ABSTRACT

Robots have a continuous increasing role in today's society as they have stepped in the human environment in order to better fulfill the more demanding and complex tasks. Ubiquitous technologies can enhance interaction between human and robot in order to achieve a more natural interaction. In this paper a framework for off-line programming of an industrial robot using ubiquitous technologies is presented. The system allows controlling a virtual model of an industrial robot in an immersive CAVE-like projection system, configuring robot trajectories and simulating the robot actions before the real robot performs the task.

KEY WORDS
Ubiquitous technology, natural user interface, robot programming.

1 INTRODUCTION

The field of robotics exhibits a continuous development in the attempt to ease the human existence. Starting from first generation factory robots that have replaced human operators doing highly automated tasks, robots have evolved and today they are found in the close vicinity of humans, who can interact with them through virtual reality technologies. One aspect of virtual reality programming languages is their ability to create in a 3D environment a visual representation of the robot and associated objects, together with their movement for controlling a real robot. Virtual reality allow the user to view a replica of the robot – the virtual robot – and the environment in which it operates in a 3D virtual world, allowing human operators to remotely control robots that are able to work in environments inaccessible for them.

One of existing interaction method between humans and virtual robot makes use of natural languages [1], such as voice, hand gestures, eye gaze, etc. When the human operator gives tasks to the robot in a natural way, the robots have to identify the operator and to detect his/hers gestures and movements, and translate them into the desired actions. A possible approach in programming robots with natural languages uses ubiquitous technologies [2], in which the robot directly receives environmental data.
Ubiquitous technologies are the technologies that allow for information processing to be incorporated into everyday objects and activities. This paradigm is described as an ambient intelligence, into which everyday objects constantly communicate and interact with each other, in a mobile, self-forming, fully connected, always available network [3]. The underlying communication is usually based on non-intrusive, low power wireless technologies. The ubiquitous paradigm can also enhance the human-robot interaction, making it dynamic, interactive and last but not the least, more natural.

This paper presents one method in which these ubiquitous technologies can improve the interaction between human operators and virtual robots. The focus will be on describing and implementing a paradigm for controlling a robotic arm by integrating ubiquitous technologies and human natural language. We evaluate the system with a test scenario and conclude by presenting further improvements of current developed paradigm and further phases of our project.

2 UBIQUITOUS TECHNOLOGY, A SERVICEABLE TECHNOLOGY FOR HUMANS

Constant technological evolution pushed robots in replacing or assisting humans in more and more tasks. To fulfill human necessities the interaction between human and robot has to be very efficient.

Our purpose is to develop a human-robot interaction system that can improve human day-to-day life by using real-time interaction paradigms between human and robot as close as possible to natural ones. Ubiquitous technologies can improve existing interaction systems by combining wireless devices, artificial intelligence, voice and graphical recognition with the end goal of creating an environment with transparent and reliable intercommunications [4].

Devices built with ubiquitous technologies are “hidden” in the surrounding environment and controlled by the users even without being aware of that [5], [6]. Thus they fit the vision of a more natural environment, and sustainable at the same time. The user is surrounded by miniature intelligent low-power devices that can harvest the energy directly from renewable sources like the sun. The system is a low-cost one and universal, fit to be used for different types of robots, or with minimal changes to another applications. It can be said that ubiquitous technologies allow for repurposing application, being a foundation brick for serviceable human life.

In many research activities, the human interacts with the virtual environment and robots through standard input devices, i.e. keyboard and mouse, or with the help of multi-modal devices, e.g. data glove [7], [8]. The greatest disadvantage of this interface is that interactions between human and environment are limited. It is preferable for the interaction to be made in a direct manner, using natural language. Using ubiquitous technologies the interaction is done in the real surrounding environment and the user is not constrained in any way to a specific environment. While using human operator hand gestures as a command language is convenient, even more advantageous is to use a full range of natural languages as a robot programming language. Beside human gesture, the user can dialogue with a virtual robot using gaze tracking or voice, and the
robot should perform the requested activities. The human operator gestures can be identified using ubiquitous technologies that detect the human natural motion.

According to [9], the interaction using ubiquitous technologies has the following characteristics: 1) collaborative – the human user collaborates with the robot by communication through a natural language and realistic content exchange; 2) portable – mobile devices offer personalized services to the human user anytime and anywhere; 3) intelligent – the interaction interface is transparent.

3 INTERACTION INTERFACE BASED ON UBIQUITOUS TECHNOLOGY

Virtual reality technologies can be used to achieve collision free robot trajectories with high accuracy during off-line programming of an industrial robot. Considering the ubiquitous paradigm of natural interaction, human motion tracking is required in order to set robot configurations.

We propose a framework for ubiquitous human interaction with a virtual reality interface for robot programming, shown in Fig. 1, based on the Microsoft Kinect controller. The system allows programming a virtual industrial robot using only human arms motion and fulfills the interaction characteristics mentioned at the end of the previous section.

Kinect, originally developed as a game interface, is a controlled free interface that enables users to control and interact with virtual environment through natural interaction using gestures, spoken commands, or presented objects and images [10]. The human-device natural interaction paradigms used render external peripherals such as remote controls, keypads or mouse obsolete. Coupled with corresponding software algorithms this device is can provide the following capabilities: full-body 3D motion capture, facial recognition and voice recognition [10].

![System architecture diagram](image-url)
Kinect platform is able to track 6DOFs (degree of freedom) human motion through a combination of hardware and software technologies. An infrared light ray is scattered throughout the scene and the reflected matrix pattern is captured by a CMOS sensor. Based on this pattern the 3D depth image of the scene is reconstructed. In addition to these the Kinect device also has the following features: a RGB camera, a multi-array microphone used for voice recognition, and motor that moves up and down the device after the environment. Other advantages are the ability to capture 3D video data in 3D under various ambient light conditions, software adjustable detection range of the depth sensor, and automatic sensor calibration to focus only users, excluding still objects around them.

The system is designed around a flexible, modular architecture. Computer vision algorithms implemented in the PrimeSense Natural Interaction Middleware process sensory data from the depth and RGB image sensors and generate body and limbs related information for skeleton and hand gestures tracking. OpenNI provides standardized software interfaces for hardware sensors, sensor data processing algorithms and user applications. By using OpenNI the scalability of our proposed solution is greatly increased, since future interaction paradigms based on different ubiquitous devices can be easily integrated into our platform.

The software application of our system was developed in the instrantreality framework which is a high-performance Mixed-Reality system, preferred for its comprehensive set of features and support for classic Virtual Reality and advanced Augmented Reality. In addition, this framework provides sensor abstraction to access the low-level data streams directly as well as high-level device and device-independent components (e.g. in our application: IOSensor-NI).

At application start-up a calibration step is required to identify the human body to be tracked. This is accomplished by the OpenNI interface through a specific “PSI” pose [11]. The IOSensor-NI component interfaces with the OpenNI API and continuously returns the JointPosition and JointOrientation of user hand, and detected body/limbs Gesture. Based on this we compute the hand position and orientation in scene coordinates, which will coincide with the robot end-effector position and orientation. Inverse kinematics is used to extract individual position and orientation for all the robot joints in the kinematic chain. Hand gestures are used to command actions of the robot end-effector (i.e grasp/release). The virtual model of the robot is updated with the new computed coordinates and the loop is repeated. The display and rendering graphics scenes are done in an immersive CAVE system to provide users a strong visual feedback. Using this system makes the virtual environment scale and the human operator environment to be equal.

4 TEST METHODOLOGY
To evaluate the suggested paradigm and the implemented system we developed an experimental scenario based on a practical experiment, i.e. a pick-and-place operation. A robotic task is performed combining the natural hand movement with intuitive hand gestures.
In this operation, shown in Fig. 2, the robot is programmed to move to a position \( P_1 \), with orientation \( O_1 \), grasp a block object, and move it to position \( P_2 \), with orientation \( O_2 \), and release the object. The trajectory between \( P_1 \) and \( P_2 \) and the revolution between \( O_1 \) and \( O_2 \) are defined for the purpose of avoiding obstacles and yielding a smoother motion. Using the above presented framework, the user controls the virtual arm of the robot by moving the hand in the real environment. The grasping action was implemented by RaiseHand gesture that identifies rising of the user left hand.

![Fig. 2 Interaction between human and robot to perform a task](image)

The trajectory obtained by the simulation can be used in programming of the real robot. We conclude that using the proposed framework, simulations of complex robot tasks are possible. Thus, robot end-effectors trajectory efficiency can be optimized. However, in spite these positive results the system has his limitations, mainly when foreign objects between the user and the Kinect device occlude the device vision field, which makes the identification of user and his motion difficult.

**5 CONCLUSION AND FUTURE WORK**

Ubiquitous technologies are becoming more used in every-day life since ubiquitous computing is the next paradigm in interaction with intelligent embedded devices. This article presents a framework for ubiquitous human interaction with a virtual reality interface for robot programming. In comparison with classic virtual reality technologies an improvement of the user comfort when using ubiquitous technologies is observed. User motion tracking can be done in a transparent way by devices that use these technologies without the user being aware of their presence. The human motion tracking is done and virtual robot response is presented to the user in real-time and the user interacts with the virtual robot using natural interaction. The advantage of the framework is the rapidity of creation, quicker revision and analysis of the robot trajectories. The experiment proves that our method which uses an inexpensive tracking system like the Kinect is feasible for robot programming.

Given all these advantages, we conclude that ubiquitous technologies can be successfully integrated in human-robot interaction systems. A ubiquitous technology based system to facilitate the intelligent interaction between human and robot is proposed. Future work will extend the system to allow real-time tele-operation of a real robot, evaluate its performance and propose further improvements.
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7 REFERENCES