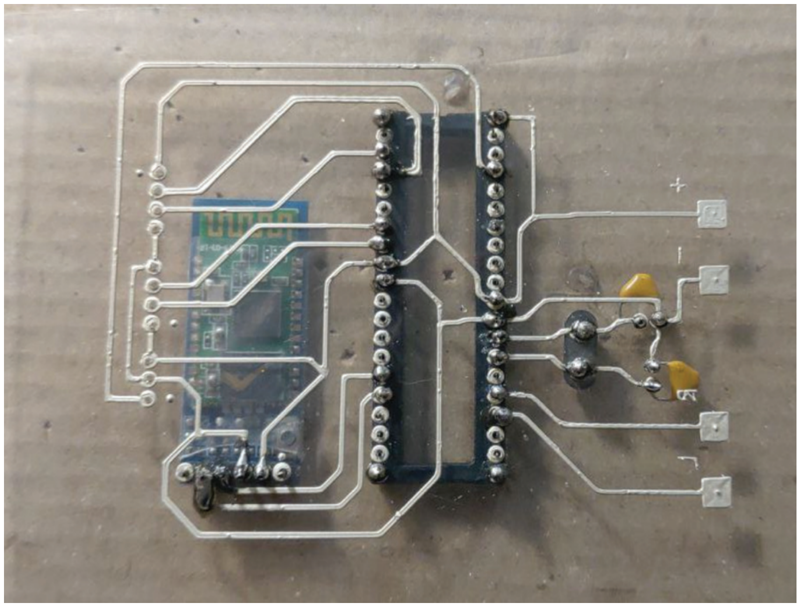

Fig 4. Soldered flexible board.

The welding is composed of three layers: two flexible and one rigid. These being the polypropylene sheet, followed by the conductive ink and finally there is the tin layer that makes up the weld. When the polypropylene sheet is flexed, a force is created that separates the ink from the solder. To prevent this, a resin coating with polyester finish was applied. At last, the fully flexible circuit can be seen in Fig.5. One of the advantages of this resin is that by completely covering the circuit it protects it from damage caused by fluids. Finally, operational tests were done to the final circuit and all components worked according to the coding.

Figura 5. Resin covered board.

Conclusions

A fully operational flexible circuit was created using the Voltera V-ONE to print and cure conductive ink into a polypropylene sheet. Several problems appeared along the process but solved using the incremental methodology. This type of circuits could be beneficial for applications in healthcare, due to its ability to adapt to the patient's body o garments, making them more comfortable to wear. This could improve the functionality of wearable devices.

Another key benefit of our prototype is the ability to repel humidity thanks to the resin coat. This characteristic is important for patients, who are our final users, because exposure to water and sweat won't generate a problem. In the case of our object detection system, its use won't be limited to only indoors. The patient could wear the prototype even on a rainy day and it wouldn't be damaged.

As mentioned before, the implementation. of IoT in health- care through wearables can help monitor and alert patients about their physiological signals and surroundings using several sensors. The prototype we developed could be the first step to the development of more flexible wearables devices in the industry to monitor patients remotely and help the impaired to perform their daily activities.

Acknowledgement

This work was supported by the Research Fund of Universidad Tecnológica Centroamericana (UNITEC), Honduras.

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Design and Development of Flexible Board and their Application to Biomedical Engineering

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Introduction

Wearable devices in the healthcare industry require to be easy to use, comfortable to handle, and reliable in their operation. This article presents a study on the design and manufacture of flexible circuits and their applications in the field of biomedical engineering. The methodology used in this study is the incremental methodology, which implies a step-by- step approach of the design and fabrication process. The study focuses on the fabrication of a flexible circuit using conductive ink and a flexible substrate. The results showed that the Voltera V-ONE printer can be used to create these circuits with a high accuracy and precision. Various substrates were used for the testing process due to their different characteristic. The final circuit was tested and found to be functional for applications in biomedical engineering.

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Materials and Methods

For this project the incremental methodology was used to create a prototype that could be implemented in a real environment. The analysis takes in consideration what has been learned from previous increments.

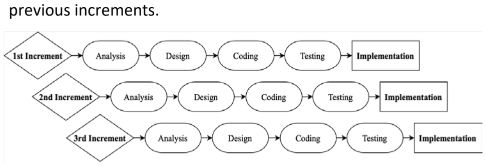

Fig 1. Incremental method.

The design is based the literature review done previously. The code section integrates what is designed to make a complete and functional product for the research. Before creating a deliverable product, testing is done to understand where the objective was met, where it failed and, where it can improve.

Results and Discussion

In the first increment, the design of a functional circuit was pursued to recreate it in a flexible substrate. The circuit design was done in Proteus. The circuit consists of a PIC18F45K22 micro- controller, two sensors (2 ultrasonic range finder). Two vibration motors controlled using a MOSFET transistor modulated by a PWM signal.
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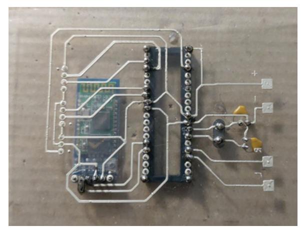

Fig 2. Soldered flexible board.

The test for increment 3 consisted of the fabrication of a flexible circuit. It was necessary to change the substrate on which the conductive ink would be printed. The materials that were chosen for this purpose were polypropylene, which was found in the form of lamination sheets for the plastification of documents and PETG (Polyethylene Terephthalate Glycol) sheets, these materials are resistant to temperatures of approximately 80 °C.

Fig 3. Soldered flexible board with resin protection.

Conclusions / Next Steps

A fully operational flexible circuit was created using the Voltera V-ONE to print and cure conductive ink into a polypropylene sheet. Several problems appeared along the process, but solved using the incremental methodology. This type of circuits could be beneficial for applications in healthcare, due to its ability to adapt to the patient's body o garments, making them more comfortable to wear. This could improve the functionality of wearable devices.
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Biogeochemistry analysis to assess water quality and the aquatic ecosystem in rivers using drones and sensors

Análisis biogeoquímico para evaluar la calidad del agua y ecosistema acuático en ríos mediante sensores

Daniel Barrantes-Esquivel[1]

Barrantes-Esquivel, D. Biogeochemistry analysis to assess water quality and the aquatic ecosystem in rivers using drones and sensors. *Tecnología en Marcha*. Vol. 37, special issue. June, 2024. IEEE Latin American Electron Devices Conference (LAEDC). Pág. 85-91.

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Keywords

Biogeochemistry; biodiversity; human activities effects; water quality; water pollution.

Abstract

River pollution is a common problem in many countries, and its analysis from a biogeochemical perspective allows us to understand the full impact on aquatic ecosystems. By examining nutrient cycles, chemical processes in living organisms, and interactions between biological and chemical factors, we can gain a deeper understanding of river pollution. Through the use of technology such as drones and specialized sensors, we can collect essential data to assess key biogeochemical parameters, such as nutrient concentration, oxygen levels, and the presence of contaminants. These analyses provide a comprehensive view of river health, enabling us to take appropriate measures for their protection and restoration, with the aim of preserving the overall health of aquatic ecosystems. The availability of nutrients in the water is crucial for the survival of aquatic organisms. These organisms rely on a variety of essential nutrients to maintain their health and balance in the ecosystem. Biogeochemistry allows us to understand how nutrient cycles and chemical processes in the water influence the availability of these vital elements. When certain nutrients are lacking or present in low concentrations, we can predict the impact on the ecosystem's health based on the organisms or living beings that depend on those specific nutrients to survive. By analyzing biogeochemical processes, we can gain a more comprehensive understanding of how the health of the aquatic ecosystem is related to nutrient availability. This approach helps us comprehend how changes in nutrient cycles and chemical interactions affect the composition and dynamics of aquatic communities. Additionally, it enables us to take appropriate measures to maintain a healthy balance in the ecosystem and ensure the survival of aquatic beings that depend on these vital nutrients.

Palabras clave

Biogeoquímica; biodiversidad; efectos de las actividades humanas; calidad del agua; contaminación del agua.

Resumen

La contaminación de los ríos es un problema común en muchos países y su análisis desde una perspectiva biogeoquímica nos permite comprender el impacto completo en los ecosistemas acuáticos. Al examinar los ciclos de nutrientes, los procesos químicos en los organismos vivos y las interacciones entre factores biológicos y químicos, podemos obtener una comprensión más profunda de la contaminación de los ríos. Mediante el uso de tecnología como drones y sensores especializados, podemos recopilar datos esenciales para evaluar parámetros biogeoquímicos clave, como la concentración de nutrientes, los niveles de oxígeno y la presencia de contaminantes. Estos análisis nos proporcionan una visión integral del estado de los ríos, permitiéndonos tomar medidas adecuadas para su protección y restauración, con el objetivo de preservar la salud de los ecosistemas acuáticos en su conjunto. La disponibilidad de nutrientes en el agua es crucial para la supervivencia de los seres acuáticos. Estos organismos dependen de una variedad de nutrientes esenciales para mantener su salud y equilibrio en el ecosistema. La biogeoquímica nos permite comprender cómo los ciclos de nutrientes y los procesos químicos en el agua influyen en la disponibilidad de estos elementos vitales. Cuando falta o hay una baja concentración de ciertos nutrientes, podemos predecir el impacto en la salud del ecosistema basándonos en los organismos o seres vivos que dependen de esos nutrientes específicos para sobrevivir. Al analizar los procesos biogeoquímicos, podemos

obtener una visión más completa de cómo la salud del ecosistema acuático está relacionada con la disponibilidad de nutrientes. Este enfoque nos ayuda a comprender cómo los cambios en los ciclos de nutrientes y las interacciones químicas afectan la composición y la dinámica de las comunidades acuáticas. Asimismo, nos permite tomar medidas adecuadas para mantener un equilibrio saludable en el ecosistema y garantizar la supervivencia de los seres acuáticos que dependen de estos nutrientes vitales.

Introduction

Drones are currently a very useful tool for monitoring different scenarios and collecting data for subsequent analysis. Therefore, this tool will be one of the foundations of this research with a focus on biogeochemistry. One of the main problems in many regions is the high pollution and poor water quality in numerous rivers. This situation affects many countries in Latin America and other regions, largely resulting from human activity and a lack of awareness about natural resources, as well as other environmental factors present in some areas.

The objective of this research is to study rivers and collect data through sensors to determine the level of pollution and water quality of a particular river from a biogeochemical perspective. In this regard, the aim is not only to analyze pollution itself but also to understand how the biogeochemistry of the river is affected by different processes and how this influences the health of the aquatic ecosystem and its interaction with humans. By focusing on biogeochemistry, we will be exploring aspects such as:

- Water quality
- How this pollution affects the aquatic food chain
- Diversity of species
- Impacts on human health
- Regional or global effects of rivers since they are interconnected with oceans

Figure 1. The most polluted rivers in the world.

This research focuses on evaluating five key aspects related to water quality and the health of the aquatic ecosystem. Through the analysis of specific nutrients and proteins collected by sensors, we can evaluate each aspect. The first aspect we analyze is water quality, which serves as the basis for the analysis of the other four.

The difference between analyzing river pollution in a general way and focusing on biogeochemistry lies in the fact that, by focusing on biogeochemistry, we take into account not only the presence of pollutants in the water, but also how these pollutants affect the biogeochemical processes in the river's aquatic ecosystem, which results in a more in-depth analysis of what we want to evaluate, given the information that can be collected by focusing on biogeochemistry.

When analyzing river pollution in a general manner, the levels of different pollutants present in the water, such as heavy metals, toxic chemicals, or excessive nutrients, can be measured. However, when analyzing pollution from a biogeochemical perspective, consideration is given to how these contaminants affect key biogeochemical processes occurring in the river's ecosystem. These processes include photosynthesis, respiration, decomposition of organic matter, and nutrient cycling. By focusing on biogeochemistry, it is also possible to assess how pollution impacts the aquatic organisms that rely on these processes and how it can alter water quality and the ecological balance of the river. This approach provides us with a more comprehensive understanding of the effects of pollution on the biogeochemical functioning of the river and its impact on the health of the aquatic ecosystem.

Components

To carry out this project, the main approach will be to utilize a drone as the primary tool for data extraction in river environments. Emphasis will be placed on the application of biogeochemistry to gather valuable information about the composition and chemical processes in rivers.

There are many drones that can be used to perform this task. For example, one option could be a drone like this: DJI M30T.

Figure. 2. DJI M30T

The drone will be equipped with specialized sensors that allow for the detection and measurement of relevant parameters for the biogeochemical study of water bodies. Some of the sensors that could be incorporated include:

Water temperature sensor

To obtain precise measurements of the temperature at different points in the river. This is crucial as temperature directly affects biogeochemical processes such as the rate of organic matter decomposition and nutrient availability.

Dissolved oxygen sensor

To assess the concentration of oxygen dissolved in the water. This provides information about water quality and the health of aquatic ecosystems, as certain species rely on appropriate oxygen levels for survival.

pH sensor

To measure the acidity or alkalinity level of water. pH influences nutrient exchange processes and the availability of metals and other chemical compounds in the aquatic environment.

Electrical conductivity sensor

To determine the amount of salts and minerals dissolved in water. Electrical conductivity is a useful indicator for evaluating salinity and pollution in bodies of water.

Chlorophyll-a sensor

To estimate the amount of chlorophyll present in water, which indicates the presence of algae and primary productivity in the aquatic ecosystem.

In addition to the sensors mentioned earlier, heavy metal sensors could also be added to the drone. These sensors would allow for the detection and quantification of the presence of toxic elements such as mercury, lead, cadmium, arsenic, among others, in river water.

The presence of heavy metals in bodies of water can result from industrial, agricultural, or mining activities, and can pose a significant risk to human health and aquatic ecosystems. Therefore, it is crucial to monitor and assess the concentration of these contaminants.

Similarly, new technologies can revolutionize related areas. For example, scientists from the School of Chemistry at the Costa Rica Institute of Technology (TEC) have patented a chemical analysis device with a unique design in the world. This innovative device aims to expand the capabilities of assessing water quality, both in terms of human health and ecosystem health. MSc. Laura Hernández Alpízar and MGA Ricardo Coy Herrera led this project.

Indeed, integrating such new technologies into a drone can help reduce costs and minimize the weight of the equipment.

By reducing the weight of the drone, it achieves greater efficiency in its performance and optimizes its flight capacity. This translates into increased autonomy and improved stability during data collection operations.

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Biogeochemistry analysis to assess water quality and the aquatic ecosystem in rivers using drones and sensors

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Introduction

The preservation of aquatic resources has become a global concern due to the increasing impact of pollution on river ecosystems.

The biogeochemical analysis of pollution in rivers encompasses a wide range of factors, such as

- Presence of nutrients
- Heavy metals
- Toxic chemicals
- Organic contaminants

This study allows us not only to quantify pollutant levels but also to understand how they affect the following:

- Aquatic ecosystems
- Natural biogeochemical cycles

Materials and Methods

The study is based on the use of drones equipped with specialized cameras and sensors, complemented by other equipment.

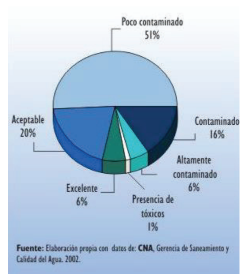
Examples of sensors

- Electric conductivity sensors
- pH sensors
- Temperature sensors
- Contaminant sensors such as heavy metal sensors

The analysis begins with:

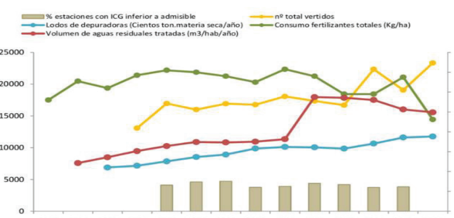
- Flight route planning that covers the target areas of the river.
- During the flight, high-resolution aerial images are captured for subsequent analysis.
- Specific data collection is carried out using sensors.
- The collected data is subsequently processed using specialized software that allows for obtaining precise and detailed information.

Environment problem



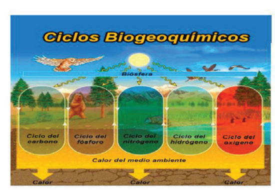
There have been numerous studies conducted in different countries addressing the issues related to rivers, the various contaminants present in them, water quality, and more. For example, one study is the "Distribución de la Calidad de Agua (ICA) en Cuerpos de Agua Superficiales, 2001" conducted by SEMARNAT (Secretary of Environment and Natural Resources) in Mexico.

The ICG (Índice de Calidad General) is a classification system that ranks the 2,415 monitoring points of the water quality control network in Spanish rivers.



Research Objective

- Analyzing river pollution from a biogeochemical perspective and its impact on aquatic ecosystems.
- Studying the dynamics of biogeochemical cycles, such as the transfer and accumulation of nutrients and contaminants.
- Gaining a better understanding of the interactions between chemical and biological processes in aquatic ecosystems.
- Understanding the potential impact on humans or the region it could generate.
- Contributing to scientific knowledge on river pollution.
- Developing strategies for the mitigation and restoration of affected aquatic ecosystems.



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Sistema de riego automatizado para zonas rurales

Automated irrigation system for rural areas

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Palabras clave

Agricultura; optimización; riego; automatización; tecnología; innovación.

Resumen

La agricultura es una actividad económica importante en nuestro país, ya que proporciona empleo a miles de personas y contribuye significativamente al PIB nacional. Según un informe de Jiménez en 2020, la agricultura contribuyó con el 9,1% del PIB en 2019. Además, el sector agropecuario genera alrededor del 11% del empleo en el país, según un artículo del periódico digital "El Guardián". Sin embargo, la agricultura también enfrenta desafíos, especialmente durante la época seca, cuando las plantaciones pueden perderse si no se riegan adecuadamente. Por lo tanto, en este proyecto se propone un sistema de riego automatizado que ayudará a los agricultores a regar sus cultivos de manera más eficiente. Este sistema de riego utilizará aspersores, sensores de temperatura y humedad, y un PLC para controlar el riego de forma automática. El objetivo del proyecto es proponer un sistema de riego automatizado con el fin de ayudar a los agricultores que más lo necesitan al mejorar la eficiencia del riego. Si se implementa correctamente, el sistema de riego automatizado puede ayudar a reducir las pérdidas de cultivos durante la temporada seca, aumentando la producción y el rendimiento de los cultivos. Esto, a su vez, puede contribuir a la economía nacional al generar más empleo y aumentar la producción agrícola. En resumen, este proyecto tiene como objetivo mejorar la agricultura en el país y aumentar su contribución al desarrollo económico.

Keywords

Agriculture; optimization; irrigation; automation; technology; innovation.

Abstract

Agriculture is an important economic activity in our country, since it provides employment for thousands of people and contributes significantly to the national GDP. According to a report by Jiménez in 2020, agriculture contributed 9.1% of GDP in 2019. In addition, the agricultural sector generates around 11% of employment in the country, according to an article in the digital newspaper "El Guardian". However, agriculture also faces challenges, especially during the dry season, when plantations can be lost if not adequately irrigated. Therefore, in this Project, an automated irrigation system is proposed to help farmers irrigate their crops more efficiently. This irrigation system will use sprinklers, temperatura, humidity sensors, and a PLC to automatically control irrigation. The Project aims to help farmers who need it most by improving irrigation efficiency. If implemented correctly, the automated irrigation system can help reduce crop losses during the dry season, increasing crop production and yield. This, in turn, can contribute to the national economy by creating more employment and increasing agricultural production. In short, this project aims to improve agriculture in the country and increase its contribution to economic development.

Introducción

Actualmente en muchas zonas del país en donde se practica la agricultura se ven fuertemente afectadas por la época seca (como por ejemplo Guanacaste o lugares en el valle central de Costa Rica como Ujarrás), la cual se da entre los meses de diciembre a mayo. Muchos agricultores se ven afectados por esta época y como solución a ello deben implementar sistemas de riego como lo son los aspersores de agua (Figura 1) o bien personas que de manera manual se movilizan a lo largo de los cultivos con mangueras regando las plantas con agua de una en una (Figura 2). Ambos sistemas tienen muchas desventajas, empezando por los aspersores estos deben de activarse y desactivarse de manera manual que por lo general es mediante válvulas, esto tiene varios problemas, para que se entienda mejor se va a explicar con un caso real, en la zona de Ujarrás de Paraíso de la provincia de Cartago es una zona en la que la agricultura es la principal actividad económica y cuyo principal cultivo es el chayote hay muchos agricultores tanto pequeños como medianos, así como grandes empresas dedicadas a cultivar y exportar el chayote, todos estos agricultores comparten un problema en común, la época seca, para combatir este problema se aprovechan las aguas de los ríos o bien se hacen excavaciones para tener acceso al preciado líquido. Sin duda alguna saber aprovechar este líquido es de vital importancia por lo que se requiere disminuir el desperdicio, utilizando sistemas de aspersores es una buena solución, sin embargo, el hecho de que tengan que ser activados y desactivados manualmente puede resultar en gastos mayores, tanto de agua como de dinero en personal. Debido a que en algunos casos las fincas son grandes el riego debe hacerse por zonas y por determinado tiempo, como se presenta en la figura 3 la finca se divide en zonas ya que la cantidad de agua no da abasto para poder ser regada toda la finca

simultáneamente y se debe tener a uno o más trabajadores pendientes todo el día para cerrar o abrir las válvulas necesarias. Y por otra parte se tiene el sistema de riego manual, el cual consiste en una o más personas regando las plantas de una en una, lo cual no cabe duda de que es lento e ineficiente debido a los desperdicios de agua que se originan. Se les consultó a tres pequeños agricultores y a un mediano sobre cuántas eran las pérdidas estimadas en la época seca, ellos nos comentaron que alrededor del 80% de los productos se pierden si no se riegan las plantas con agua en comparación a lo que se produce durante la época lluviosa, en cambio cuando ellos hacen uso de aspersores tienen pérdidas aproximadas al 15% pero además de esto se le debe sumar los costos por inversión en sistema de riego y el personal adicional que se requiera para esto. Por lo que se puede ver hay un problema al que se le puede aportar una solución.

Figura 1. Sistema de riego por aspersión.

Figura 2. Riego de plantas manual.

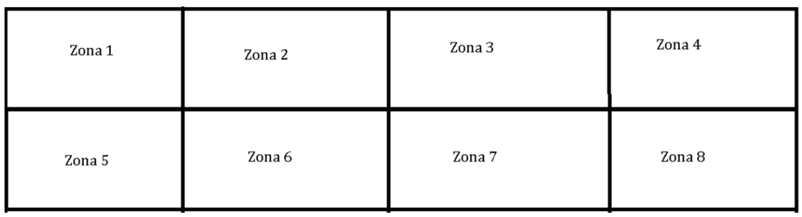

Figura 3. Distribución de una finca para el riego por aspersores.

Los objetivos de este proyecto se detallan a continuación:

- Proponer un sistema de riego por aspersores automatizado para las empresas agricultoras que deseen optimizar y mejorar sus procesos de riego.
- Demostrar que la realización de este proyecto es rentable y que mediante él se pueden hacer ahorros no solo de dinero sino también de uno de nuestros recursos naturales más preciados que es el agua.
- Simular el sistema de riego mediante el software de computadora llamado CadeSimu, con esta simulación se podrá corroborar que el proyecto funciona.

Definición del problema a resolver

El problema como ya se ha mencionado anteriormente consiste en mitigar lo más posible los efectos ocasionados por la época seca de nuestro país en la agricultura. Los métodos que se tienen actualmente para combatir este problema son básicamente dos, el primero de ellos es el sistema de aspersores y el segundo el sistema de riego manual. El problema de estos métodos es que son ineficientes, por ejemplo, se le consultó a la empresa B Y C Exportadores (empresa real ubicada en Ujarrás) sobre sus métodos de riego y ellos nos comentan que utilizan los dos métodos mencionados anteriormente, nos dicen que los principales problemas de estos es depender demasiado del personal, ya que para el sistema de riego por aspersores deben tener a dos personas por turno encargadas de abrir y cerrar las válvulas, algunos de estos aspersores trabajan inclusive de noche por lo que se debe tener personal en la noche lo que implica más gastos. Mientras que para el sistema de riego manual se tienen lo que la empresa consultada llama "cuadrillas" el cual consiste de un grupo de al menos cuatro personas por finca (no se nos reveló el número de fincas, pero se estima que pueden ser alrededor de diez) que van regando las plantas de una en una con grandes mangueras, lo cual genera aún más gastos para la empresa. En la tabla 1 se pueden apreciar los gastos aproximados (ya que la empresa no quiso dar datos exactos) en salarios cuando se utiliza el sistema de riego por automatización, según nos dijo la persona de la empresa con la que hablamos por día hay seis encargados del sistema de riego, distribuidos en todas las fincas, se nos dijo también que los días de trabajo por mes son quince debido a que no se riegan las plantaciones todos los días, sino que cada día por medio. Además, en la tabla 2 se pueden observar los gastos en salarios para cuando el riego se hace de manera manual, cabe aclarar que ambos métodos se usan muchas veces simultáneamente en diferentes fincas, es decir, hay fincas en las que aún no se han instalado los sistemas de riego por aspersión ahí es donde se utiliza la forma de riego manual. Por lo tanto, si se suman los gastos de ambos métodos de riego se tendría un gasto total de ₡28 080 000,00 por época seca. Cabe aclarar que los salarios mencionados a continuación en la columna llamada salario por persona se refiere al salario diario de una persona en colones.

Cuadro 1. Gastos aproximados en salarios de trabajadores encargados del sistema de riego por aspersión en la empresa ByC Exportadores.

Cantidad de trabajadores	Salario por persona	Total por día	Total por mes (15 días)	Total por época seca
6	₡12 000,00	₡72 000,00	₡1 080 000,00	₡6 480 000,00

Cuadro 2. Gastos aproximados en salarios de trabajadores de las cuadrillas para riego manual en la empresa ByC Exportadores.

Cantidad de trabajadores	Salario por persona	Total por día	Total por mes (15 días)	Total por época seca
20	₡12 000,00	₡240 000,00	₡3 600 000,00	₡21 600 000,00

Justificación

La propuesta de este proyecto va dirigido a implementar nuevas tecnologías así como de mejorar las actuales que existen en el campo de la agricultura, en nuestro país no es para nada común ver mucha tecnología en los campos. Este proyecto se debe hacer porque las empresas están gastando dinero de más en sistemas de riego que no son eficientes o al menos pueden mejorarse, se pueden implementar sistemas tecnológicos y tener ahorros muy significativos. A pesar de que la inversión inicial puede ser algo que a la empresa no le guste se puede comprobar que a mediano y largo plazo tiene resultados muy buenos, además de que no requiere mucho personal (con una o dos personas encargadas de monitorear y darle mantenimiento al sistema puede que sea suficiente). Otra razón de peso para realizar este proyecto es el ahorro que se genera y no solamente de capital sino también del agua ya que con este sistema propuesto se evitan desperdicios debido a que este tendrá los tiempos bien establecidos mediante temporizadores, ya que cuando el sistema de riego no está automatizado depende directamente de una persona para que las válvulas se cierren por lo que si una persona se tarda mucho en llegar debido a contratiempos o porque es un personal ineficiente el agua se puede estar desperdiciando y se le estaría regando a las plantaciones más de lo que necesiten. Esto es una razón muy importante para implementar el proyecto ya que si la empresa tiene agua limitada con este sistema se regula muy bien el agua, además de que se ahorra dinero por uso innecesario de agua.

Marco teórico

Para la implementación de este proyecto se requiere conocer sobre la lógica programada, la cual según Oliver (2007) “son circuitos integrados que contienen una gran cantidad de celdas básicas, específicamente compuertas y registros, cuyas interconexiones pueden ser configuradas por el usuario para dar lugar a un diseño determinado”, la ventaja de utilizar este método y no utilizar lógica cableada es que resulta más fácil implementarlo ya que se puede programar de manera s encilla mediante computadora y luego cargarlo al PLC mediante cables de ethernet, además de que ocupa menos espacio y al estar en una finca no es necesario construir algo grande para guardar los contactores, con una construcción sencilla en la que se guarde el PLC de la intemperie es suficiente. Para la elaboración del sistema con lógica programada se requiere de un PLC (controlador lógico programable), sensores de temperatura los cuales como su nombre lo indica cambiarán de estado conforme se le indique a qué temperatura debe hacerlo, sensores de humedad, temporizadores y electroválvulas. Cabe destacar que un PLC puede ser programado en varios lenguajes de programación. Una vez definido los conceptos más importantes se debe proceder a plantear el sistema en uno de los idiomas de programación en este caso el lenguaje escogido es el grafcet (gráfico funcional de control de etapas y transiciones), se elige este por su sencillez para entender su funcionamiento, lo cual facilita su instalación y su mantenimiento. Para la creación de un grafcet primero tenemos que definir las entradas y salidas que tenemos en el sistema, esto lo podemos ver en la siguiente tabla de símbolos.

Cuadro 3. Entradas y salidas.

Entradas	Simbología	Salidas	Simbología
Arranque	A	Luz verde	LV
Pare	P	Timer 0	T0
Timer 0	T0	Electroválvula 1	EV1
Sensor de calor	SC	Timer 1	T1
Timer 2 días	T2	Sensor de humedad	SHum
Timer 1	T1	Timer 2	T2
Electroválvula	SH	Electroválvula 3	EV3
Timer 2	T2	Timer 3	T3
Timer 3	T3	Sensor de humedad 2	SHum2
Sensor de humedad 2	SH2	Timer 4	T4
Timer 4	T4	Electroválvula 3	EV3
Timer 5	T5	Timer 5	T5
Sensor de humedad 3	SH3	Sensor de humedad 3	SHum3
Timer 6	T6	Timer 6	T6
Timer 7	T7	Electroválvula 4	EV4
Sensor de humedad 4	SH4	Timer 7	T7
Timer 8	T8	Timer 8	T8

Como paso siguiente se tiene que hacer el diafragma de etapas y transiciones (Grafcet) que va a representar el funcionamiento del proceso, este va a reflejar todos los pasos que se requieran y la secuencia que se seguirá.

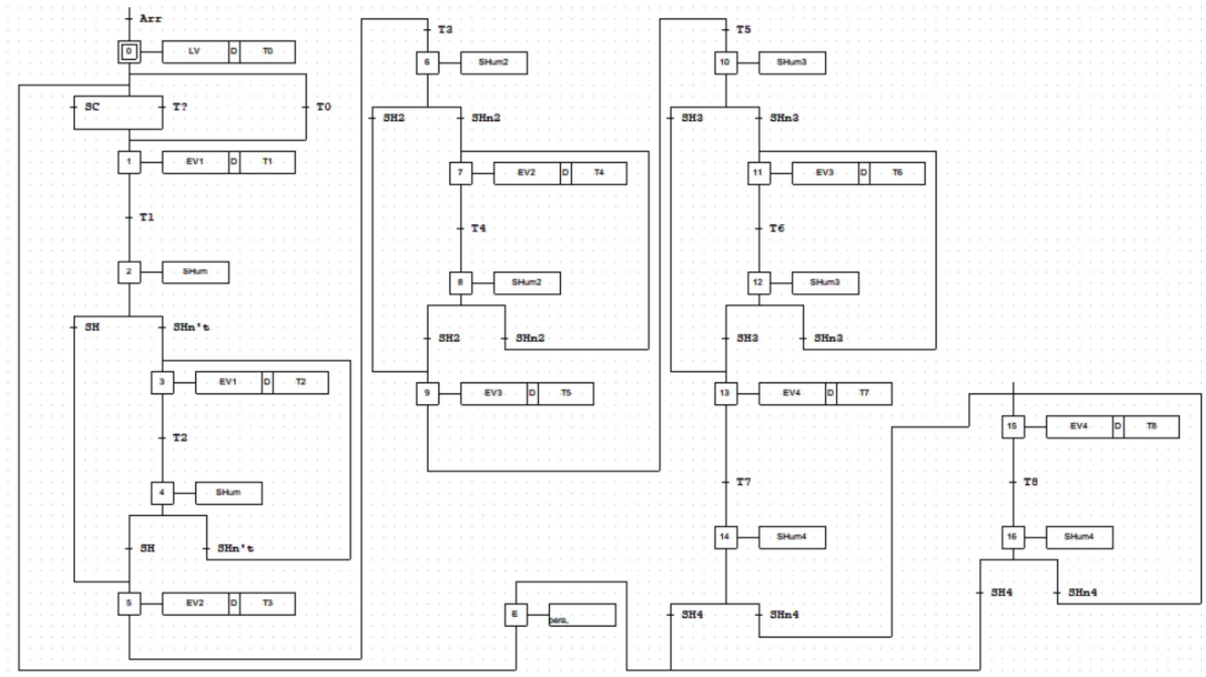

Figura 4. Grafcet del sistema.

Después de todo el contexto técnico se va a enfocar, en el aspecto económico, este es de suma importancia para la empresa, ya que este es el principal eje para decidir si un proyecto es aprobado o no, debido a que si se presenta un sistema que genera más gastos, es casi imposible que se aplique en una empresa. Cabe aclarar que los montos presentados a continuación se muestran en colones.

Cuadro 4. Gastos estimados de realizar el trabajo automatizado.

Automatizado			
Costo	Cantidad	Mensual	Anual
Salarios (Mantenimiento)	1	500000	6000000
Sensor de humedad	4	120000	Inversión Inicial
Electroválvulas	4	160000	Inversión Inicial
PLC	2	1077680	Inversión Inicial
Mangueras	1 km	2000000	Inversión Inicial
Cableado General	1	300000	Inversión Inicial
Aspersores	40	3120000	Inversión Inicial
Instalación	1	2000000	Inversión Inicial
Total		4077680	Por Finca

Resultados y explicación de la solución propuesta

Se tiene una finca utilizada para la plantación de productos agrícolas en la que se desea automatizar un sistema de riego, la finca se divide en cuatro secciones y cada sección posee diez aspersores por los que sale el agua, estos aspersores se interpretan como electroválvulas en el grafcet y en el esquema de contactos. Las electroválvulas se activarán por zonas de manera progresiva, es decir, primero la zona uno, luego la zona dos y así sucesivamente. Cada zona tendrá las electroválvulas abiertas por una hora y al finalizar cada zona mediante sensores de humedad se determinará si la humedad es adecuada o si es insuficiente, en caso de ser insuficiente se vuelven a activar las electroválvulas por media hora más y si es suficiente no se activará más y pasará a la siguiente zona, si todas las zonas están listas el proceso entra a una etapa de espera la cual determinara el siguiente riego el cual será dentro de 2 días, existe la posibilidad de que el sistema se active antes de tiempo en caso de que un sensor de calor se active al alcanzar una temperatura establecida para evitar el reseque de la tierra y el daño a la plantación. El sistema se activa mediante un botón pulsador por un operario, donde hará un riego inmediato. Para la creación del sistema se inicia con la idealización de un sistema grafcet ya que este permite la automatización de un proceso de una manera simple y accesible para todo usuario en este caso dirigido a dueños de fincas y campesinos, el sistema grafcet consta de una serie de etapas de activación donde se riega la zona requerida de una forma temporizada y se comprueba el grado de humedad de la tierra para garantizar un riego exitoso, de ser contrario existe un lazo para un segundo riego el cuál se repetirá hasta que el sensor de humedad garantice el riego deseado.

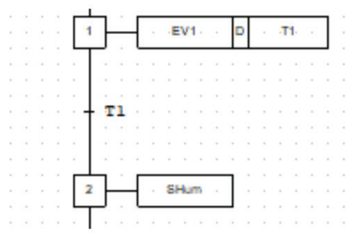

Figura 5. Etapa de riego y sensor de humedad.

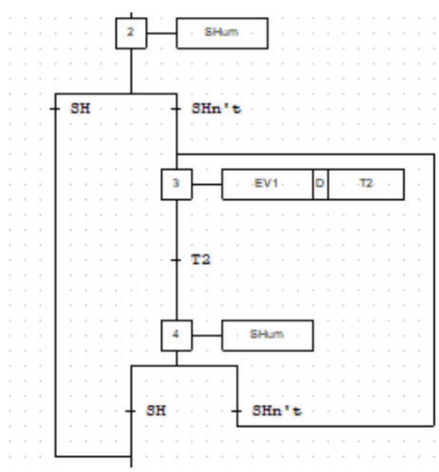

Figura 6. Segunda etapa de riego y lazo cíclico.

Este proceso se repite para las 4 zonas de riego hasta cumplir con todos los parámetros de humedad deseados, una vez finalizado se entra a la etapa de espera donde se esperará la siguiente señal de activación sea el timer de 2 días o el sensor de calor.

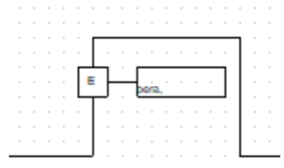

Figura . Etapa de espera (E)

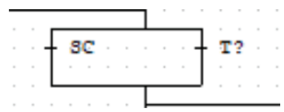

Figura 7. Convergencia en O para la nueva activación.

Conclusiones

1. La propuesta del sistema de riego automatizado se realizó de manera satisfactoria y se le puede presentar a cualquier empresa agrícola que requiera sistema de riego y que posea personal destinado al área de riego o un sistema de riego ineficaz en general.
2. En la sección “Definición del problema a resolver” de este paper se estimó que los gastos actuales de la empresa por año son de ₡28 000 000 (por todas las fincas), mientras que en la tabla 3 se estimó que para el primer año la inversión debe ser de ₡4 100 000 por finca, es decir ₡41 000 000 en total, es un precio elevado debido a que se debe realizar la compra de los equipos necesarios y se debe hacer la instalación, para el segundo y demás años los gastos serán únicamente de salarios y mantenimiento estimado en ₡5 000 000 anual por todas las fincas de la empresa, por lo que si se analiza en un plazo de cinco años los gastos por métodos actuales serían de ₡140 000 000, mientras que si se automatiza el proceso los gastos serán aproximadamente de ₡66 000 000, lo cual a este punto se lograría reducir los gastos de la empresa a la mitad recuperando así la inversión inicial y ahorrando hasta ₡20 000 000 anuales una vez recuperada la inversión inicial.
3. La implementación de un sistema automatizado permitió realizar el trabajo de riego, garantizando un riego adecuado y eficiente, sin necesidad de hacerlo manualmente lo cual requeriría de personal y sería un trabajo bastante complejo y longevo. La disminución de mano de obra humana beneficia al propietario ya que no debe invertir en personal que realice el trabajo y se ahorra tiempo el mismo en caso de tener que hacer este trabajo de forma manual.

Recomendaciones

1. Los propietarios de terrenos de agricultura tienen que empezar a interesarse por la automatización de sus procesos, ya que estos pueden hacer más sencillos y más baratos sus procesos.
2. La automatización no solo se encuentra en procesos tecnológicos de alto costo, con pequeños procesos que puedan realizarse de forma automática mediante soluciones simples se pueden optimizar mucho los recursos.
3. Una continua actualización de los métodos de producción genera una industria que puede llegar a competir de forma más fácil con otras debido a los bajos costos de producción.
4. Es recomendable tratar de implementar sistemas de lógica programada en lugar de lógica cableada por la facilidad de implementación de cambios en el sistema.

5. La agricultura actualmente es un área olvidada en una sociedad moderna, esto debido a la falta de modernización en los procesos. Una reforma en cada uno de los sectores agrícolas puede generar un cambio en cómo se visualiza esta área.

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LATIN AMERICAN ELECTRON DEVICES CONFERENCE

AUTOMATED IRRIGATION SYSTEM FOR RURAL AREAS

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Introduction

Agriculture is a vital economic activity in our country, providing employment and contributing significantly to the GDP. A proposed project aims to improve irrigation efficiency by implementing an automated system using sprinklers, sensors, and a PLC. This system can help reduce crop losses during the dry season, increase production, and create more employment opportunities. The project's goal is to enhance agriculture and its contribution to economic development

Materials and Methods

The project requires understanding logic programming and its advantages over hardwired logic. Using programming allows for easier implementation and can be done on a computer before uploading it to the PLC. In terms of construction, a simple shelter for the PLC is sufficient in the agricultural area. The chosen programming language for this project is Grafcet, known for its simplicity and ease of understanding, installation, and maintenance. Inputs and outputs of the system need to be defined for the Grafcet design.

Results and Discussion

The most effective approach for this project is to use solenoid valves that are progressively activated by zones. Each zone's solenoid valves will be open for one hour. At the end of each zone, humidity sensors will assess the moisture level. If it's insufficient, the solenoid valves will be activated for an additional half an hour. If it's enough, no further activation is needed, and the system moves to the next zone. Once all zones are completed, the system enters a waiting stage to determine the next irrigation, scheduled within two days. This process continues for all stages of the irrigation system.

Conclusions / Next Steps

The proposal for the automated irrigation system has been successfully implemented and can be presented to agricultural companies in need of an efficient irrigation solution. This automated system eliminates the need for manual intervention, reducing labor costs and complexity. By continuously updating production methods, agricultural companies can compete effectively by benefiting from lower production costs.

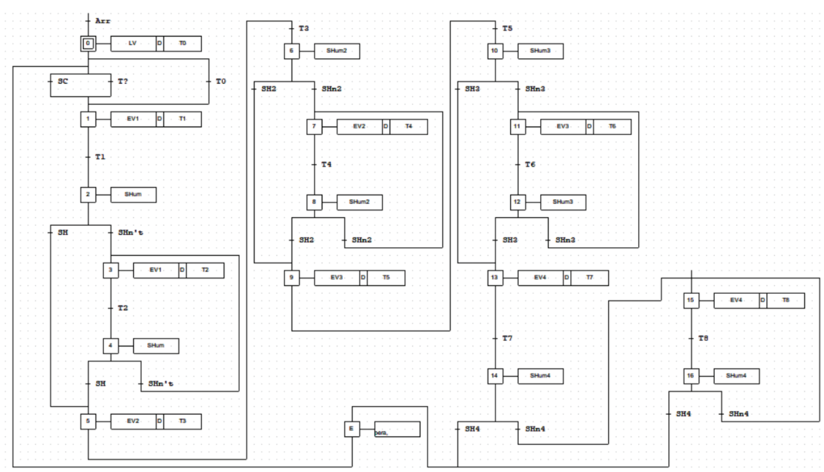

Figure 1. Grafcet of the system (own elaboration)

Development of electric hand prothesis controlled by voice commands and muscle sensors

Desarrollo de prótesis de mano eléctrica controlada por comando de voz y sensores musculares

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Keywords

Electric hand prosthesis; voice commands; muscle sensors; prosthetic technology; limb loss; mobility; sophisticated devices; everyday tasks; amputees; electromyography.

Abstract

Prosthetic technology has advanced significantly in recent years, giving people who have lost limbs the chance to restore mobility and independence. Electric hand prosthesis controlled by voice instructions and muscle sensors represent one interesting area of advancement. This study focuses on the creation of an electric hand prosthesis that can be voice-controlled and muscle-sensing, with a focus on the usage of 3D-printed polylactic acid (PLA) and fiberglass reinforced with pineapple leaves. The goal of this project is to examine the viability and advantages of using these cutting-edge materials in the manufacture of prosthetic components. The project also seeks to investigate the possibilities of implantable myoelectric sensors in conjunction with voice instructions for natural prosthesis control. The inquiry is still in its early stages, with a focus on gathering real-time system values while it is in use. This research aims to advance prosthetic technology by shedding light on these developments, ultimately improving the lives of those who have lost limbs. And developing a prototype of the discoveries.

Palabras clave

Prótesis de mano eléctrica; comandos de voz; sensores musculares; tecnología de prótesis; pérdida de extremidades; movilidad; dispositivos sofisticados; tareas cotidianas; amputados; electromiografía.

Resumen

La tecnología de prótesis ha avanzado significativamente en los últimos años, brindando a las personas que han perdido extremidades la oportunidad de recuperar movilidad e independencia. Las prótesis de mano eléctrica controladas por instrucciones de voz y sensores musculares representan un área interesante de avance. Este estudio se centra en la creación de una prótesis de mano eléctrica que pueda ser controlada por voz y sensores musculares, con un enfoque en el uso de ácido poliláctico (PLA) impreso en 3D y fibra de vidrio reforzada con hojas de piña. El objetivo de este proyecto es examinar la viabilidad y las ventajas de utilizar estos materiales de vanguardia en la fabricación de componentes protésicos. El proyecto también busca investigar las posibilidades de sensores mioeléctricos implantables en conjunto con instrucciones de voz para el control natural de la prótesis. La investigación aún se encuentra en sus primeras etapas, con un enfoque en la recopilación de valores del sistema en tiempo real mientras está en uso. Esta investigación tiene como objetivo avanzar en la tecnología de prótesis al arrojar luz sobre estos desarrollos, mejorando en última instancia la vida de las personas que han perdido extremidades y desarrollando un prototipo de los hallazgos.

Introduction

Prosthetic technology has advanced significantly in recent years thanks to improvements in engineering methods and material science. These developments have opened the door for the creation of very complex devices that provide amputees with greater independence and mobility. Electric hand prosthesis, which may be operated via voice instructions and muscle sensors, represent one particularly innovative and promising field. This state-of-the-art technology has the power to drastically improve the lives of amputees by enabling them to carry out a variety of routine tasks with ease.

These prosthesis' capabilities are further increased using cutting-edge materials throughout the production process. Polylactic acid (PLA) in 3D printing and pineapple leaf reinforced fiberglass are two materials that have drawn attention. For complex and personalized prosthetic components, 3D printing increasingly uses PLA, a biodegradable and biocompatible thermoplastic.

Conversely, pineapple leaf reinforced fiberglass, which is made from used pineapple leaves, demonstrates outstanding strength and lightweight characteristics, making it a desirable option for building strong and effective prosthetic constructions.

In addition to using cutting-edge materials, electronic hand prosthetics use implantable myoelectric sensors that can recognize and decipher the electrical signals produced by the user's remaining muscles. These sensors record and convert muscle movements into precise commands, enabling intuitive control of the prosthesis. A further alternative control mechanism that enables users to communicate with their prostheses verbally is voice command technology. It is possible to create prosthetic devices that closely resemble real hands and offer a seamless user experience by combining implantable myoelectric sensors with voice instructions.

Methodology

The type of this investigation is an experimental investigation, this implies the development of a prototype or project of an electric hand prothesis. The investigation will take place in a specialized robotic and biomechanical laboratory, equipped with all the necessary resources for the development of the electric hand prothesis and testing.

The objective population of this study are people with a hand amputation that can benefit from the electric hand prothesis controlled by muscular sensors and if necessary, voice commands. The size of the sample for this study is going to depend on the availability of the resources and the recruitment of participants. The sample size represents about 20 or 25 individuals with hand amputation that meet the inclusion criteria and are willing to participate in the study.

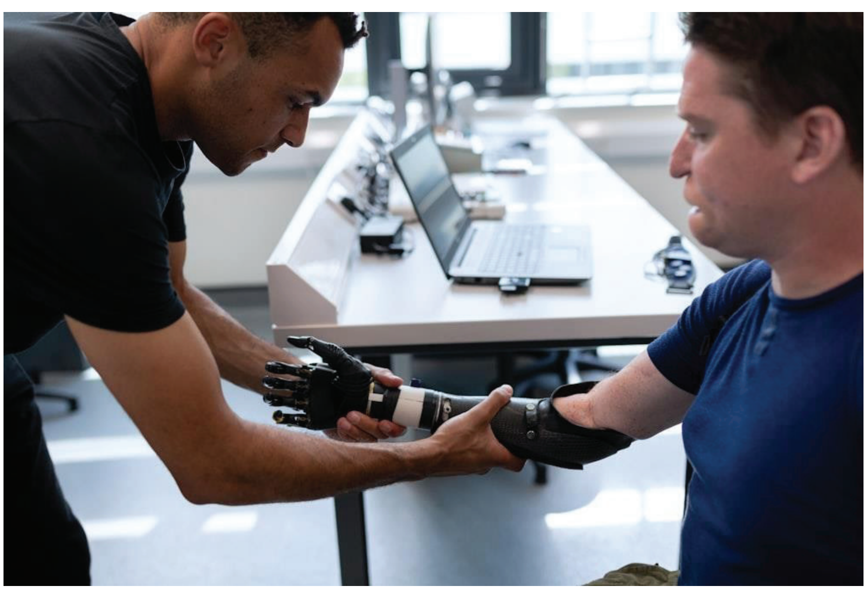

Figure 1. A prosthetic arm being placed for testing.

Control system design

For the design, it is proposed that a similar approach that P.F. Pasquina and collaborators.[1] It is planned to use an implantable myoelectric sensor (IMES) to detect wirelessly transmitting EMG signals to the prosthetic hand. It will also allow more natural control and offer more freedom. There will be processing algorithms to interpret the muscle signals and convert them into commands for the prothesis. Finally, an implementation of an extra feature will be made available that allows by using a interface that will recognize voice commands by using an artificial neural network, and depending on the command, a movement is developed, like the proposal of J.P. Angel and N. Arzola.[6]

The reasoning for combining both methods even though it is planned to keep the voice command as a secondary feature and therefore the amount of commands that it will recognize will be short, is to take advantage of the effectiveness of both methods normally used in prosthetics development, giving a more natural control sensation using IMES and keep the comfort and take advantage of the easy training process of the voice commands.

Material selection

For the prothesis material there are two possible options, the use of an open-source 3D printer upper limb prothesis. According to K. Wendo et all most studies of 3D printing prosthetics, used Polylactic Acid that is a hard-plastic 3D printing material to build their prothesis.[4] The use of this material with a production fee with a range cost of 449 dollars up to 862 dollars and the manufacturing ranging from 20 to 25 dollars.

The other alternative is the use of pineapple leaf reinforced fiber glass proposed by A. Kohli et all.[5] In their investigation they made physical and virtual testing to test if the material and the elastic properties, it was proven that is a good material for a prothesis, and its cost is halve as much as the material used till today Carbon 395.

Figure 2. Prosthetic arm.

Prototype construction

The following steps outline the expected following procedure:

Computer-Aided Design (CAD)

- Using specialist tools, a thorough CAD model of the electric hand prosthesis would be created.
- The design incorporated mechanical parts such finger joints, the structure of the palm, and housing for electrical parts.
- Ergonomics, functionality, and the integration of diverse pieces would all be taken into consideration.

Mechanical component production

- A 3D printer's machine-readable instructions would be created from the CAD model in case of choosing to use a 3D printing material.
- The material in the case of the 3D printer would be as mentioned before would be Polylactic Acid or the prosthetic hand would be manufactured with pineapple leaves reinforced fiber glass.

Integration of Electrical Components

- Motors, sensors, and control circuits were among the electrical parts that were chosen and will be prepared for integration.
- To help with assembly, wiring schematics and connection plans are going to be created.

Circuitry and Control System

- To accommodate the control system, circuit boards will be created and made.
- The vocal commands, the motors, and the signals from the muscle sensors will all be handled by microcontrollers or other programmable logic devices.
- The necessary capabilities, such as user interface and signal processing techniques, would be implemented using software programming.

Methods of evaluating and testing

It is planned to perform evaluations and testing that will be performed once the prosthetic hand is functional. To evaluate the performance and functionality of

the hand prothesis, it is planned to enlist 20 to 25 people with hand amputation. They will receive detailed instructions on the voice commands and muscle sensors to operate the prothesis. To make sure the system is customized to each person's specific traits, calibration tests will be carried out.

Several tests are planned to be conducted to gauge the prosthetic's control abilities. Specific hand motions, such as grasping, realizing, manipulating items of various shapes and sizes, are going to be required of the participants. Precision, quickness and smoothness are going to be examined in the movements. At the end, a questionnaire will be taken by the participants to receive feedback to measure comfort and usability.

Figure 3 Prothesis getting ready for testing.

The information gathered throughout the evaluation and testing phase will then be thoroughly examined. Statistical techniques are planned to be used to find any significant variations in user groups and task performance. The results of this evaluation are expected to provide insightful comments for the prosthetic design and control system's continued improvement.

Results

The inquiry is still in its early stages, and its intended results center on gathering real-time system values while it is in use.

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LAEDC 2023

Development of electric hand prothesis controlled by voice commands and muscle sensors.

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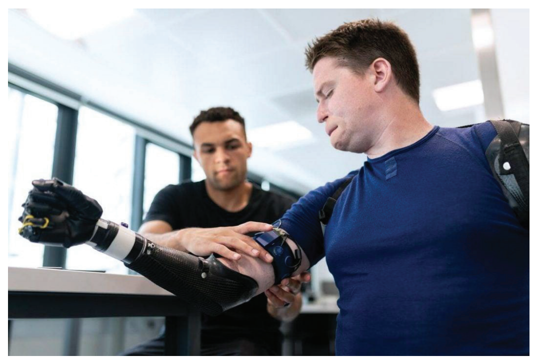
Introduction

Prosthetic technology has advanced greatly due to improvements in engineering and material science. This has led to the development of complex electric hand prostheses that can be controlled through voice instructions and muscle sensors. These cutting-edge prosthetics, made with innovative materials like PLA and pineapple leaf reinforced fiberglass, offer enhanced strength, lightweight characteristics, and personalized components. Additionally, implantable myoelectric sensors and voice command technology enable intuitive control and seamless user experiences. Overall, these advancements in prosthetic technology greatly improve the lives of amputees by providing greater independence and the ability to perform everyday tasks with ease.

Results and Discussion

The inquiry is still in its early stages, and its intended results center on gathering real-time system values while it is in use.



Materials and Methods

Material selection for the prosthetic includes two options: Polylactic Acid (PLA) in 3D printing or pineapple leaf reinforced fiberglass. PLA is commonly used due to its biodegradability and biocompatibility, while pineapple leaf reinforced fiberglass offers cost advantages over traditional materials like Carbon 395.
The construction process involves creating a detailed CAD model of the electric hand prosthesis, incorporating mechanical components and considering ergonomics and functionality. Mechanical parts can be 3D printed using PLA or pineapple leaf reinforced fiberglass.
Electrical components like motors, sensors, and control circuits are integrated, with wiring schematics and connection plans created. Circuit boards are developed to accommodate the control system, which includes handling vocal commands, motor control, and signals from muscle sensors through microcontrollers or programmable logic devices. Software programming is used for user interface and signal processing.
Evaluation and testing involve recruiting amputees to assess performance and functionality. Calibration tests ensure customization, and various tasks are performed to evaluate control abilities. Precision, speed, and smoothness of movements are examined, and user feedback on comfort and usability is collected through questionnaires.
Gathered data is analyzed using statistical techniques to identify variations and provide insights for further improvement of the prosthetic design and control system.

Conclusions / Next Steps

The process of material selection for prosthetics includes options such as the use of Polylactic Acid (PLA) in 3D printing or pineapple leaf reinforced fiberglass. Both materials offer advantages in terms of biodegradability, biocompatibility, and costs. The construction of the prosthesis involves creating a detailed CAD model, integrating mechanical and electrical components, and programming software for system control. Evaluations and tests are planned with amputees to assess the performance and functionality of the prosthesis and use the results to continuously improve the design and control system. Overall, the use of 3D printing technology and advanced materials is driving significant advancements in prosthetic manufacturing, providing greater independence and quality of life for amputated individuals.

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Comparative study of steep switching devices for 1T dynamic memory

Estudio comparativo de dispositivos de conmutación rápida para memoria dinámica 1T

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Keywords

Dynamic memory; capacitorless; tunnel field effect transistor; zero sub-threshold swing; zero impact ionization FET; thin-capacitively coupled thyristor; field effect diode; retention time; power.

Abstract

This work focuses on understanding the operation and performance of various steep switching devices (subthreshold slope sub 60 mV/decade), namely Thin-Capacitively Coupled Thyristor (TCCT), Field Effect Diode (FED), Zero sub-threshold swing and Zero impact ionization FET (Z^2-FET), and Tunnel Field Effect Transistor (TFET) as capacitorless dynamic memory. Functionality as 1T DRAM depends on creation of potential well which must be induced in a p-i-n structure, achieved through precise doping of p-region (TCCT), asymmetric gate alignment (Z^2FET, TFET) and use of two independent gates (FED and twin gate TFET). While TCCT, FED and Z^2FET operate in forward bias, TFET operates in reverse bias. The work shows a comparative analysis of these devices in terms of retention time, sense margin, current ratio, power and speed which are crucial metrics for future DRAMs and also provides a guideline for application specific design.

Palabras clave

Memoria dinámica, sin condensador, transistor de efecto de campo de túnel, oscilación de subumbral cero; FET de ionización de impacto cero, tiristor de acoplamiento capacitivo delgado, diodo de efecto de campo, tiempo de retención, potencia.

Resumen

Este trabajo se centra en entender la operación y el rendimiento de varios dispositivos de conmutación abrupta (pendiente subumbral inferior a 60 mV/década), a saber, el Tiristor de Acoplamiento Capacitivo Delgado (TCCT, por sus siglas en inglés), el Diodo de Efecto de Campo (FED), el FET de Pendiente Subumbral Cero y Cero Ionización de Impacto (Z^2-FET) y el Transistor de Efecto de Túnel (TFET) como memoria dinámica sin condensador. La funcionalidad como 1T DRAM depende de la creación de un pozo de potencial que debe ser inducido en una estructura p-i-n, lo cual se logra mediante el dopaje preciso de la región p (TCCT), la alineación asimétrica de la compuerta (Z^2FET, TFET) y el uso de dos compuertas independientes (FED y TFET de doble compuerta). Mientras que el TCCT, el FED y el Z2FET operan en polarización directa, el TFET opera en polarización inversa. El trabajo muestra un análisis comparativo de estos dispositivos en términos de tiempo de retención, margen de detección, relación de corriente, potencia y velocidad, que son métricas cruciales para las futuras DRAMs, y también proporciona una guía para el diseño específico de aplicaciones.

Introduction

In the conventional DRAM cell (1T-1C), data is stored in the capacitor as electrical charge that leaks over time. Scaling the capacitor is the most critical issue in DRAM as it reduces the charge storage [1-3]. This adversely affects the charge retention, and thus, requires more refresh cycles [1]. Moreover, transistor scaling leads to higher leakage current that results in higher power dissipation and reduction in retention time. Thus, high retention is essential to reduce refresh cycles that consume ~40-50% of energy in off-chip memory hierarchy [1]. Due to difficulty in scaling the capacitor associated with the conventional DRAM cell [1-3], the single transistor (1T) cells [2] have been proposed. Further, the quest for DRAM with high retention and low power necessitates use of steep switching devices as dynamic memory [3-9]. These devices are p-i-n FETs (have different types of dopants for source and drain) and include Thin-Capacitively Coupled Thyristor (TCCT) [3,4], Field Effect Diode (FED) [5], Zero sub-threshold swing and Zero impact ionization FET (Z^2-FET) [6,7], and Tunnel Field Effect Transistor (TFET) [8,9].

Device Operation

TCCT, FED and Z^2-FET (Figs. 1(a)-(c)) exhibits a very steep transition from off-to-on state, operate in forward bias and utilize the positive feedback mechanism for conduction while TFET (Fig. 1(d)) operates in reverse bias and utilize band-to-band tunneling mechanism for conduction. These devices form a *p-n-p-n* structure with an electron (V_n) and hole (V_p) injection barriers (Fig. 1(e)). When electrons are injected into the channel, a few of the holes accumulated in the barrier reduce the barrier height for electrons and so does the electron accumulation for conduction due to holes [5,6]. The charge reposition increases the conduction that further reduces the barrier heights, and thus, a feedback mechanism is triggered.

Device as 1T Dynamic Memory

An essential requirement for all types of dynamic memories is the storage area for charge carriers. In *n*MOSFETs, *p*-type body implicitly behaves as the storage region (Fig. 2 (a)) [4], however for the devices with a p^+-i-n^+ structure, the creation of potential well is critical as electrostatic potential well is not implicitly formed, as shown in Fig. 2(b). Therefore, the architecture is modified to be used as capacitorless DRAM.

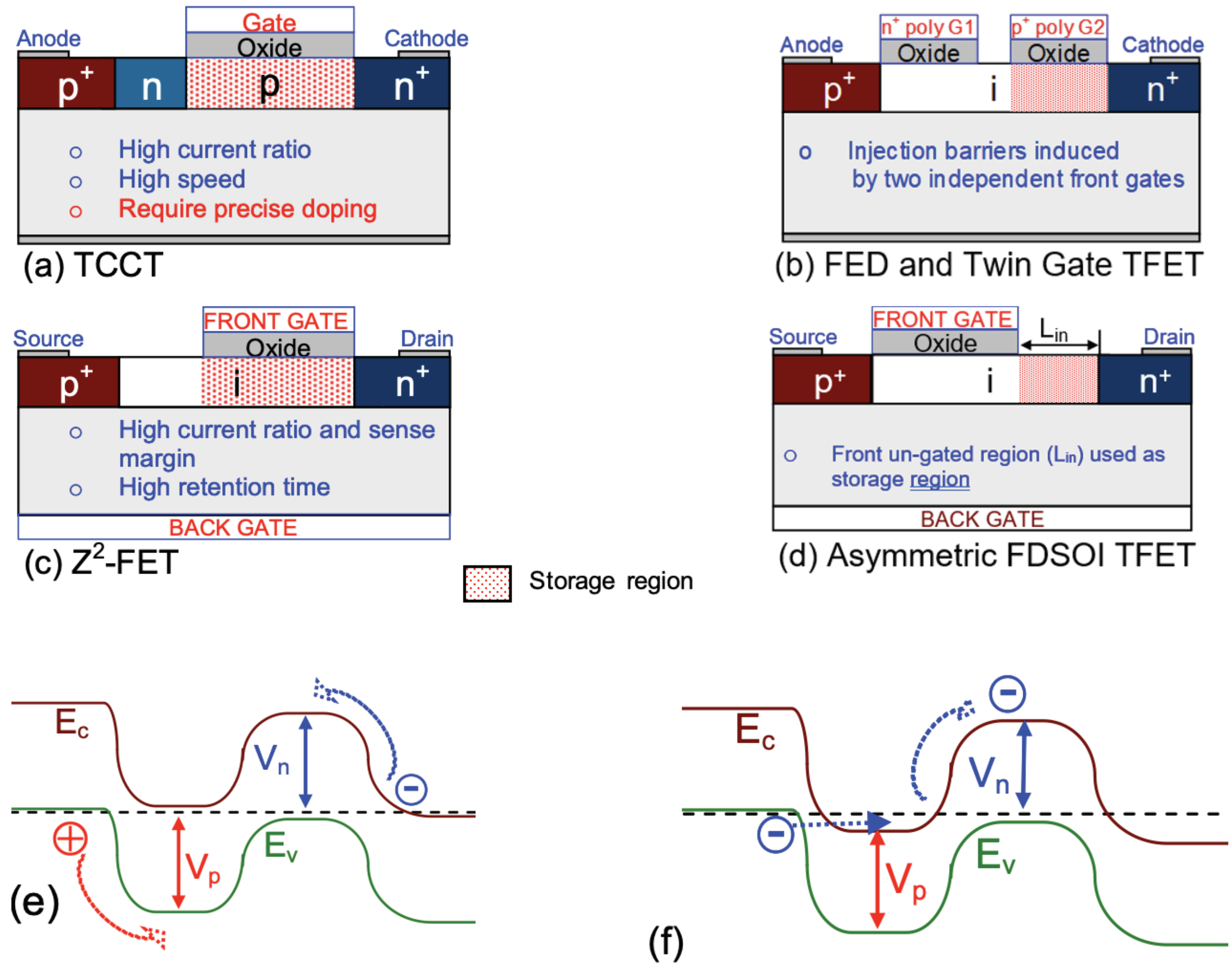

Figure 1. Schematic diagram of (a) TCCT, (b) FED and Twin gate TFET, (c) Z²-FET, and (d) asymmetric TFET along with their storage region, represented by shaded region. (e) Operating mechanism for TCCT, FED, Z²-FET, and (f) for TFET demonstrated through energy band diagrams. V_n and V_p are the electron and hole injection barriers, respectively.

In thyristor-based feedback action [3], the injection barriers are formed through precise doping of *p*-type and *n*-type regions in the channel (Fig. 1(a)). This triggers a doping dependent bipolar action. The device utilizes the *p*-type doped region in the channel for charge storage. FED [5] utilizes two independent front gates with different gate workfunction (n^+ poly ~ 4.25 eV and p^+ poly ~ 5.2 eV) to create different injection barriers (Fig. 1(b)). Similar structure is used as twin gate TFET [9] with region under p^+ poly gate as storage region. Z²-FET (Fig. 1(c)) exploits the region under front gate [7], near n^+ doped drain region for charge storage with back gate biased positively and front gate negatively to create a *p-n-p-n* structure. A similar asymmetric Double Gate TFET in Fig. 1(d) is utilized as DRAM [8]. Unlike Z²-FET, TFET operates in reverse bias in the read operation and utilizes the underlap region for charge storage.

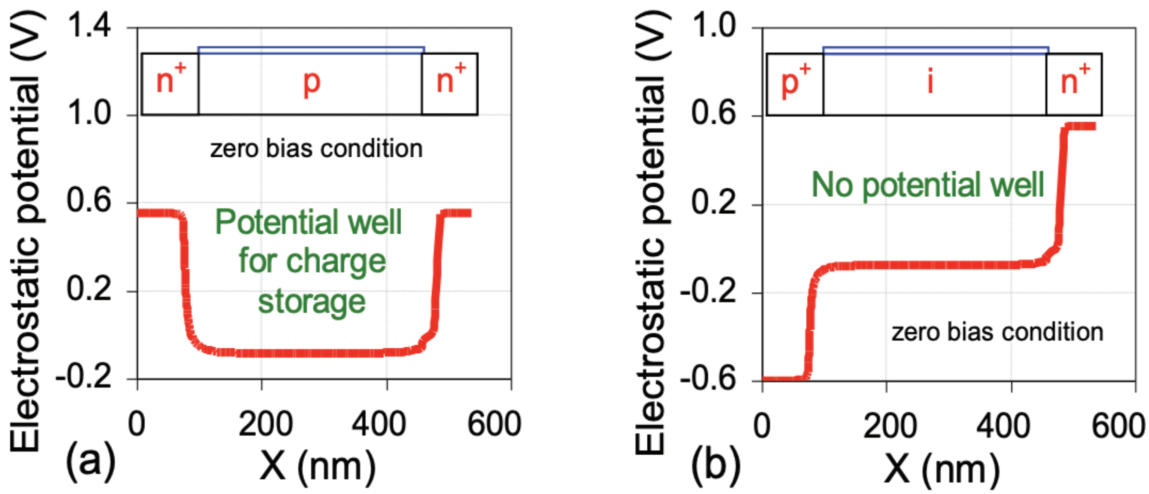

Figure 2. Variation in electrostatic potential along the channel direction (X) for (a) conventional *n-type* MOS and (b) TFET.

DRAM operation is based on generation and recombination of holes in the storage region. Storage of the majority excess carriers (holes) is defined as write '1' and the removal is termed as write '0' [4]. Fig. 3 illustrates DRAM operation and defines the performance metrics. Q_{INIT} indicates the charge in the storage region at zero bias, the charge stored between state '1' and state '0' is during write operation ($\Delta Q_W = Q_{W1} - Q_{W0}$) which decays during hold operation ($\Delta Q_H = Q_{H1} - Q_{H0;}$ $\Delta Q_W > \Delta Q_H$) due to hole recombination ($-\Delta Q_{hh1}$) for state '1' and hole generation ($+\Delta Q_{hh0}$) for state '0'. The maintenance of charges (Q_{H1} and Q_{H0}) during hold determine the retention time. Further during read, the hole concentration decreases for state '1' due to diffusion and thermal recombination and the charge difference observable during read ($\Delta Q_R = Q_{R1} - Q_{R0};$) determine the sense margin.

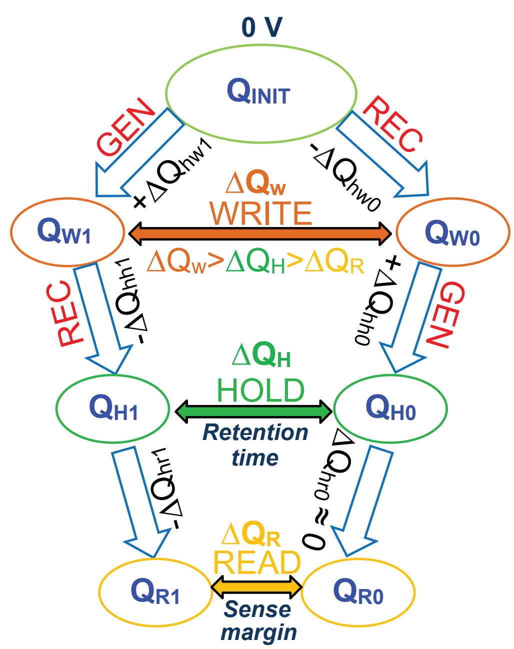

Figure 3. Schematic of charge distribution in potential well for write, hold and read, consecutively.

The power consumed is determined by the voltage applied and current generated during write as shown in Table I, while the speed is evaluated through write time. As observed through the data of Z^2FET [8,9] in Table I, power and speed are trade-off. Table shows TFET as most efficient for low power, however the ratio of read currents that determine the current sensitivity is low. TCCT show a high speed but FED memory cell is more flexible than the TCCT cell, and it needs precise control of the film doping profile [5]. Also, nearly intrinsic film has a higher carrier lifetime and thus other p-i-n architectures show a higher retention time (RT) as shown in Fig. 4.

Table 1. Comparison of write time and power during write '1', and current ratio of read currents for state '1' and '0' (I_1/I_0) for different architectures.

Device	L_s (nm)	$\lvert V_d \rvert$ (V)	I_d (µA)	Power (µW)	Write time (ns)	Current ratio (I_1/I_0)
TCCT [3]	250	1.2	-	-	2	10^7
TCCT [4]	100	1.2	~15	18	2	10^7
FED [5]	400	1.2	~10^2	120	4	10^7
Z^2-FET [6]	400	1.3	500	650	1	10^7
Z^2-FET [7]	200	0.5	10	5	350	-
TFET [8]	400	0.5	10^{-2}	0.005	~10^3	1
TFET [9]	100	1.0	0.3	0.3	5	10^3

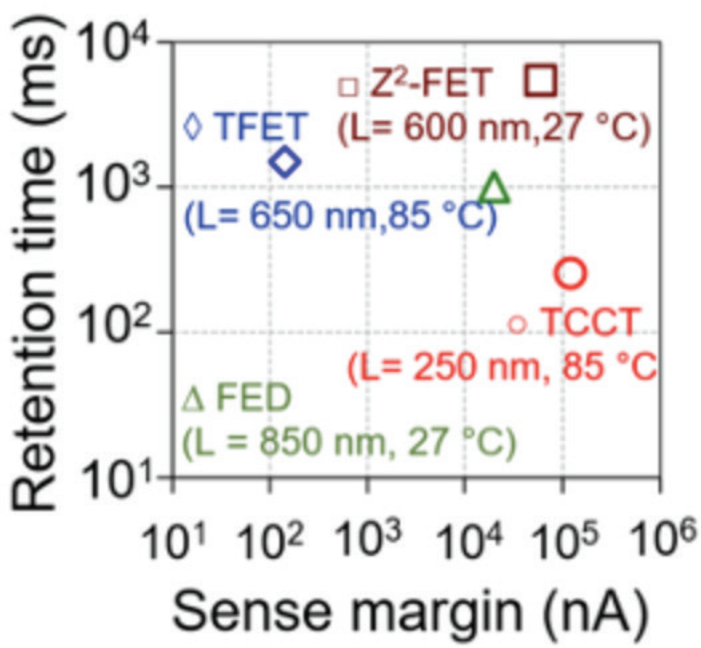

Figure 4. Comparison of retention time and sense margin of various p^+-i-n^+ based architectures (TCCT [3], FED [5], Z^2-FET [7], TFET [9])

Comparing all the structures as in Fig. 4 shows TCCT has a high sense margin (SM) and a good retention characteristic with RT > 100ms at 85 °C, TFET has high RT but a low SM, FED and Z^2FET show an optimal performance in terms of both high SM and RT, but Z^2FET have shown better and promising results. The study reflects the feasibility of steep devices for low power DRAM and criteria to select among the proposed devices for application specific design.

Conclusion

Steep switching devices have been showing immense potential for replacing conventional MOS transistor as 1T DRAM. Z^2-FET, FED and TCCT based dynamic memories have shown high operating current, current sensing margin and operates in forward bias and utilizes feedback mechanism. TCCT shows fast operation, however, the need of precise doping for storage is a drawback. TFET performance in terms of retention time and power is well-suited, however low sense margin and current ratio is an issue. FED has shown potential as 1T DRAM but Z^2FET have shown promising results. The study reflects the possibility to improve the performance metrics of the proposed devices.

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Comparative Study of Steep Switching Devices for 1T Dynamic Memory

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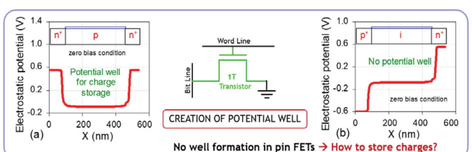
Introduction

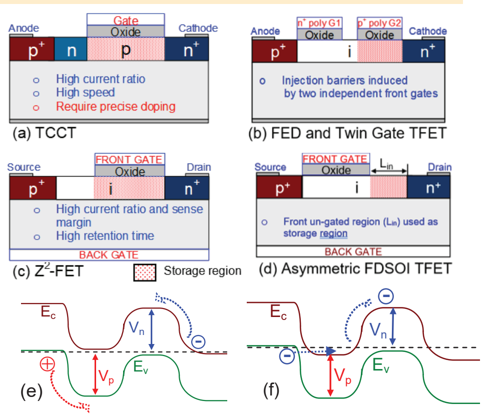
Quest for Low Power Capacitorless (1 Transistor) DRAM:

- Capacitor scaling in Conventional DRAMs with 1T – 1C difficult [1]
- Require more refresh cycles and hence, power consumption
- Steep switching devices as Capacitorless DRAM with p⁺ - i -n⁺ structure namely,
  - Thin-Capacitively Coupled Thyristor (TCCT) [2]
  - Field Effect Diode (FED) [3]
  - Zero sub-threshold swing and Zero impact ionization FET (Z²-FET) [4,5]
  - Tunnel Field Effect Transistor (TFET) [6,7]

Functionality as 1T DRAM



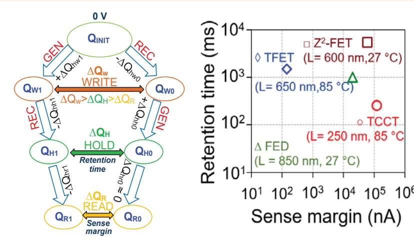
GATE ENGINEERING



Structure	Storage Region	Mechanism
TCCT	doped p-type region	Forward bias feedback
FED / TFET	p⁺ poly front gate	Forward bias feedback
Z²FET	Under front gate	Forward bias feedback
Asymmetric TFET	Underlap region	Reverse bias

Results and Discussion

OPERATION & DRAM METRICS



- **TCCT** has a high sense margin (SM) and a good retention characteristic with RT > 100ms at 85 °C
- **TFET** has high RT but a low SM
- **FED and Z²FET** show an optimal performance in terms of both high SM and RT

Comparison of write time and power during write '1', and current ratio of read currents for state '1' and '0' (I_1/I_0) for different architectures.

Device	L_s (nm)	$\lvert V_d \rvert$ (V)	I_d (µA)	Power (µW)	Write time (ns)	Current ratio (I_1/I_0)
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FED [4]	400	1.2	~10^2	120	4	10^7
Z²-FET [5]	400	1.3	500	650	1	10^7
Z²-FET [6]	200	0.5	10	5	350	-
TFET [7]	400	0.5	10^{-2}	0.005	~10^3	1
TFET [8]	100	1.0	0.3	0.3	5	10^3

Conclusions / Next Steps

- Steep switching devices have potential for replacing conventional MOS transistor for low power applications.
- **Z²-FET, FED and TCCT** DRAMs have shown high operating current and current sensing margin.
- **TCCT** shows fast operation, however, the need of precise doping for storage is a drawback.
- **TFET** performance in terms of retention time and power is well-suited, however low sense margin and current ratio is an issue.
- **FED** has shown potential as 1T DRAM but lacks extensive study.
- **Z²FET** have shown promising results amongst all the pin FETs based DRAM.
- Study shows the shortcomings and advantages of each device, reflecting the potential for further exploitation.

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Proposal of an open-source accelerators library for inference of transformer networks in edge devices based on Linux

Propuesta de biblioteca de aceleradores de código abierto para inferencia de redes Transformer en dispositivos perimetrales

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Araya-Núñez, A; Fernández-Badilla, J; González-Vargas, D; León-Huertas, J; Obregón-Fonseca, E.A; Xie-Li, D. Proposal of an open-source accelerators library for inference of transformer networks in edge devices based on Linux. *Tecnología en Marcha*. Vol. 37, special issue. June, 2024. IEEE Latin American Electron Devices Conference (LAEDC). Pág. 118-125.

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Keywords

Artificial intelligence; driver; FPGA; hardware accelerator; Linux; transformers.

Abstract

Transformers networks have been a great milestone in the natural language processing field, and have powered technologies like ChatGPT, which are undeniably changing people's lives. This article discusses the characteristics and computational complexity of Transformers networks, as well as, the potential for improving its performance in low-resource environments through the use of hardware accelerators. This research has the potential to significantly improve the performance of Transformers in edge and low-end devices. In addition, Edge Artificial Intelligence, Hardware Acceleration, and Tiny Machine Learning algorithms are explored. The proposed methodology includes a software and hardware layer, with a Linux-based minimal image built on top of a synthesized RTL. The proposal also includes a library of hardware accelerators that can be customized to select the desired accelerators based on the device's resources and operations to be accelerated.

Palabras clave

Inteligencia artificial; driver; FPGA; acelerador por hardware; Linux; transformers.

Resumen

Las redes de Transformers han sido un gran hito en el campo del procesamiento del lenguaje natural y han impulsado tecnologías como ChatGPT, que indudablemente están cambiando la vida de las personas. Este artículo discute las características y la complejidad computacional de las redes de Transformers, así como el potencial para mejorar su rendimiento en entornos con pocos recursos mediante el uso de aceleradores de hardware. Esta investigación tiene el potencial de mejorar significativamente el rendimiento de los Transformers en dispositivos de *edge* y de gama baja. Además, se exploran la Inteligencia Artificial en el *edge*, la Aceleración de Hardware y los algoritmos de *Tiny Machine Learning*. La metodología propuesta incluye una capa de software y hardware, con una imagen mínima basada en Linux construida sobre un nivel de transferencia de registro (RTL) sintetizada. La propuesta también incluye una biblioteca de aceleradores de hardware que se puede personalizar para seleccionar los aceleradores deseados según los recursos del dispositivo y las operaciones a acelerar.

Introduction

The Transformers' architecture has achieved dominant results in various natural language processing (NLP) tasks. Usually, Transformer architectures have been trained on large GPU clusters. However, their quadratic computational complexity limits their usage in low-resource environments. One of the characteristics is that they process each input in parallel. This means each token of a sequence is stored simultaneously, which reduces execution time. An embedding is used to make a numerical representation of each token and in a positional codification module to indicate the relative position of every token in the sequence. The previous information is sent sequentially to six encoders. Each of them has an attentional module, with three matrices involved: query, key, and value vector. Attentional modules are used to analyze the text sequence and find relations among various words. To know the weight of each token in relation to the model, sinusoidal functions and a probabilistic function called Softmax are used [1].

Some important operations within the Transformer architecture include the scaled dot-product attention, which involves taking the dot product of the query, key, and value matrices within the attention mechanism. Transformers also require the normalization of certain data among the architecture, as it is used commonly in deep neural networks (DNN) to address gradient problems, leading to faster convergence. The multi-head attention mechanism involves the execution of the dot product attention among different dimensions, which allows the model to attend to more information given at different positions. Transformers are based on an encoder-decoder architecture. Generative pre-trained models (GPT) can be based only on decoder-only architecture, although some models might be based on different approaches depending on the task being performed [1, 2]. It uses stacked self-attention and point-wise, fully connected layers for both the encoder and decoder [1], shown in Figure 1.

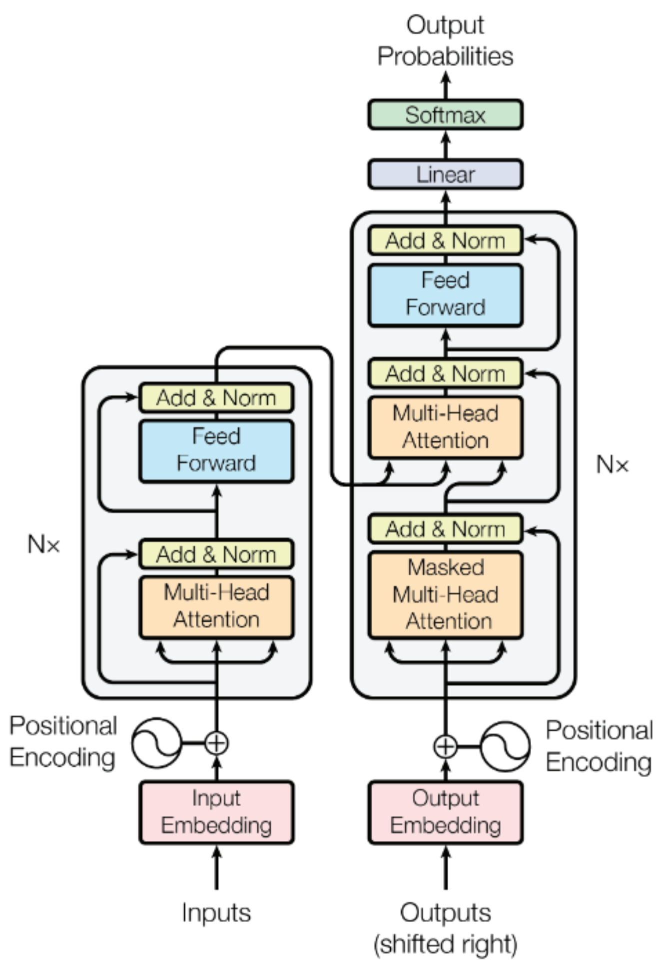

Figure 1. The Transformer – model architecture. Retrieved from Attention is all you need [4].

Hardware acceleration is a process where applications or systems delegate certain tasks to specialized hardware, giving more performance to the CPU and releasing the latter from that load [3]. The acceleration of DNN training is computationally expensive, requiring fast and efficient hardware acceleration [4]. Edge devices have limited computational capabilities, so energy-efficient accelerators and processors are needed. Lowering the access to external memory is challenging, but modern algorithms have reduced this access and others have focused on model parameters' reduction, like weight quantization and pruning [5, 6, 7]. The biggest constraint on the performance of inference accelerators is the limited bandwidth of the memory. Also, the GPU power consumption surpasses the power budget of a stand-alone embedded system. Since this, reductions in the precision of input data and hardware weight have been explored in the research field to reduce hardware accelerators' power consumption [8]. Tiny machine learning (Tiny ML) algorithms are a fusion of machine learning (ML) and the Internet of Things (IoT). This field is mostly used in edge computing, where systems have constraints in memory, power consumption, and computation time. This requires the utilization of approximation techniques, which are grouped into three families: pruning of processing layers, quantization of parameters, and activations with limited precision of binary parameters [9].

Related Work

Hardware Accelerators for Transformers

Numerous hardware accelerators have been proposed for Convolutional Neural Networks (CNN) model inference [14, 15]. However, there has been limited research on Transformer accelerators. In one study [10], authors introduced a hardware accelerator for the multi-head attention Resblock and the position-wise feed-forward network Resblock layers. This approach efficiently partitions large matrices to share hardware resources, optimizes the nonlinear functions, and achieves high hardware utilization using a systolic array. The hierarchical pruning framework in [13] presents a hierarchical pruning framework that optimizes the sparse matrix storage format to reduce memory usage for FPGA implementation. The framework's goal is to select the best device among multiple options for deploying a model while satisfying latency and accuracy constraints.

To address the computation and memory demands of transformers, a Sparse Transformer accelerator has been developed [11]. This accelerator utilizes a sparsity structure and features a specialized computing engine capable of handling sparse matrix multiplications. It includes a scalable softmax module to minimize latency from off-chip data communication. In the context of vision applications, a row-wise scheduling technique efficiently executes the major operations by treating them as a single dot product primitive. This approach promotes weight sharing in columns, leading to data reuse and reduced memory usage. Furthermore, it leverages a low gate count and SRAM buffer for improved performance [12].

Hardware Back-end

The hardware where the transformer model is running take a significant role to increase the time response of the Edge device. Different hardware backends such as GPUs and FPGAs can help accelerate the DNN processing. For the present study, FPGAs are the hardware backend due to the architectural flexibility that allows the design to handle multiple instructions [16].

Methodology

Modules

In general, the project has two layers. The first layer is the hardware layer. A minimal system is synthesized with memory and CPU, and the hardware accelerators selected by the user. The other layer is the software. A Linux-based minimal image is built on the synthesized RTL. Inside it, the Transformer model and API are added to the Linux image using Yocto recipes, as well as a driver for each synthesized accelerator instance, which is loaded in the Linux kernel. The model interacts directly with the API to transmit each layer's inputs and get each output result from it. The API is also in charge of scheduling the data transmission between the model and the different hardware accelerators, in the most efficient possible way. This will distribute the processing load in all the accelerators to take advantage of the available resources. In Figure 1, the different components of the projects are shown, as well as in Figure 2, the tools used for each part are also shown.

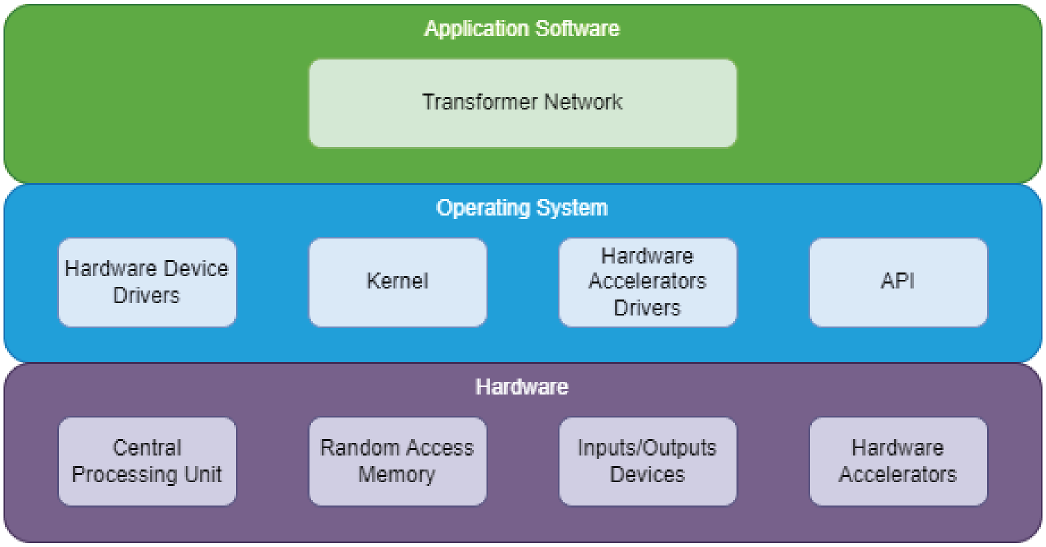

Figure 2. Project modules for the proposed architecture.

Figure 3. Project tools for each module.

API

The API is required to initialize the run time environment or context, which starts detecting the available hardware accelerators and allocates the memory for each of them. To send commands to the hardware accelerator is a requirement to define a command queue in which the context and device need to be set.

After that, allocating memory for the inputs and outputs is needed for each layer of the Transformer model. For these tasks, buffer objects are created and during the process of creation, the size of the buffer must be specified, based on the inputs and outputs size. With a buffer created, it is possible to write or read from memory to the CPU. A parameter should be set as true or false according to the task.

To process the data for the layer of the model, the CPU's buffer could be copied to the hardware accelerator to get a result to be returned to the model by doing the same process in the opposite direction. The API is in charge of copying a source to a destination buffer without losing the data to get a result to return to the Transformer model.

For the ending of the execution, the API must deallocate memory that was previously allocated by buffers. Furthermore, it is necessary to release the command queue and the environment that was created for the instance of the accelerator.

Hardware accelerators library

The hardware accelerators library consists of several accelerator instances that can be chosen and synthesized from a wide range of high-end to low-end FPGAs. A hardware accelerator is implemented for each operation of the Transformer model. Thanks to the high parallelization of this network architecture, multiple instances of the same accelerator can be synthesized by the library. This will let the user decide which operations can have more or null accelerators, and prioritize resources for a wide range of FPGAs.

Linux Drivers

A Linux driver is developed per hardware accelerator, and each instance has its own driver to transmit the data efficiently. When the Linux image is built, the accelerator instance is added with its corresponding driver loaded in the kernel. The API will take care of scheduling the data through the different hardware accelerators to take advantage of the resources properly.

Future work

The complete implementation of the proposed architecture is planned for future work. The design and implementation of the hardware accelerator library will leverage the state-of-the-art techniques explored in this research. In addition, the definition of validation tools for RTL will be explored later on, covering different open-source tools for static and dynamic verification to be used in the best scenarios.

Additionally, an extensive exploration of optimization strategies for the hardware accelerators will be conducted. These optimizations aim to enhance resource utilization and minimize power consumption. Moreover, efforts will be made to develop efficient device drivers that reduce communication overhead. These optimizations will contribute to the overall performance and efficiency of the hardware accelerators.

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TEC Tecnológico de Costa Rica
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Proposal of an Open-Source Accelerator Library for Inference of Transformer Networks in Edge Devices based on Linux

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ABSTRACT

Transformers networks have been a great milestone in the natural language processing field, and have powered technologies like ChatGPT, which are undeniably changing people's lives. This article discusses the characteristics and computational complexity of Transformers networks, as well as, the potential for improving its performance in low-resource environments through the use of hardware accelerators. This research has the potential to significantly improve the performance of Transformers in edge and low-end devices. In addition, Edge Artificial Intelligence, Hardware Acceleration, and Tiny Machine Learning algorithms are explored. The proposed methodology includes a software and hardware layer, with a Linux-based minimal image built on top of a synthesized RTL. The proposal also includes a library of hardware accelerators that can be customized to select the desired accelerators based on the device's resources and operations to be accelerated.

Keywords. *Artificial Intelligence; Driver; FPGA; Hardware Accelerator; Linux; Transformers.*

I INTRODUCTION

Multi-Head Attention is the key component of transformer architecture. It allows the model to attend to different parts of the input sequence. The number of operations required to compute the attention weights grows quadratically with the length of the input sequence.

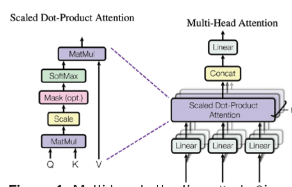

Figure 1. Multi-head attention mechanism. Recovered from [1].

III FUTURE WORK

- Designing and implementing the hardware accelerator library.
- Defining validation tools and methodology for RTL.
- Exploration of optimizations for the hardware accelerators to enhance resource utilization and reduce power consumption.
- Investigating optimization techniques to minimize the communication overhead in drivers.

II METHODOLOGY

The project consists of two layers:

1. **Hardware layer**: A minimal system is synthesized with memory and CPU, allowing users to select their desired hardware accelerators.
2. **Software layer**: A Linux-based minimal image is constructed using the synthesized RTL. Within this image, the Transformer model and API are integrated via Linux image using Yocto recipes. Additionally, a driver for each synthesized accelerator instance is loaded in the Linux kernel. The model interacts directly with the API to transmit each layer's inputs and get the corresponding output. The API also handles the scheduling of the data transmission between the model and the various hardware accelerators, ensuring optimal efficiency. This approach distributes the processing load across all the accelerators, effectively utilizing the available resources.

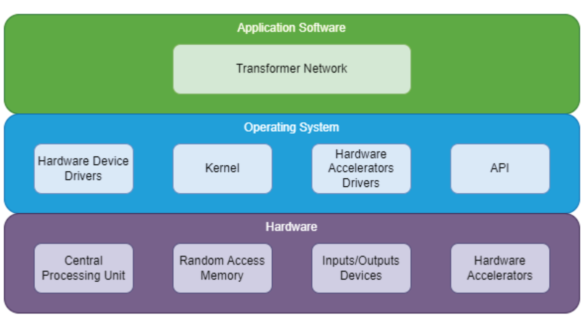

Figure 2. Project modules for the proposed architecture.

Figure 3. Project tools for each module.

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Electron Devices Society

Breaking down barriers: encouraging participation of underserved groups in STEM for the future

Rompiendo barreras: Fomentando la participación de grupos desfavorecidos en STEM para el futuro

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Keywords

STEM education; educational experiences; disadvantaged groups; sociocultural challenges; social impact; equal opportunities.

Abstract

This article focuses on a project carried out by the IEEE Computer Society Student Chapter at the Costa Rica Institute of Technology. The project was aimed to encourage the participation of underprivileged groups in STEM (Science, Technology, Engineering, and Mathematics) careers through workshops and educational activities. It was conducted in four schools with low economic growth, with a focus on the participation of women in the activities. The project successfully brought STEM education closer to these groups, providing them with opportunities and tools to explore these areas. The results obtained during the workshops reflected increased interest and understanding among the students regarding STEM career options. The article highlights the importance of this project in the context of Latin American countries, where the growth of STEM careers has been slow due to prejudices and sociocultural problems. Topics addressed in the article include the objectives, significance, and results of the activity, the definition of underprivileged groups, the challenges these groups face in choosing STEM careers, as well as the associated statistics. The article also includes post-project observations from the perspective of students, teachers, and volunteers, providing a more comprehensive view of the impacts and challenges faced.

Palabras clave

Educación STEM; experiencias educativas; grupos desfavorecidos; desafíos socioculturales; impacto social; igualdad de oportunidades.

Resumen

El presente artículo se centra en un proyecto realizado por parte del Capítulo Estudiantil de IEEE Computer, en el Instituto Tecnológico de Costa Rica. Este proyecto tuvo como objetivo incentivar la participación de grupos desfavorecidos en carreras STEM (Ciencia, Tecnología, Ingeniería y Matemáticas) a través de la realización de talleres y actividades educativas, se llevó a cabo en cuatro colegios con bajo crecimiento económico, priorizando la participación de mujeres en las actividades. El proyecto logró acercar la educación STEM a estos grupos, proporcionándoles oportunidades y herramientas para explorar estas áreas. Los resultados obtenidos durante los talleres reflejaron un mayor interés y comprensión por parte de los estudiantes en cuanto a las opciones de carreras STEM. El artículo destaca la importancia de este proyecto en el contexto de países latinoamericanos, donde el crecimiento de las carreras STEM ha sido lento debido a prejuicios y problemas socioculturales. Abordaremos temas tales como el objetivo, importancia y resultados de la actividad, la definición de grupo desfavorecido, la problemática de estos grupos alrededor de la elección de carreras STEM, así como las estadísticas asociadas a ello. También se incluyen observaciones post-proyecto desde la perspectiva de estudiantes, maestros y voluntarios, que brindan una visión más completa de los impactos y desafíos enfrentados.

Introduction

According to the World Health Organization's glossary of terms used for Health Impact Assessment (HIA), a disadvantaged group applies to groups of people who, due to factors beyond their control, do not have the same opportunities as other more fortunate groups in society [6]. For example, economic or social factors.

The inclusion of these disadvantaged groups in science, technology, engineering and mathematics (STEM) careers is important, as the growth and development of these areas of education has generated a clear impact on society and the economy, which is expected to remain and increase in the future.

Despite this, there are still barriers that impede the participation of these groups in STEM careers. According to T. Wang and L. Degol [2], several studies have shown that teachers, as well as family caregivers, promote the belief that boys outperform girls in courses such as mathematics, even when the grades of both genders are similar. Thanks to this, these figures of power promote the participation of boys in science and mathematics activities, as opposed to girls. Although this adult influence may be unintentional, girls are likely to grow up thinking that the field of study of science and mathematics is dominated by the male gender [2]. In accordance with the research conducted by [1], it is concluded that, despite the efforts of the Costa Rican government and universities during the period from 2000 to 2018, women continue to be underrepresented in STEM careers in Costa Rican universities.

Likewise, the lack of equal opportunities compromises the choice of STEM careers for secondary school students. Purchasing power and educational experiences are factors associated with the choice of university careers [3]. In Costa Rica, there is a social and technological gap that threatens the interest of the student population in STEM areas. According to the study conducted by [4], private education in Costa Rica involves students in better technological opportunities to develop knowledge in mathematics, programming, robotics, science, among other areas of study, in addition to better prepare students to apply successfully to the most prestigious universities in the country. Due to the lack of interaction and exposure to STEM fields in Costa Rican public education, in addition to the disparity in opportunities, students in public schools present more obstacles to study STEM careers [4].

Studies suggest that interest in STEM careers should be influenced from an early age [1], as students' understanding of STEM concepts can drive the learning process and sustain their interest throughout elementary, high school, and even college [5].

This is why this project is proposed, with the main objective of encouraging disadvantaged groups to participate in STEM careers. A series of workshops and educational events have been held, in which students from low-income schools have attended and participated, focusing on the participation of women in the activities. This document presents the methodology used in the project, the analysis of the results and the conclusions obtained.

Materials and methods

The project was organized in different stages: planning, design and implementation. These phases allowed a structured execution of the project to obtain better results. Each of these phases is described below.

First, a brainstorming discussion, goal setting and definition of the main objective were conducted as part of the project planning. From the beginning, the objective of promoting STEM areas among primary and secondary school students was established. Through brainstorming, plans were analyzed such as moving to different educational centers to give workshops or conducting the workshops virtually, however, it was finally decided to invite the students to the central campus of the Instituto Tecnológico de Costa Rica.

This decision was made with the idea of being able to carry out not only the workshops, but also a series of tours through different spaces of the university to show the participants of the activity enclosures such as classrooms and labs of computer, plasma, industrial maintenance, among other areas of study. This would favor the increase of students' interest and curiosity about the different STEM fields.

Regarding the workshops to be given, it was proposed to present basic concepts on the use of Arduino, App Inventor, Visualino and Snap Circuits, since the teaching of these principles brings students closer to the STEM development environment. At the same time, several proposals of educational institutions were analyzed, to invite to participate in the activities. Institutions located in places with little economic development, social problems and few opportunities for growth in STEM careers were taken into consideration, giving importance to the participation of a large number of female students.

Secondly, a schedule of activities was designed and the content of the workshops was prepared. Once the topics to be taught in the workshops had been analyzed, the content was presented to the volunteers who would teach the courses through a training process. Likewise, the work calendar was organized, assigning dates for the activities and their respective schedules. It was agreed to have work spaces with breaks for meals and a tour of the campus. Similarly, material was designed to present the different topics to the students participating in the activities.

In the same way, the physical components to be used in the workshops were prepared. For this, it was necessary to make an inventory of the elements that were available at the moment. There were some Arduino Uno electronic boards, whose operation had to be checked. In addition, some other components to work in conjunction with Arduino, such as servomotors, electrical cables, LEDs, buttons and other similar elements were reviewed.

Once having the information about the functional components available for the workshops, it was decided to purchase more Arduino Uno boards in order to increase the capacity to teach a larger number of students. In the same way, the educational institutions selected in the planning stage were contacted in order to coordinate dates in which to carry out the activities.

The third and final step was the implementation of the activities with the participating students. Members of the different educational institutions were received, among them the Colegio Técnico Profesional de Orosi, the Colegio Técnico Profesional de Santa Lucía and the Colegio Iribó. Each of these visits were carried out on the dates previously planned with each of the institutions.

During the participants' stay, the following activities took place: a talk on STEM principles, an introductory workshop on block-based programming with App Inventor, a workshop on the principles of Arduino operation, a tour of the central campus of the Instituto Tecnológico de Costa Rica and plasma lab, a workshop on Snap Circuits, an introductory workshop on Arduino programming with Visualino and, finally, a small project competition with Arduino.

During the execution of the activities, a technique that combines teaching and putting into practice for the students was applied. During the first part of the workshops, the volunteers were expected to demonstrate the contents, and then to promote the application of the knowledge acquired to the participants by allowing the controlled use of the different tools of the workshops.

Results

It should be clarified that the participants came from three different institutions, mentioned above. Two of the institutions correspond to technical highschools, i.e., highschools in which a technical degree is obtained upon completion, while the third highschool consisted of a women's highschool with no specialized orientation.

Figure 1. IEEE TEC Student Branch volunteers and students from the Colegio Técnico Profesional de Orosi.

Several of the participants from technical schools were already oriented towards STEM careers, while the third school had no STEM orientation.

During the workshops it was observed that especially in the women's school, the technological bases and interests in these subjects were biased, so that students who did not participate in extracurricular activities before the workshop, followed a tendency of interest towards traditional careers.

Taking into account the questions and conversations held during the activity among students, volunteers and speakers, the following table was created, in which we can see that there is a strong orientation of students from technical schools towards STEM careers, while the women's school has a lower percentage of interest. Despite this, the project successfully managed to generate greater interest in these careers in all schools, clarifying doubts and even introducing options to the project participants.

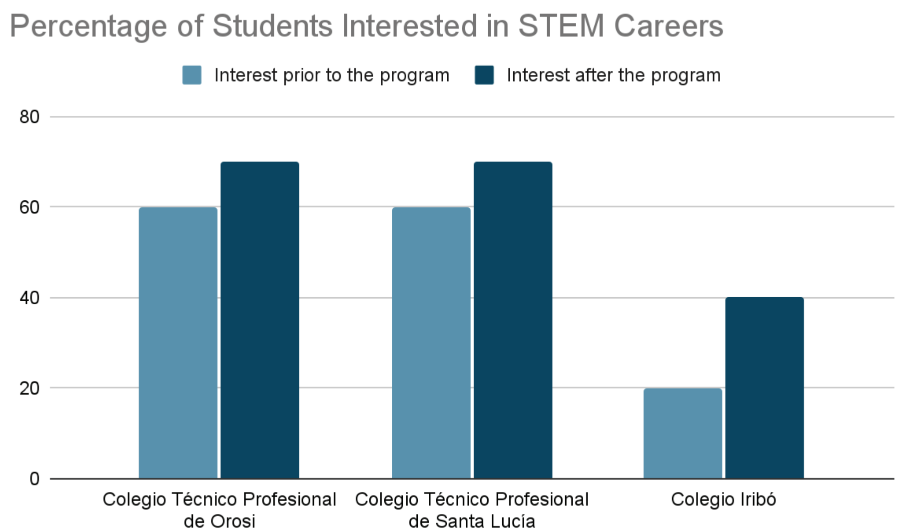

Figure 2. Student interest in STEM careers.

Additionally, we were able to observe a growth in the number of volunteers interested in participating in these workshops, indicating that there is greater involvement and commitment to increase knowledge and spaces for new generations of students to be involved in STEM activities.

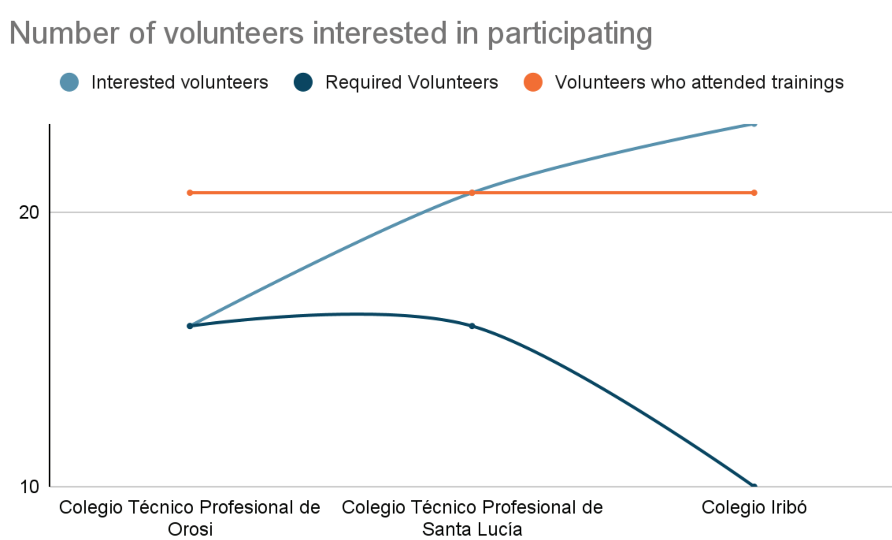

Figure 3. Interest of volunteers in participating in the workshops.

Conclusions

In summary, throughout the project, certain ways to promote STEM fields among high school students have been explored. Through the activities carried out, the main objective of the project was achieved from different working points.

First of all, the students acquired technical skills. The participants of the activities gained knowledge in basic Arduino programming, handling of basic Arduino components, block programming with App Inventor and handling of Snap Circuits components. These skills are valuable for the students' future academic and professional development.

In the same way, a space for teamwork and collaboration among the participants was created. Through the implementation of the knowledge acquired, students had the opportunity to work together with their peers in the creation of small projects using the different tools provided by the workshops. The importance of these collaborative work techniques is highlighted because they are essential in a work environment to promote creative and innovative thinking.

Participants were also given the opportunity to experience a real-world connection to STEM fields. Through lectures, workshops, and tours of laboratories in the different fields of study, students were able to get an up-close look at real-world applications of STEM skills. This generates a new perspective in the participants and motivates them about different STEM careers.

Figure 4. Students from the Colegio Iribó.

Along the same lines, a long-term impact on the students was generated. The project laid the groundwork for continuing to develop the skills and interest acquired in STEM throughout their professional careers. Furthermore, in addition to the collaborative work technique, students are expected to be able to apply this knowledge in their personal and professional lives.

Finally, the project succeeded in awakening the interest of participating students in STEM careers. Through the various workshops, lectures and tours of the Central Campus of the Instituto Tecnológico de Costa Rica, students increased their interest in the fields of science, mathematics, engineering, and technology.

We highly recommend other institutions, groups and organizations to replicate these kinds of activities. As commented before, it is of great importance to incentivize STEM careers for everyone, leaving behind the stigmas and stereotypes associated with them, and hopefully reducing the gap of underserved groups representation in these areas.

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Breaking Down Barriers: Encouraging participation of underserved groups in STEM for the future

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Introduction

Deprivation groups refer to individuals who do not have equal opportunities in STEM careers due to factors beyond their control, such as economic or social factors. The inclusion of disadvantaged groups in STEM careers is crucial, as the growth and development of these areas have a significant impact on society and the economy. However, barriers still hinder their participation in STEM careers. Teachers and family caregivers often promote the belief that boys outperform girls in courses, leading to girls being underrepresented in STEM careers.

Despite efforts by the Costa Rican government and universities, women continue to be underrepresented in STEM careers. The lack of equal opportunities in secondary school students and a social and technological gap threaten the interest of the student population in STEM areas.
Studies suggest that interest in STEM careers should be influenced from an early age, as students' understanding of STEM concepts can drive the learning process and sustain interest throughout elementary, high school, and college. This project aims to encourage disadvantaged groups to participate in STEM careers through workshops and educational events, focusing on the participation of women in STEM activities.

Materials and Methods

The project was organized in three stages: planning, design, and implementation. The main objective was to promote STEM areas among primary and secondary school students. The project involved brainstorming discussions, goal setting, and analyzing various options for workshops. The central campus of the Instituto Tecnológico de Costa Rica was chosen to host the workshops, which included tours of various university spaces. The workshops focused on basic concepts of electronic circuits and programming, bringing students closer to the STEM development environment. Educational institutions were also considered, considering areas with limited economic development, social problems, and opportunities for STEM careers.

The final step involved implementing the activities with participating students, including visits to the Colegio Técnico Profesional de Orosi, Colegio Técnico Profesional de Santa Lucía, and Colegio Iribó. During the participants' stay, various activities were held, including a talk on STEM principles, an introductory workshop on block-based programming with App Inventor, a tour of the central campus, a workshop on Snap Circuits, and an introductory workshop on Arduino operation.

Results and Discussion

Participants from three institutions attended workshops focusing on STEM careers. Two were technical highschools, while the third was a women's highschool without a specialized orientation. The workshops revealed a bias towards traditional careers in women's schools. The project generated greater interest in STEM careers, clarifying doubts and introducing options. The number of volunteers participating in the workshops grew, indicating greater commitment to increasing knowledge and opportunities for new generations of students.

Conclusions / Next Steps

The project aimed to promote STEM fields among high school students by acquiring technical skills in Arduino programming, teamwork, and collaboration. Participants gained knowledge in basic Arduino components, App Inventor, and Snap Circuits components, which are valuable for their academic and professional development. They also had the opportunity to experience real-world connections to STEM fields through lectures, workshops, and tours of laboratories.

This experience generated a new perspective and motivated them about different STEM careers. The project laid the groundwork for continuing to develop STEM skills and interest throughout their professional careers. It is crucial to incentivize STEM careers for everyone, reducing the gap of underserved groups representation in these areas.