# Conversational Agent for Industrial Processes through Virtual Environments

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# Conversational Agent for Industrial Processes through Virtual Environments

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**Abstract.** This paper presents the implementation of a conversational agent in virtual environments oriented to industrial control processes in order to contribute to the improvement of teaching-learning processes. The application simulates the level control process in two virtual environments, the first one as a virtual laboratory and the second environment as an industrial process. The environments have been created with three-dimensional models based on Piping and Instrumentation Diagram (P&ID) diagrams. The models have been simulated and animated using Unity 3D software. The environments exchange information in real time with MATLAB mathematical software to simulate the industrial process controller, achieving a high degree of realism. Each environment is assisted by a conversational agent who communicates with Dialogflow, a natural language understanding platform, to guide the user during their training. Test users were asked to provide feedback through a usability questionnaire, and these results are discussed at the end of this article.

**Keywords:** Virtual Environments, Industrial Process, Conversational Agent, Education, Information Technology.

## 1 Introduction

Virtual Reality (VR) defined as a "human immersion in a synthetic world" [1], has allowed interaction with an artificial world that offers an unlimited range of applications: surgical procedures simulators, virtual tours, museum visits, medical treatment of phobias, etc. In the field of education, virtual reality is widely used. With the help of sensory immersion [2], VR can improve and facilitate learning, increase memory, as well as allow better decisions to be made in simulated conditions. For example, virtual labs can provide learning outcomes similar to those of real labs in a shorter time frame [3].

Currently, the training of professionals and students in the industrial sector is a determining factor to promote the good management of the elements of an industrial plant, and thus maximize the efficiency of production processes and services offered by companies [4]. Practical training processes in real environments present several challenges: increased risk of lost productivity, property damage and injury, as well as geographical, time and availability limitations [5, 6]. In contrast, the use of virtual reality as a training tool can be very accessible, with low-cost devices; in addition, it allows the user to learn without harming his physical integrity and to experiment with events that could be potentially dangerous in real scenarios, such as simulating explosions or possible risks caused by errors in the industrial process [5, 7].

On the other hand, with the development of artificial intelligence, current software systems can interact with the user by using a natural language such as Spanish. Chatbots or conversational agents (CA), can use Natural Language Processing (NLP) technologies to understand the information received and provide human-like responses [8]. The applications of conversational agents are very diverse; they can be used in marketing, customer service, virtual therapy, and learning support environments, among others [9]. The implementation of a conversational agent allows the user to interact with the system as if he were talking to another person, thus decreasing the dependency on personal assistance, increasing the accessibility and response time of a system [10].

Based on the aforementioned background information, this work presents a virtual reality system that simulates the level control processes, assisted by a conversational agent for educational and training purposes, in two environments *i) Laboratory Scenario* similar to industrial control practices in real laboratories and *ii) An industrial environment* in which the user interacts with industrial equipment and processes, following safety standards and procedures, in order to acquire practical knowledge and experience [11].

## 2 Related Work

The development of a virtual reality system that simulates the industrial processes environments is not a new approach. Several research works have taken real industrial process scenarios to the virtual world with the aim of improving learning processes and training workers and students. Romo et al. [4] implement a realistic and intuitive virtual environment for training on pumping stations for drinking water supply systems. Their approach achieved a realistic immersion experience in the integrated station and verified through experimental tests. A similar approach is followed by Porras et al. [12], which develops a virtual training system for an industrial pasteurization process.

These approaches develop industrial process training environments, but without the assistance of a conversational agent during the process, which is the objective of this work. Rosero et al. [13] have developed an environment for training on industrial emergencies similar to Porras's work. However, unlike the previous work, Rosero's paper is focused on emergencies that may arise in industrial environments.

While the existing works focused only on the training aspect of the virtual environment, we aim to improve the teaching-learning process through virtual assistance to support the user during the entire practice. Also, based on Ortiz et al.'s [11] work, we implemented two different environments with the same process control; *i)* a laboratory to simulate a level control process in a laboratory environment and *ii)* the level control process in an industrial environment.

## 3 System Architecture & Methodology

Fig. 1 shows the proposed architecture for the development of the virtual industrial process assisted by a conversational agent.

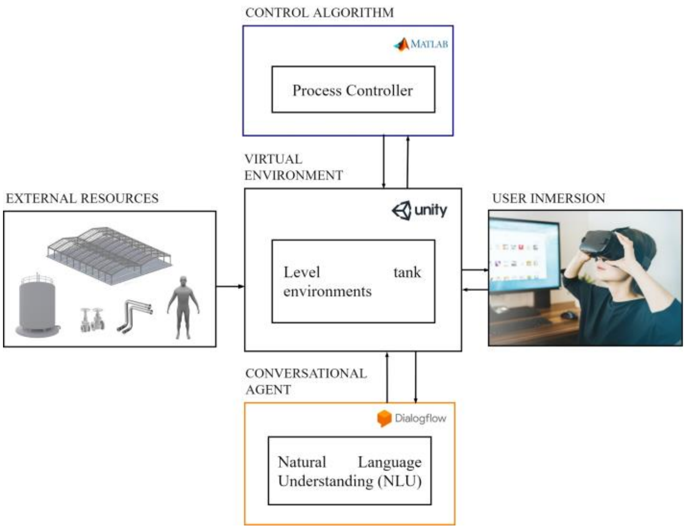


**Fig. 1.** Proposed System Architecture

The system has five main components: *i) External resources*, the environment is designed using external elements, abstracted from the real process to be virtualized; *ii) Virtual Environment*, the simulation of the environment is done through the use of the Unity 3D graphic engine. This tool renders the virtual environment using different scripts, drivers and libraries that allow the correct integration of the virtual environment; *iii) Control Algorithm*, the use of MATLAB program to simulate the environment controller by calculating variables according to the mathematical model; *iv) Conversational Agent*, the use and training of the virtual assistant using Dialogflow. Finally, *v) User Immersion*, which represents the interaction of the user with the system, through input and output devices.

For the development of this system, the Scrum methodology is used, which is a framework focused on an iterative and incremental life cycle. Each component of the system is developed in periods of time called sprints. This iterative process helps to reduce the risk of incorrectly developing the system compared to the use of a traditional methodology [14].

Finally, to measure the simplicity of the system's operation, a usability survey based on the "system usability scale" (SUS) was conducted. SUS makes it possible to evaluate virtually any type of system quickly, easily, and reliably. The "system usability scale" consists of a 10-question survey that users must answer with a weighting from 1 to 5 according to what they consider relevant to each question [15].

# 4 System Development

The level control process virtualization system has been developed with two practical approaches: the first is oriented to a laboratory for educational purposes; and the second allows for simulations of the process in industrial environments. The detailed architecture of the system is shown below (See Fig. 2).

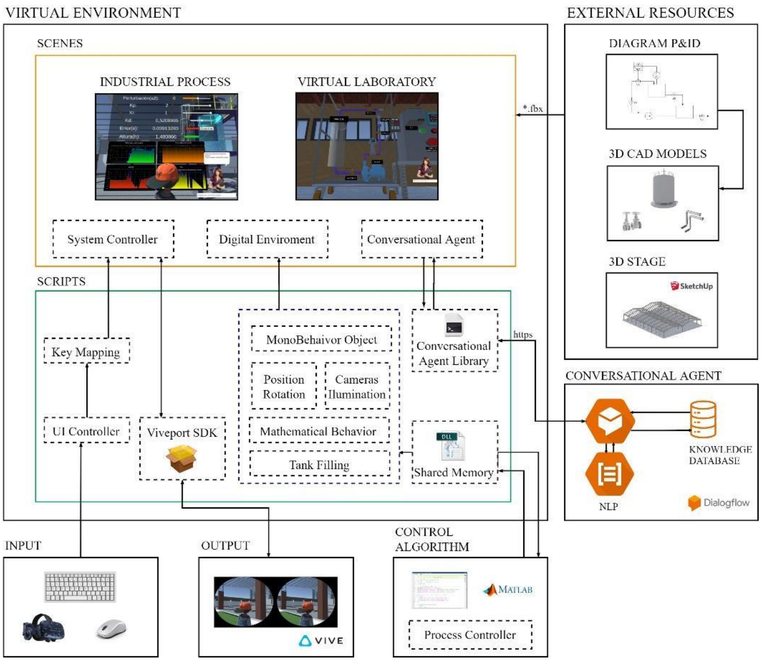


**Fig. 2.** Detailed System Architecture

## 4.1 External Resources

The external resources consist of 3D models that are necessary for the development of the virtual environment. These include: *(i) The virtual scene,* which is developed with SketchUp graphic design and three-dimensional modeling software. In this section the scenario composed of structures and buildings of the virtual laboratory scene and the industrial plant is modeled; all of this is used to add more realism to the system; *(ii) The industrial process* is digitized using AutoCAD Plant 3D and SolidWorks, to model the plant based on P&ID diagrams of the level control process; and *(iii) The 3D model of the avatar* and character animations are obtained from the *Mixamo* tool. All these resources must be exported in *.fbx* format to use them in the virtual environment.

## 4.2 Virtual Environment

For the development of the virtual environment of the system, the graphic engine Unity 3D is used. In this tool, the 3D models developed in Section 3.1 are imported for the digitalization of the scenes. It is necessary to focus into the details of light, materials, and animations. Also, emergency events such as tank explosions or liquid spills when maximum capacity is exceeded should be programmed to create a sense of realism in the environment and to train the user in emergency situations. The Scenes contain *(i) The Virtual Laboratory*, where practices are executed for educational purposes on level control issues and the student can interact with the system without physical or material risks and learn about the control processes; and the *(ii) Industrial process*, in which specific tasks related to the control and maintenance of industrial processes are carried out. The user acquires experience in the industry and in safety protocols, with the possibility to manipulate the environment and acquire the knowledge to solve problems that may occur in an industrial plant.

In addition, the virtual environment executes scripts, which are a sequence of commands that allow the creation and validation of actions within the environment's simulation. It also allows for the addition of the avatar's physical movement and the components of the industrial process, as well as managing the position, rotation, and disposition of the cameras in the scenarios. An important script within the level control system is *Tank Filling*, which contains the mathematical model that represents the characteristics and dynamic behavior of the virtualized industrial process.

The virtual environment has scripts that map keys and buttons of input devices that allow the entry of commands by the user. It is also possible to view the virtual environment through the Viveport SDK with the HTC ViVe virtual reality glasses.

Finally, the environment has libraries that allow for interaction with the components that are part of the system. These libraries are used for session authentication of the conversational agent and for the exchange of information with the Dialogflow platform, while the industrial process controller uses shared memory in .dll format to communicate from the Unity 3D environment with MATLAB mathematical software.

## 4.3 Control Algorithm

With the aim of implementing a control technique that simulates the industrial behavior of a level process, a closed loop control scheme is implemented between the virtual environment developed in the Unity 3D graphics engine and the MATLAB software (see Fig. 3).

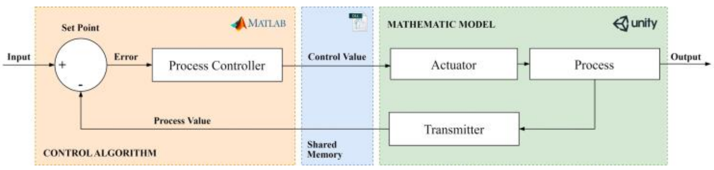


**Fig. 3.** Proposed control scheme

The proposed control scheme is subdivided into two main functionalities: i*) Mathematical Model*, implemented in the Unity 3D through the dynamic of the process represented by the formula:

$$X = \frac{k_1.a_1(t) - k_2.a_2(t)\sqrt{2g.h(t)}}{A} \quad (1)$$

The equation (1) is deducted by Fig. 4. The dynamic model considers the characteristics and limitations of a real process, in order to generate greater realism for the interaction and immersion of the user in the virtualized environment;

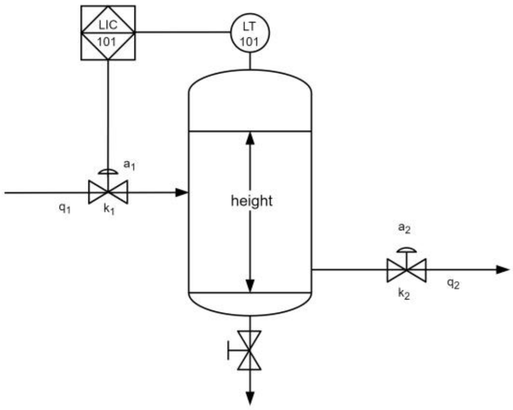


**Fig. 4.** Process Diagram

And *ii) Control Algorithm* is implemented in real time in MATLAB software, which allows proposing different control strategies, for example, PI, PID, among others [16]. These two functionalities exchange information through shared memory in the system.

## 4.4 Conversational Agent

**Table 1.** PNL Cloud Services Comparison

| Features | DialogFlow | Wit.ai | Microsoft Bot Framework | Watson Assistant |
|---|---|---|---|---|
| **Speech to Text** | 10(yes) | 10(yes) | 10(yes) | 10(yes) |
| **Text to Speech** | 10(yes) | 10(yes) | 10(yes) | 10(yes) |
| **Multiple Languages** | 10(yes) | 9(yes) | 9(yes) | 9(yes) |
| **Ecosystem** | 10(completed) | 8(limited) | 9(completed) | 8(completed) |
| **Unity Integration** | 10(yes) | 9(no) | 9(no) | 9(no) |
| **API Calls** | 9(180/min) | 10(240/min) | 9(10000/month) | 9(10000 max) |
| **Price** | 9(free tier) | 10(free) | 8(free tier) | 8(free tier) |
| ***Total*** | 68 | 66 | 64 | 63 |

The integration of a conversational agent within the virtual environment is intended to assist the user during the use of the system. Natural language processing (NLP) services are needed to develop it. Table 1 shows a comparison of Google's DialogFlow, Facebook's Wit.ai, IBM's Watson Assistant and Microsoft's Bot Framework, which are cloud-based platforms for the development of conversational agents using NLP [11, 17]. Dialogflow was chosen for the development of the conversational agent that would assist users in the control processes due to its superior features.

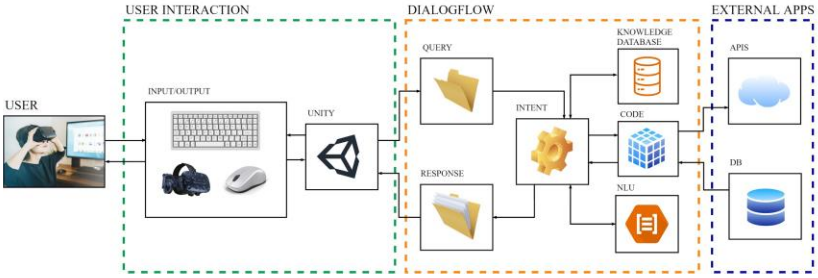


**Fig. 5.** Conversational Agent Architecture

Fig. 5, shows the conversational agent architecture that consists of the following components: *i) User Interaction*, queries are made to the graphic interface of the agent integrated into the virtual environment, the queries are sent and the response is obtained from the platform in the cloud, Dialogflow, using the hypertext transfer communication protocol (HTTP); *ii) Dialogflow*, receives queries known as intents, uses natural language understanding, to respond the user's requests. The ability of the conversational agent to understand and properly answer the questions asked depends on the information provided by experts as a knowledge base. Finally, in *iii) External Apps* information is requested to external services such as databases or APIs in case the application requires it.

### 4.5 Input & Output

The user interaction with the system is done through the input devices (mouse, keyboard) accompanied by the virtual reality device HTC Vive which allows the user to be immersed in the system. Once the input devices interact with the system, generating events and simulations, they are visualized by the HTC Vive.

## 5 Results and Discussion

This section presents the results obtained in the development and implementation of the virtualized industrial process, assisted by a conversational agent. These results are divided into two stages, *i) Interaction with the system*, which details the functionality of the developed system through the main screens of the virtual environment and *ii) Validation of the application*, which analyzes the results obtained from the manipulation of the system by a group of users.

### 5.1 Interaction with the system.

To access all the system's functionality, it is necessary for the user to identify himself, through the login screen (See Fig. 6), where the user can enter through his credentials. This validation restricts the access of unauthorized users to the system.

Once the user accesses the system correctly, they must choose the environment needed. The system implements two main scenarios: the first scenario simulates a level control process in a laboratory environment, while the second scenario simulates the level control process in an industrial environment that reflects the processes in a real environment. This environment allows training of the processes to members of those industries in which real testing means high risks or costs. Both scenarios virtualize the same industrial process but have different approaches and magnitudes. This variety provides a greater openness of the possible uses of the system, allowing the user to choose the scenario he wants to access (See Fig. 7).


**Fig. 6.** Login Page


**Fig. 7.** Environment options

By choosing the scenario, the user enters the 3D virtual environment. The virtual environment is a simulation of the industrial process. In this case, the industrial process represents a level control process. The virtual environment has the user's avatar which can move through the environment and manipulate the different elements of the virtualized industrial process, thus simulating a real interaction. The manipulation and analysis of the elements in the industrial process is carried out by information panels within the virtual environment. In the panels that allow a human-machine interaction, relevant information for the process is shown, and these values are constantly updated according to the changes and alterations made to the elements of the level control process (See Fig. 8).

The use of virtual environments for the simulation of industrial processes allows for the representation of the different states that the physical process can take, without putting at risk the integrity of the machinery or the health of the people (i.e. explosions or errors). The following Fig. 9 shows an example of an explosion of a tank in the industrial process.

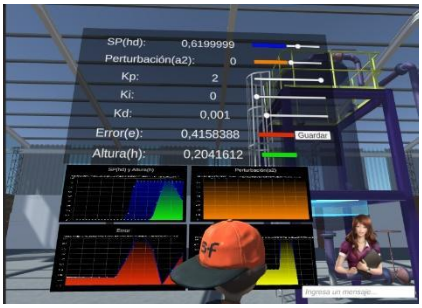


Fig. 8. Industrial process in a virtual environment

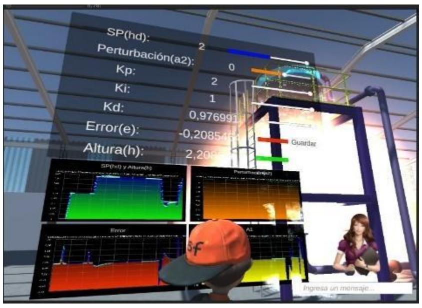


Fig. 9. System explosion animation

The virtual environment has an integrated conversational agent. This virtual assistant has the ability to answer different questions that users have in relation to the industrial process. The assistant imitates the conversation with a real person, who provides personalized assistance throughout the system execution process.

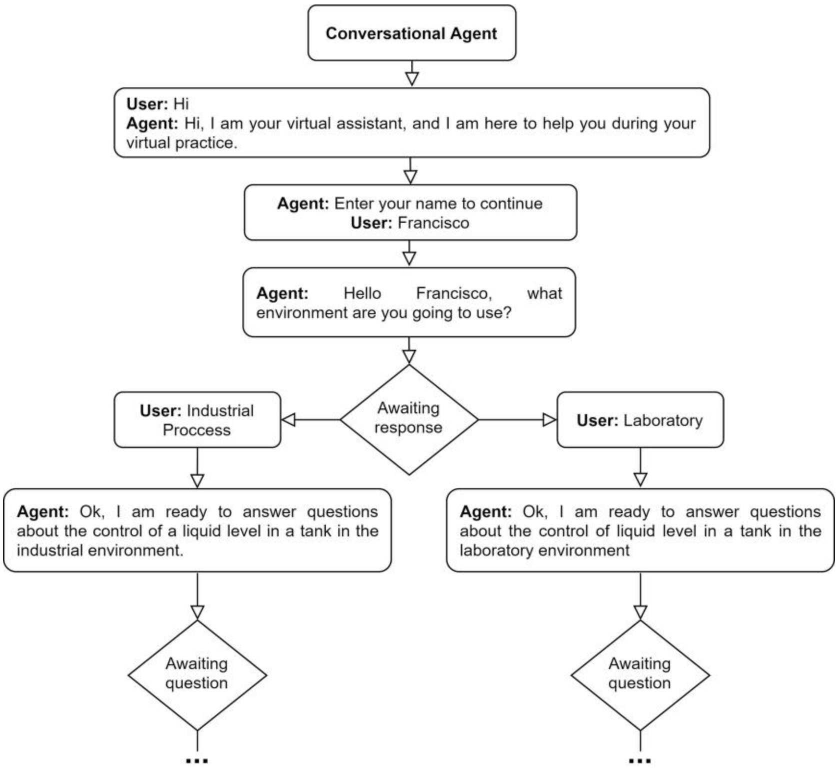


**Fig. 10.** Conversational Agent Flowchart

To interact with the conversational agent, the user must start a conversation using the text box drawn under the assistant's avatar (See Fig. 8). A greeting is sent to the agent's instance on the DialogFlow platform. Then the agent follows the steps of Fig. 10; the agent responds to the user asking for his name, the name is stored in the platform as a variable for use during the conversation.

After the user inserts his/her name in the text box, the agent responds to the user by asking about the environment with which he will interact. The student inserts the name of the environment. Since several environments or industrial processes could exist and the vocabulary used may be totally different from one process to another one, the agent uses *follow-up intents* and *context* of Dialogflow to determine what dataset of knowledge to use based on the user's input. The conversational agent responds, confirming the laboratory selected and waits for questions about the current environment; for example, the values of constants or the use of the control panel, among other virtual environment related questions. For training of the conversational agent a set of 100 questions for each environment are uploaded to the platform.

## 5.2 Validation of the Application

The virtual environment for level control process, assisted by a conversational agent, was tested with a group of 28 users. Fig. 11 shows the user's interaction with the system. Users belonged to a group of engineering students, and had industrial processes laboratory requirements within their college curriculum. For the execution of this application a computer with the following characteristics is required: Windows 10 Home Operating System, 8 GB of memory RAM DDR4, Intel Core i7 processor, System Type x64-based PC, NVIDIA® GeForce® GTX 1650 video card and input and output devices (screen, mouse, keyboard, speaker and virtual reality glasses).

**Fig. 11.** User interaction with the system

To measure the usability of the system, the System Usability Scale (SUS) is used, which consists of a questionnaire with ten questions that have five options for each one. The results are then tabulated and the usability score is calculated, with 100 being the maximum value and 0 the minimum. If a value higher than 80.3 is obtained, the system can be said to have a high degree of usability for users, while if the value is lower than 68 it is below the acceptable average, which yielded the following results. The results presented in Table 2, show that the average usability of the system is 89.25, which can therefore be deemed as user-friendly.

**Table 2.** System Usability Assessment

| Evaluated parameters | Average | Weight | Score |
|---|---|---|---|
| I think that I would like to use VEFIP frequently | 4,8 | x-1 | 3,8 |
| I found VEFIP unnecessarily complex. | 1,3 | 5-x | 3,7 |
| I thought VEFIP was easy to use | 4,6 | x-1 | 3,6 |
| I think that I would need the support of a technical person to be able to use VEFIP | 1,4 | 5-x | 3,6 |
| I found the various functions in VEFIP were well integrated. | 4,0 | x-1 | 3,0 |
| I thought there was too much inconsistency in VEFIP. | 1,8 | 5-x | 3,2 |
| I would imagine that most people would learn to use VEFIP very quickly | 4,8 | x-1 | 3,8 |
| I found VEFIP very cumbersome (awkward) to use. | 1,9 | 5-x | 3,1 |
| I felt very confident using VEFIP. | 4,9 | x-1 | 3,9 |
| I needed to learn a lot of things before I could get going with VEFIP. | 1,0 | 5-x | 4,0 |
| ***Total Amount*** | | | **35.7** |
| ***Final percentage - SUS*** | | | **89,25** |

## 6 Conclusions

An application was developed to simulate the level control process through the use of virtual reality. The system virtualizes the industrial process in two environments: a virtual laboratory and an industrial stage. It allows users to manipulate the elements of the control process safely and reduces the spatial, temporal and economic limitations considerably. Additionally, each user can receive individual assistance during the use of the system, through a conversational agent integrated in the virtual environment, thus improving teaching-learning processes.

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