26TH INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
5-6 SEPTEMBER 2024, ASTON UNIVERSITY, BIRMINGHAM, UNITED KINGDOM

IMMERSIVE LEARNING IN AGRICULTURE: XR DESIGN OF ROBOTIC MILK PRODUCTION PROCESSES

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ABSTRACT
During the confinement of COVID-19, learning about virtual and augmented reality grew exponentially; universities were the accelerators of this knowledge. Distance learning was the trigger to consolidate emerging technologies in education and professional life [1], including virtual reality (VR) and augmented reality (AR). Given the rising interest in virtual simulations, this paper targets authentic design challenges and how distributed collaboration may enhance the immersive learning potential by utilising network resource efficiency. According to the Institute for the Future of Education of the Tecnologico de Monterrey, in the Tec21 educational model, the most important part is the challenge, which is defined as a problematic situation posed by the partner trainer, and when analysed, a problem is defined by mutual agreement. The project is defined on this problem. One of our most essential training partners is CAETEC, where we carry out challenges ranging from precision agriculture to data science, experiment design, and forecasting [2] [3].
To 3D model this robot, we need to work with the former partner, whose headquarters are in Sweden, through a collaboration agreement between universities that pursue the same educational purpose. We will work with the University of Mälardalen on the design of the lessons and with the University of Mondragon on the interaction between humans and robots.
This research results from joint work between three educational institutions with a multicultural and multidisciplinary project approach.

Keywords: Immersive learning, agriculture, XR Reality, Industry 5.0, higher education. educational innovative

1 INTRODUCTION
Due COVID-19 confinement, universities were the driving force for the surge in virtual and augmented reality adoption for education and professional use [1]. This paper explores how distributed collaboration enhances immersive learning and optimises network use in virtual simulations. In the Tec21 model, challenges set by partner trainers, like CAETEC, guide problem-solving and shape projects in areas ranging from precision agriculture to data science [2, 3]. The implementation of virtual reality (VR) is a growing concern in order to improve data visualisation for education and industry. The use of virtual flows and simulations through digital twins has shown importance for enabling new forms of interaction and efficiency, presenting a high correlation between its use and the increase in quality indicators and productivity [4].

2 BACKGROUNDS
In recent years, the Tecnologico de Monterrey, through its new Tec 21 educational model, started in 2019, brought a new opportunity for the rise and use of new and emergent technologies globally. With these new technologies, it was possible to implement and train the current student population with our partner CAETEC (Experimental Agricultural Field from Tecnologico de Monterrey, Spanish acronym) to analyse and identify new efficient solutions. Doing so, it increases the range of opportunities for the

university and our partners to collaborate, share knowledge, and apply new current technologies to controlled study grounds allowing for the development of more complex projects regarding precise agriculture, data science, digital twins emulation, and create better design of experiments using current milk production processes.
CAETEC, despite being the largest laboratory at Tecnologico de Monterrey, has different restrictions on bringing entire groups to its facilities. So, one among the institutional projects is the development of a virtual plant, in this case, a virtual experimental agricultural laboratory to provide access to students, international & national collaborators, private companies, among others, to the facilities. The robots that are being used for milk production at CAETEC are manufactured by DeLaval, which is a Swedish company that currently is the world leading provider of solutions to enhance food producer farms. The company has had more than 125 years of experience in milk production innovation [5]. The term robotic milking system refers not only to the use of an articulated hydraulic arm but also to the concept of global automation of a facility and the voluntary assistance of the cows to the robotic milking module, also known as VMS for its acronym in English: Voluntary Milking System.
This interdisciplinary project has allowed academic collaboration between three universities to achieve the established objectives where the University of *Mondragon* will work with the impact between users and robots, thinking in a future context in which Mexican and other livestock farmers can replicate this technology. And both Tecnologico de Monterrey and Mälardalen University, collaborate to designed the digital twin for the VMS system and virtual reality lessons for the training of DeLavals Latin America employees and for students in the area of mechanical engineering, mechatronics, and digital systems, which all this areas are members of Tecnologicos de Monterrey School of Engineering and Sciences (EIC) Figure 1.

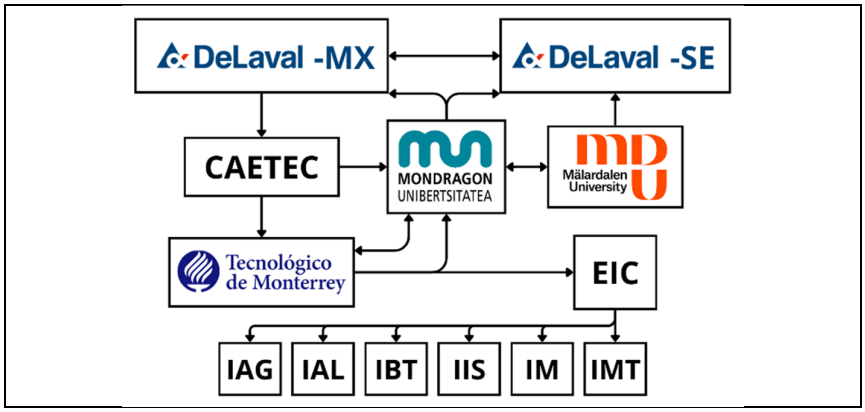

Figure 1. Process to interaction between universities and the process to get the project's findings

3 DEVELOPMENTS

Through a digital twin that simulates the complete process of the milk production data is generated; starting from when the cow is in the stable, showing the station where the robot is, how the milking process is carried out, and the final moment when the cow returns to the stable. Data can be used for learning different topics, such as Design of experiments, Forecasts for decision-making, Inferential Statistics, Statistical Engineering, Data science, Engineering in the robotic milking system, and Integration of bio productive processes.
This digital twin consists of the simulator and the virtual reality practices, where students from campuses located in different sites can interact with the VMS system without the need to travel to CAETEC. If the students belong to the Tecnologico de Monterrey system, they can practise within the VR Zone of their own campuses, better known as Mostla. CAETEC currently receives applications to be a training partner of training units, mainly from the Engineering and Science schools of the Tecnologico de Monterrey's different campuses, specially form Querétaro campus, from the departments of Industrial Engineering, Mechatronics, Robotics, Agronomy, and Biotechnology. Nonetheless, it also receives requests for visiting CAETEC from other universities and research centres. It has experimental fields for extensive agriculture (open sky), mainly corn, where different precision agriculture technologies are applied. The

main objective of planting corn is for it to become the basis of the cows' diet, which are of the Holstein breed, and the milk produced by these cows is sold to the Alpura Cooperative for human consumption. Other activities of CAETEC are intensive agriculture (in greenhouses), vineyards, fruit trees, and pumpkins. Using soft systems methodology, the current situation of CAETEC was described. The rich picture reflects how CAETEC operates from a systems point of view and the problem has been defined. With this, the best solution proposal is the design of a digital system for the milking part. Figure 2

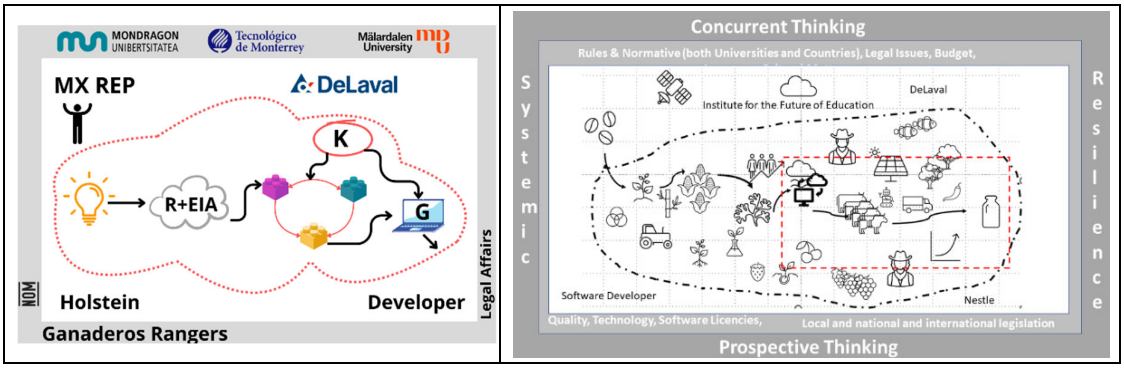

Figure 2. CAETEC Systemic map and Rich Picture to show the milking system

A problematic situation is that CAETEC does not have the infrastructure in human resources and facilities to receive large groups that want to learn about the milk milking process and satisfy the demand for challenges requested by different teachers. One of the objectives of CAETEC is to be a living laboratory for Tecnologico de Monterrey students, serve as a research centre, and be a reference to other educational centres, private companies, and researchers. Unfortunately, this has not been achieved.

Based on known information and using the Kepner and Tregoe methodology [6, 7], the problem has been defined as follows: CAETEC needs to have the capacity in human resources and infrastructure to receive students who request to visit the VMS facilities to learn about its functioning and the daily performance.

To solve this problem, a digital twin model of the milking robot was designed based on virtual reality and augmented reality technology for remote learning. The academy and the company worked together to ensure that said design meets the needs of the student's knowledge and the needs of the company regarding marketing its product and maintaining and using the robot by its employees. The design we are working on consists of the following milestones: the digital twin will be an interactive solution and it must show the technology devices involved in the CAETEC milking system. It is worth mentioning that the application will guide the user step by step during the operation.

Two development phases were defined for the interactive stable:

Phase 1: Interactive map of the stables where the general system of the milking area and the milk cycle is explained, Figure 3; here, the user interacts with the virtual world and the elements are mainly selected with the click of the mouse. The user will be able to select up to 10 elements in the scenario, for example, VMS, cows, feeding area, rest area, sensors, and doors, to name a few; the information of the selected elements (statistics and relevant information) will be displayed on the screen.

The design of the solution also includes a dashboard with the operation's strategic KPIs [4]. The user will also be able to view and analyse the cow control panel, where there is a list of cows and view data of research interest such as age, milking time, milk produced, last milking, and calving number. The user will be able to select all the components. The application will have a tutorial that guides the user to perform the following actions:

- Select all components of the interactive map.
- Select the cow panel.
- View the information on three different cows.

Phase 2: A general panel has been designed where the general statistics of the entire stable will be displayed, accompanied by dashboards such as graphs of (e.g., Average milk production, Average milking time, Amount of food consumed per day). The user will be able to design the cow diet (food generation). At this point, the user can modify the food formula by changing the percentages that make it up. For the cow simulation module, the system is designed for the user to manipulate the behaviour of

the cows going executed through the following four phase commands (1-Send to a veterinarian, 2-Send to feeding, 3-Send to milking, 4-Send to rest) Figure 3.
For the virtual reality lesson, the design has been thought to have a prospective and concurrent approach since the lesson is being built in standard modules, to later derive the application for students (academic) and for the robot manufacturer in these lessons.
The application will guide the user step by step during the operation. The scope and design of the lessons have been made for HTC Vive headsets. We aim for the user to interact with the virtual world and the elements mainly by selecting them with the control. There will be narration in Spanish and English; subtitles can be activated for this narration. In the same way, the design has considered deploying signage on those elements relevant to the learning process.

Figure 3. Voluntary Milking System, front end of the process simulator

The simulator and VR lesson have been a work of progress for many hours in a multidisciplinary and international cultural project that started a year ago with the proposal to the Institute for the Future of Education through the Novus funds, where we won the competition to access financial funds to develop virtual reality lessons. The first design phase was carried out through video calls, and in October 2023, a representative of the University of Mälardalen visited to intensively work on the design of the practices and the simulator. The second phase was to incorporate the vision of interaction between the robot's management and the human with the help of the University of Mondragon.

4 METHODOLOGIES

To evaluate the current stage of development of the virtual reality lesson and the milking process simulator, an augmented reality lesson was applied in the IN2006B training unit, groups 501 and 502, with a sample of 39 Tecnologico de Monterrey students and 25 CAETEC employees and Tec de Monterrey professors, in which the challenge is carried out in the stables using the robots.
A survey was carried out to analyse human interaction with robots based on a 5-point Likert scale developed regarding the relationship between human and robots [4].
It is worth mentioning that at the beginning of their professional studies at Tecnológico de Monterrey, students sign an agreement in which they consent that their responses and/or interactions during class may be used as evidence to analyse the impact of technological applications focused on educational innovation. This evidence can include tests, exams, surveys, among others. Thus,

5 RESULTS

The analysis was guided by a series of questions, answered by students and users of said robot. The survey aimed to understand the impact of the robot on the work performance and productivity of the users; it was designed to evaluate aspects such as the user-friendliness of the robot, the ability to use the robot without written instructions, and the level of trust and confidence users have in it. The results provided insights into how well users can adjust the robot to assist them in their tasks and whether the robot helps in completing tasks in a shorter time; it was observed that majority of the sampled individuals agreed that the robot can enhance their work performance, help them complete task in shorter time, said that it's easy to use without instructions and they can adjust it to their needs, and that it increase their confidence when using the robot. On the other hand, the majority strongly agreed that they trusted the

robot so that it would not harm them. And finally, it was observed that the majority neither agreed nor disagreed that the robot could help them be more productive and is user friendly. Figure 4.

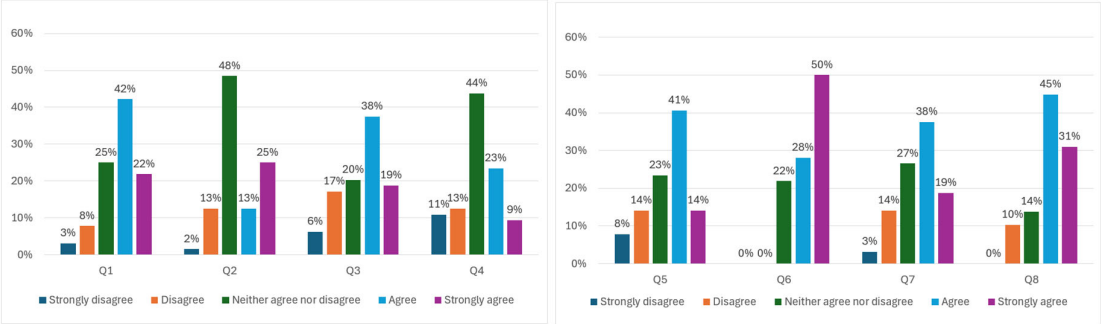

Figure 4. Survey results applied to students and users of the voluntary milking system. Q1: The robot enhances my work performance. Q2: The robot helps me to be more productive. Q3: The robot helps me to complete the task in a shorter time. Q4: The robot is user-friendly. Q5: I can use the robot without written instructions. Q6: I trusted the robot would not harm me. Q7: I am very confident in my ability to control the robot. Q8: I can adjust the robot so it will help me carry out my tasks

The results show that the use of the robot has not only allowed the users to learn about the automation of the milk milking process, but it also has provided valuable information for decision-making in the daily operation of CAETEC. Based on the data provided, daily handling and interaction with the robot is simple. And the use of digital twins for distance learning shows good acceptance by both students and professors.

6 CONCLUSIONS

Digital twins are a more efficient and democratic gateway to knowledge. The construction of this design has allowed us to be at the forefront of the Tec21 educational model in terms of generating remote learning experiences. The interaction and collaboration between academics from the three universities has also been an experience worth sharing. It has shown how different visions can converge in designing high-value learning activities through educational innovation. The project will be released in May and will be fully implemented before the end of the school year in June 2024. The research group will show the final results during the E&PDE conference.

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