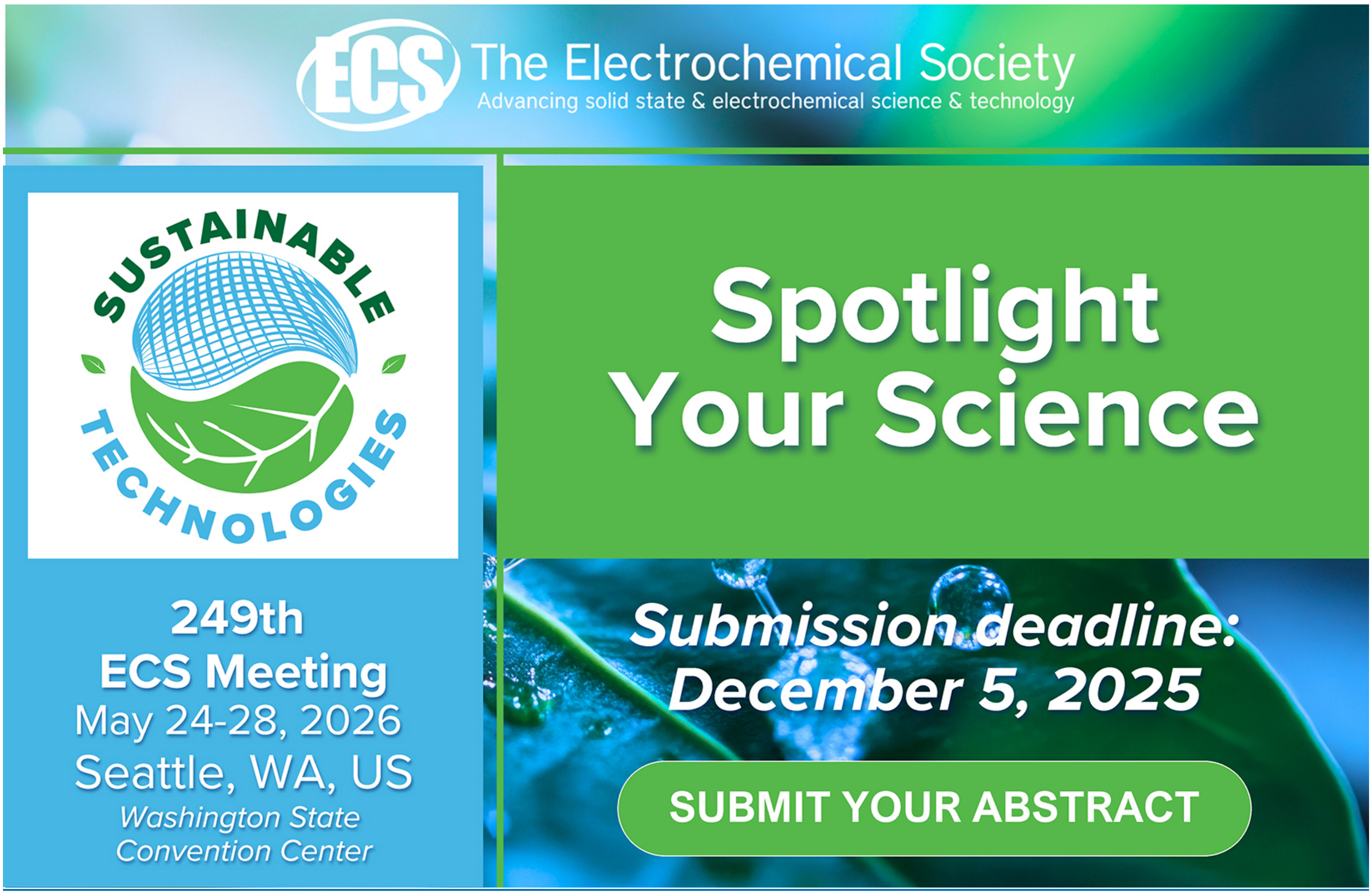
PAPER • OPEN ACCESS

Virtual robot arm controlled by hand gestures via Leap Motion Sensor

To cite this article: O A Rusanu *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **514** 012021



IOP Conf. Series: Materials Science and Engineering **514** (2019) 012021 doi:10.1088/1757-899X/514/1/012021

Virtual robot arm controlled by hand gestures via Leap Motion Sensor

O A Rusanu[1], L Cristea[1], M C Luculescu[1], P A Cotfas[2] and D T Cotfas[2]

[1] Product Design, Mechatronics and Environment Department, *Transilvania* University of Brașov, Brașov, Romania
[2] Electronics and Computers Department, *Transilvania* University of Brașov, Brașov, Romania

E-mail: oana.rusanu@unitbv.ro

Abstract. This paper proposes a LabVIEW instrument aimed to design and control a 3D virtual robot arm using hand gestures translated into commands with the help of Leap Motion Controller. In order to acquire signals and translate them into basic swipe gesture commands, a LabVIEW toolkit was used. The application is useful for providing assistance for people with disabilities who cannot move or lack strong muscle strength. They can use the virtual simulation for training purpose in order to achieve the ability to control a real robot arm. Moreover, they have a visual feedback that sustains and adjusts their movements. The 3D model is a robot arm placed on a flat surface. Translation along two perpendicular directions in the base plan is allowed and also the rotation of its joints. The virtual robot arm can provide several benefits regarding moving to a target, grasping it and bringing it to the patient.

1. Introduction

A robotic arm proves its major usefulness in assisting people with disabilities during their daily life activities, such as: eating, drinking, entertainment, household and self-care tasks. Thus, a mobile telethesis helps these patients by offering them the necessary independence, safety, comfort and self-management in different situations: grasping, raising and bringing some things of various dimensions and weights that are either placed far away or are hard to reach. A major contribution in this field was brought by the research work presented in the scientific paper [1]. It should be highlighted that [1] was the first published paper which proposed the use of the Leap Motion Device for the gestures based control of a real anthropomorphic gripper. More information on the importance of a robotic arm controlled by gestures can be found in the following resources: [2][3][4][5].

This paper presents a LabVIEW instrument which consists of a 3D virtual robotic arm. It is characterized by a natural interaction with the human operator. This means that it can be controlled by natural hand gestures. From a structural-functional point of view, this mechatronic system is considered a mobile telethesis which allows the movement in two perpendicular directions both along x and y-axes.

The virtual simulation developed in NI LabVIEW graphical programming environment can be used for the following purposes:

- testing the working principle underlying a robotic arm;
- remote control of a robotic arm via a web-based application;
- training the patients with disabilities in order to improve their accuracy, precision and effectiveness in hand gestures control applications.

IOP Conf. Series: Materials Science and Engineering **514** (2019) 012021 doi:10.1088/1757-899X/514/1/012021

2. Hardware system

The application proposed in this paper is based on using the Leap Motion Sensor (Figure 1) aimed to acquire raw signals corresponding to some hand gestures in order to translate them into certain commands to the 3D robot arm. Leap Motion Controller [6] is a low-cost and portable device allowing tracking and recording the position, orientation and speed of 3D hands and fingers. It is composed of two cameras and three infrared LEDs. These components are necessary for tracking the infrared light characterized by a wavelength of 850 nanometers meaning it is outside the visible light spectrum. Leap Motion embedded device comprises wide angle lenses which provide a large interaction space with a shape similar to an inverted pyramid [7]. The viewing range across the intersection of the binocular cameras' fields of view is estimated to 80 centimeters. This range is influenced by the propagation and intensity of LED light. Firstly, the sensor data is acquired into the local memory of the device's USB controller for performing certain resolution adjustments. Secondly, raw data is streamed via USB to be analysed by the Leap Motion tracking software. Raw data is related to grayscale stereo images of the near-infrared light spectrum, which is divided into the left and right cameras [7].

The most important part of the Leap Motion Sensor is the specialized software based on advanced algorithms applied to the raw sensor data in order to process the acquired images, compensate for background objects and ambient environmental lighting and reconstruct a 3D representation of the viewed sight. The smooth temporal coherence of the acquired data is achieved thanks to using filtering techniques [7].

MakerHub provides LabVIEW developers with an intuitive library of functions aimed to access the entire functionality of Leap Motion Controller [8]. Thus, by using the LabVIEW based toolkit, it is possible to access the position and velocity of points and hands as well as to read the following gestures: swipe, screen tap, key tap and circles. Moreover, it facilitates reading of raw frame data related to rolling, pitch, yaw, velocity and position for every point, hand or gesture in the frame.

3. Software system

3.1. Design of the 3D interactive model based on the kinematic structure of a robotic arm

This challenge was solved by taking advantage of the NI LabVIEW graphical programming environment that provides the '3D Picture Control' Functions Palette necessary to design and control certain complex 3D models. Accordingly, the virtual instrument developed in LabVIEW includes:

- the parameters used for the building of 3D geometric shapes;
- wired linking or suitable correspondence between introduced components so that they can be correctly positioned and properly oriented;
- the necessary transformations for the translation and rotation movements.

3.2. Control of the 3D interactive model based on the working principle of a robotic arm

The natural interaction between the robotic arm and human operator is based on the intuitive hand gestures identified via Leap Motion Sensor.

Regarding accessing the functionality provided by Leap Motion Sensor, it was used the free LabVIEW based Toolkit developed by MakerHub [8]. There were called the two Leap based functions: *Open Connection* and *Read One Swipe Gesture Direction* (Up, Down, Right, Left, In, Out). A subsequent stage is related to some calculus in order to map the input values received from the Leap Motion Sensor to the output values sent to the *Rotate Object* for controlling or animating the 3D robot arm.

These numerical values were set after experimenting with different examples in order to get a synchronicity between the pattern of hand gestures and the visual command executed by the robot arm. Thus, there were accomplished the following controlling sequences (Figure 3) related to swipe gestures versus position changing of the robot arm:

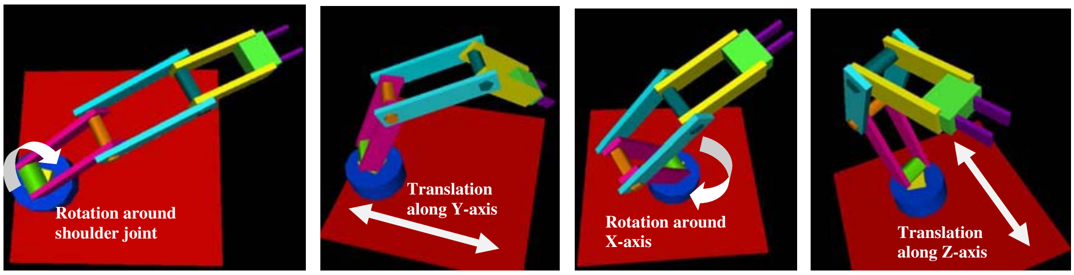


Figure 1. Different possibilities of controlling the 3D robotic arm designed in LabVIEW.

Thus, there were accomplished the following controlling sequences (Figure 3) related to swipe gestures versus position changing of the robot arm:

- Up and Down swipe gesture → move the 3D robot arm along the Z-axis (translation forwards and backwards along the virtual red coloured floor);
- Right and Left swipe gesture → move the 3D robot arm along the Y-axis (translation to the right and to the left margins of the virtual red coloured floor);
- In and Out swipe → rotate the shoulder of the 3D robot arm, respectively adjusting the angle value underlying the rotation process.

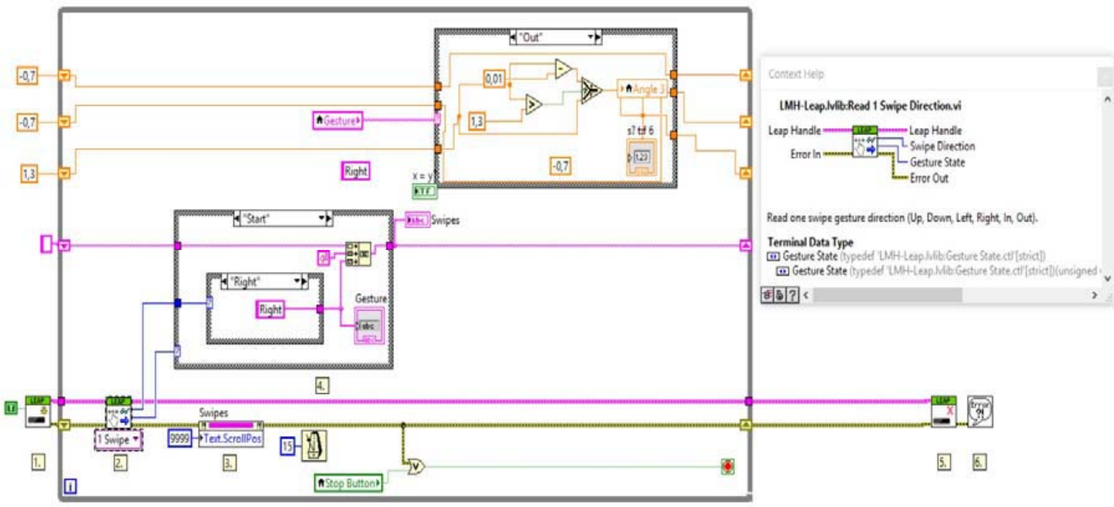


Figure 2. A LabVIEW programming sequence for the implementation of hand gestures based 3D robot arm control using Leap Motion Sensor.

According to the Figure 2, the 3D virtual robot arm is able to execute various movements so that it can easily change its position and orientation. Both design and control of the 3D structure are implemented using LabVIEW graphical programming environment.

3.3. LabVIEW based design and control of the 3D virtual robot arm

The Block Diagram is divided into the following three programming sequences (Figures 4 and 5):

- Creating the elements (geometric shapes) which are put together in order to build the 3D structure of the robot arm. There are used the following functions: Create Object, Create Cylinder, Create Box and Create Sphere. There are also invoked the following Property Nodes: Set Drawable and Add Object.
- Manual and automated control of the 3D virtual robot arm involved the following structures:

- A while loop which includes a Flat sequence structure composed by two state/frames. The first frame encompasses:
- Some functions necessary to animating or controlling the 3D robot arm: Clear Transformations, Translate Object, Rotate Object and Scale Object;
- A few while loops which allow the implementation of gesture-controlled 3D robot arm by using a Leap Motion sensor;
- Display the final result – the 3D scene which shows the animations of the 3D robot arm. This element is included by the second frame of the above mentioned Flat Sequence Structure.

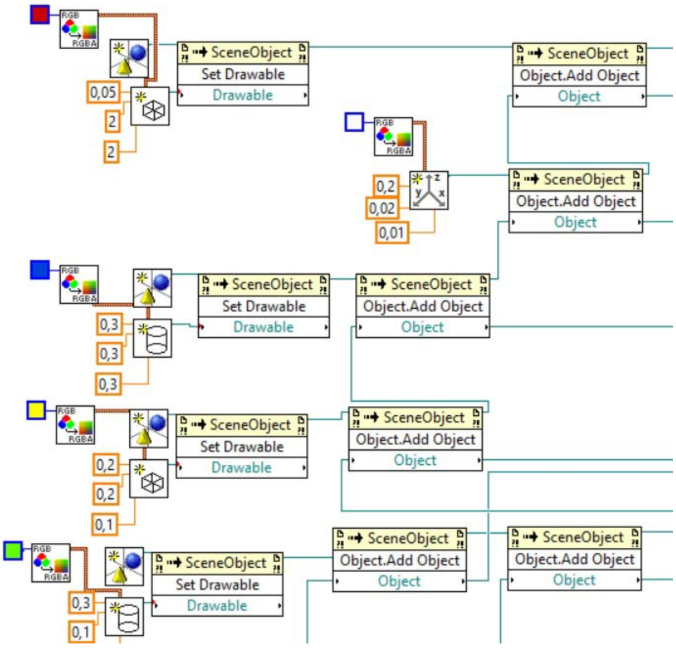


Figure 3. A LabVIEW based programming sequence using 3D Picture Control Functions and Property Nodes underlying the design of the virtual robot arm.

The programming structures and functions used in the Block Diagram are explained below.

3.3.1. Creating the elements (base, shoulder, elbow, wrist and gripper) included by the structure of the 3D robot arm. Using the *Create Object* function, it is possible to create a 3D object which will be displayed on the Front Panel. This function was necessary to create each element from the structure of the 3D robot arm. These elements could be identified by the terminal called *Name* which is a string variable. The elements have both circular and rectangular shapes.

By accessing the contextual menu of the Create Object function, the next stage consists in selecting the following features: *Create/ Method for SceneObject Class/ Set Drawable*.

Using the Drawable attribute, it was set the geometric shape (cylinder or rectangle) of the geometric elements which allowed the design of the 3D robot arm.

The *Create Cylinder* function was called in order to set the specific shape of a cylinder. There were assigned certain values corresponding to the following dimensions: detail, height and radius.

The *Create Box* function was called in order to set the specific shape of a rectangle. There were set some values according to the specific dimensions on each axis direction: X, Y and Z (height, length and width). There was also established the colour parameter for both functions: *Create Cylinder* and *Create Box*. The above mentioned values were set based on empirical experiments and continuous testing in order to get a realistic design and a robust control. The elements are also symmetrical.

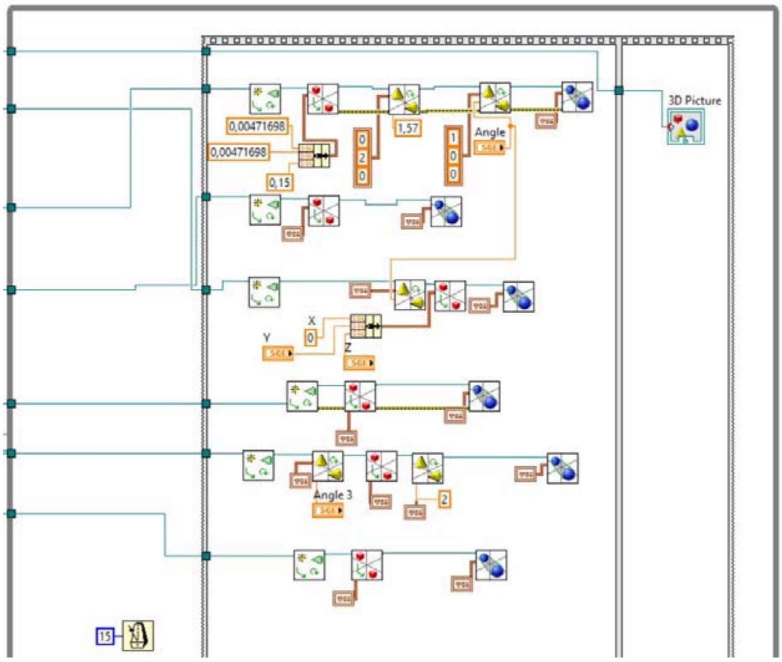


Figure 4 A LabVIEW based programming sequence using 3D Picture Control Functions enabling both manual and automated control of the virtual robot arm.

It is necessary in order to connect multiple elements to a single base element. For instance, on the virtual floor (red coloured thin rectangular area) it was placed the fundamental/base element of the robot arm (blue coloured cylinder). In a similar manner, the two green plates included by the *shoulder* joint are attached to the small green coloured cylindrical joint. The output of the Add Object Property Node was sent to the 3D Picture terminal/scene which allows the displaying of the 3D robot on the Front Panel.

An important function called *Create 3D Axis* can be also attached to the *Add Object* Property Node. An axis was defined in order to enable the rotation of the base element along with the other geometric shapes linked to it. In fact, using another Add Object Property Node, all the 3D structures are associated with that specific 3D Axis so that it is established the 3D space in the scene. The axis is characterized by the following values: length, radius and character size.

3.3.2. Manual and automated control of the 3D virtual robot arm. The manual control of the 3D robot arm is based on quickly or slowly adjusting the Knob buttons displayed on the Front Panel. The control of the 3D figure is related to running the animations shown by the 3D scene. Therefore, specific functions were used: *Clear Transformation, Translate Object* and *Scale Object*. The animations consist of the continuous movement of the elements (base, shoulder, elbow, wrist and gripper) included by the structure of the 3D robot arm. The orientation of the movement associated with these elements was achieved by calling the *Rotate Object* function. There were assigned certain values corresponding to the axis and the angle of rotation. The *Rotate Object* function plays an important role allowing the control and command of the 3D virtual figure due to setting a constant corresponding to the axis of rotation and an input numerical variable which receives specific values associated to the movement of an element (base, shoulder, elbow, etc.). These input values can be updated and modified while the simulation/application is running by adjusting the Button Knob which is attached to the *Rotate Object* function on the Block Diagram.

The input values can be introduced not only by this numerical control but also by the value sent by the Leap Motion Sensor according to the gesture executed. Therefore, the control linked to the *Rotate*

IOP Conf. Series: Materials Science and Engineering **514** (2019) 012021 doi:10.1088/1757-899X/514/1/012021

Object is substituted by another control which is used for transferring the values received as a result of performing some hand gestures.

4. Conclusion

To conclude, this paper proposed a LabVIEW based application aimed both to design the kinematic structure of a 3D virtual robot arm and to control it by using hand gestures acquired from the Leap Motion Sensor. The novelty of this virtual instrument lies in the following contributions: creating and controlling a LabVIEW based 3D model similar to a mobile telethesis and integrating the advanced functionality offered by the Leap Motion Device. Thus, it results an interactive simulation useful for achieving a training environment which provides people with motor disabilities the possibility of learning how to use hand gestures in order to control a realistic robot arm.

The Block Diagram is consisting of certain Functions and Property Nodes included by the `3D Picture` Palette necessary to firstly, create a 3D object (rectangle or cylinder) and secondly, add an object to the base in order to build the entire virtual robot arm. Further, there are also used a few functions necessary to manually or automatically control and animate the 3D model. There are used some geometrical transformations in order to translate or rotate objects across the initially set axis. The most significant feature of the LabVIEW based application proposed in this paper is related to the possibility of hand gestures based control. A programming sequence allows the process of acquiring raw data from Leap Motion Sensor and mapping them to the corresponding numerical values necessary to be transferred to the Translate Object and Rotate Object functions in order to enable the automated control of the 3D virtual robot arm. This application proves its usefulness by providing assistance to people with motor disabilities if the commands sent to the virtual model are associated with a real device. The 3D robot arm helps the disabled patients by offering them an attractive feedback during their training. Another utility is related to the remote applications of such an assistive device used by security staff during operating in dangerous media.

One of the future research directions is related to the development of a web-based instrument in order to transfer gesture-based commands across a long distance enabling the control of a real robot arm. Moreover, the research efforts are focused in the direction of extending the types of hand gestures necessary to control the virtual robot arm.

5. References

[1] Starețu I and Moldovan C 2016 *Leap Motion Device Used to Control Real Anthropomorphic Gripper* in the International Journal of Advanced Robotic Systems (IJARS) 13 pp ...

[2] Gunawardane H, Madagedara N and Madhusanka A 2016 *Control of Robot Arm Based on Hand Gestures Using Leap Motion Sensor Technology* in the International Journal of Robotics and Mechatronics **3** pp …

[3] Sathiyanarayanan M, Azharuddin S, Kumar S and Khan G 2014 Gesture controlled robot for military purpose in the *International Journal For Technological Research In Engineering (IJTRE)* **1** pp 1300 – 1303

[4] Suresh A, Gaba D, Bhambri S and Laha D 2018 Intelligent Multi-fingered Dexterous Hand Using Virtual Reality (VR) and Robot Operating System (ROS) *Proceedings of the 2018 Robot Intelligence Technology and Applications 5. Advances in Intelligent Systems and Computing 2017* pp 459 – 474

[5] Chen M, Liu C and Du G 2018 A human–robot interface for mobile manipulator in the *Journal of Intelligent Service Robotics* **11** pp 269 - 278

[6] Leap Motion, https://www.leapmotion.com/, available on 05.05.2018

[7] How does the Leap Motion Controller work, http://blog.leapmotion.com/hardware-to-software-how-does-the-leap-motion-controller-work/, available on 05.08.2018

[8] LV MakerHub – LMC, https://www.labviewmakerhub.com/doku.php?id=libraries:leap:start, available on 05.05.2018