# REMOTE CONTROL SYSTEM FOR 3D PRINTED ROBOTIC ARM BASED ON KINECT CAMERA

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## 1. INTRODUCTION

Sometimes, in industrial applications, the operatives have to use robots which are in a risky environment. Tele-control represents a good solution to control the robot from distant places (for example during handling, welding or assembling operations) maintaining the right level of safety. An innovative solution can be the use of Time-Of-Flight (TOF) cameras (for example Kinect camera, Microsoft TM) to remote control the robotic system without using other types of wearable or holding controllers [1].

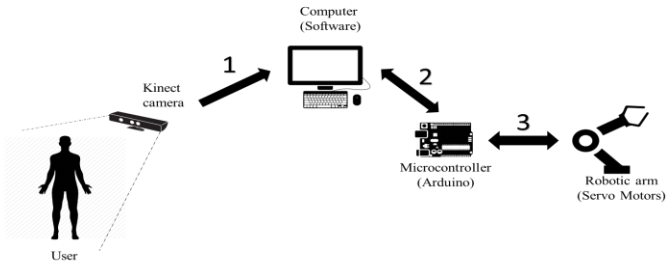



*Figure 1. Scheme of the remote control System*

In the current work, the movement of the human body is captured with Kinect Camera by measuring 3D point clouds. The human body skeleton is then tracked by using skeleton tracking developed thanks to the Microsoft Kinect Software Development Kit (SDK). Furthermore, the measured joints are used in order to calculate angles between human limbs. All these data are finally used for the remote control of a four axis robotic arm. All parts of the robotic arm were made and reconstructed using a 3D printer.

## 2. ARCHITECTURE OF THE CONTROL SYSTEM

A remote control system is created for a 3D printed robotic arm by using Kinect Sensor. The system diagram is shown in figure 1. The system is composed of three parts. The first part aims to find the angles between upper limb joints by using the point clouds acquired by the Kinect Sensor; the second part calculates the kinematics equations of the robot arm; the last part sends the processed data to the robot to control the movement [2].

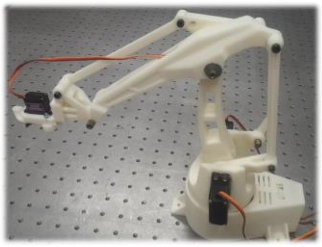
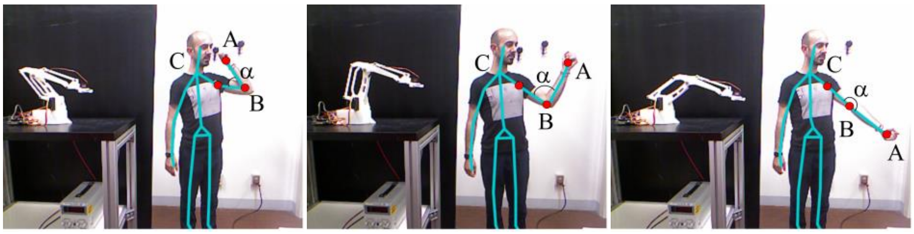


*Figure 2. The 3D printed robotic arm*

The system is composed of the following devices:

- **Kinect Camera:** TOF camera able to measure the 3D coordinate of the scene. It can be used to track the human body skeleton and to recognize the human gesture.
- **Computer (Software):** The computer is used as a bridge to receive data from Kinect sensor and to send the processed data to the microcontroller. The visual interface program is developed in Visual Studio 2015 with C# language to calculate the angles between limbs.




*(a)* *(b)* *(c)*

*Figure 3: Example of control system behavior. Robot position and elbow angle computation at (a) minimum, (b) middle, and (c) maximum arm position.*

- **Microcontroller:** Arduino Uno microcontroller is used. The purpose of the microcontroller is to drive the servo motors of the robotic arm.
- **Robotic Arm:** a four axis open source 3D robotic arm (figure 2) is used in this work (EEZYbotARM MK2, EEZYRobots$^{TM}$). All parts of the robotic arm are printed by a 3D printer and reconstructed completely.

In the following, the logic of the system will be explained more in detail. The data processing starts to capture the user joint coordinates by using Kinect camera. Data are sent to the computer in order to calculate the upper limb joints angles by using the developed software. Afterwards, the calculated angles are sent to the Arduino Uno microcontroller via USB-cable. The motors are controlled using Pulse-Width-Modulation (PWM) technique. The robotic arms were then moved by following the motion of the user body.

## 3. COMPUTATION OF THE JOINT ANGLE

The measured joint positions are used to calculate the angle between limbs. Figure 3 shows an example of such calculation: angle $\alpha$ represents the angle between the arm (BC) and the forearm (BA). The joint positions are measured by using skeleton tracking algorithms. In the example of figure 3, vectors $\overrightarrow{BA}$ and $\overrightarrow{BC}$ are calculated by using the position of the joints A, B, and C (measured by the Kinect sensor), and angle $\alpha$ is simple computed using dot product [3]. The angle computation is developed for the elbow joint and for the shoulder joint (the shoulder is described by two angles, one along the frontal plane and one along the transversal plane).

The computed angles cannot be sent to the robot's servo motors directly because human limb movements and robot movements are limited. For this reason, a mapping between human limb ranges and servo motor ranges was developed. As an example, the minimum, the middle and the maximum positions of the human elbow and of the robot are reported in figure 3. Table 1 shows the angles measured from the human arm, mapped and sent to the robot, for each measured human joint.

*Table 1. Angles measured from the human arm, mapped and sent to the robot, for each measured human joint.*

| # | Shoulder frontal angle [deg] | | Shoulder traversal angle [deg] | | Elbow angle [deg] | |
|---|---|---|---|---|---|---|
| | **Kinect** | **Actuators** | **Kinect** | **Actuators** | **Kinect** | **Actuators** |
| 1 | 160 | 160 | 160 | 165 | 179 | 155 |
| 2 | 140 | 150 | 120 | 65 | 130 | 113 |
| 3 | 95 | 127 | 130 | 90 | 100 | 87 |
| 4 | 90 | 125 | 110 | 40 | 90 | 79 |
| 5 | 50 | 105 | 105 | 27 | 50 | 45 |
| 6 | 40 | 100 | 102 | 20 | 30 | 28 |
| 7 | 30 | 95 | 100 | 15 | 20 | 20 |

## 4. CONCLUSION

The aim of this project is to create a remote control system for a robotic arm based on the Kinect sensor. The human movements were recorded and transferred to the robotic device. A well-priced control system was created which can be used for industrial purposes as well as for educational applications.

## REFERENCES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