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ABB YUMI© HIGH-SPEED PICK AND PLACE GAME IN ACTION

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Abstract

This paper discusses the use of collaborative robots in areas where un-trained users can safely interact with industrial robots. As an example of a demonstration, it was used in an application where the robot plays a game with a museum visitor. The robot continuously interacts with the user and performs its pre-defined task while communicating with PC interface where the system informs its state to the user. Similar architecture can be applied in various industrial applications where it needs to collaborate human operators with industrial robots. The collaborative robot used in this task was ABB Yumi, the dual arm robot. During the study, it was emphasized to avoid the use of sensors while examining possible ways to simplify the system to realize the task outcome with software development. The objective of this project was achieved with provided resources in Mechatronics and Autonomous Systems Centre of Tallinn University of Technology. This paper presents the methodology, hardware and software scheme deployed in the project. This project has been demonstrated for TalTech 100 years exhibition.

Keywords: ABB YuMi© Robot; human robot interaction; entertaining robots; mechatronics; collaborative robots

1. Introduction

Human-robot interaction known as HRI is the study of the interaction between humans and robots [1]. HRI research spans a wide range of field and included but not limited to methods for human-robot coordination. While robots were initially used in repetitive tasks, nowadays they are handling more complex and less structured tasks and activities. This level of complexity motivated researchers to study how humans interact with robots, and how best to design and implement robot systems capable of accomplishing interactive tasks in human environments [1] [2].

As a practice, we simulated the interaction between collaborative dual arm robot (ABB YuMi© robot) with a human for a magic card trick. Previously, the cooperation of humans and robots has been practised in industry, science and etc. YuMi© is the absolute proof of this concept and one of the reasons that motivated us to implement this practice is illustrating robots can not only cooperate but also entertain human.

2. Objective

Demonstration of modern collaborative robotics applications to students and educators to understand the technology of the industrial robots was the main objective of the task. This objective supposed to realize using a game between human user and an industrial robot manipulator. The game is playing card magic trick with YuMi© robot for TalTech>100 exhibition is the main objective of this project. For that, implementation of playing algorithm as well as human interface have practised. Also, design and manufacturing electromagnetic grippers and dynamic card holders have done.

3. Scope

The scope of the task is to get human user input from PC user interface. Coordinate the robot based on pre-defined coordinates while avoiding the use of any electro-mechanical sensors. During this task, we did not consider the feedback from the robot because of the limitation, but it would be a complementary part of this project to ensure the designers regarding the robust application of the system.

4. Methodology

The first part of our study considers problem-solving. In order to accelerate the process and make it attractive we practised electro-magnet grippers, dynamic card holders and metal cards which all aligned with project's objective. In addition, making an interactive human interface in C# synchronized with the robot controller is another outcome of this project. Meanwhile, we should bear in mind that communication between interface and robot controller is the absolute part of this project. For that, we used TCP/IP protocol that both programs, RobotStudio and Visual Studio, support.

5. Workflow/Flow of Control

The idea of the Robot performing the card trick is new, the most interesting part of the project is the interaction between the player and the robot. In order to achieve this, we have used software like RobotStudio, Arduino and Visual Studio. Essentially, the card trick has three iterations.

On each iteration, the player is prompted via the interface to validate his/her choice, upon which the command is sent to robot studio and further to the Arduino program to rotate the servo motor on which the cardholder is mounted. We felt that the cardholder rotation before the shuffling provides an immersion for the player. Upon the cardholder rotation, the cards are shuffled independently. At the end of the third iteration, based on the card's positional change, the robot picks the exact card the player desired.

6. Hardware Scheme

6.1. 3D printed objects

In order to execute the card trick, it is essential to customize the Gripper of YuMi robot. Since the gripper is manoeuvred to pick and place the card, the design is carefully selected before printing the gripper. Some components of the cardholder are also 3D printed. The cardholder is supported with servo motors for the purpose of the rotation. Care has to be given to the stability of the cardholder. All objects were made out of PLA material that is used by 3D SYSTEMS 3D printer. ABS material has been used as a raft material. [3]

6.2. 3D printed Gripper

The design of the 3D Gripper was of fundamental importance. The existing YuMi© Gripper was not customizable to facilitate a 24V solenoid [4][5]. To execute this trick picking and placing the cards are mandatory. Therefore, each card is sandwiched with a 2mm cold rolled metal sheet. In principle, as the gripper moves into its position to pick the card, a pulse is sent to switch the solenoid ON. Hence, the card can be grabbed and traversed to its destination position.

The Gripper design was modelled using SolidWorks. Various considerations were entertained while modelling the gripper. Due to the support required by the card while the gripper picks the card, the final design has been modified providing a chamfer for the card to slide and get attached to the solenoid with ease. The 3D printed gripper (Fig. 1) has three components, the fingers, the cylinder to support the solenoid and the base which gets attached to the arm. The components were independently printed and pasted to form a complete assembly.

The gripper had to undergo major design changes due to practical limitations. For instance, the magnetizing surface of the solenoid was 30mm in diameter against the card with 65mm length and 3mm thickness [6]. Although, the card can be efficiently picked with these parameters, however, or poses a threat while traversing the cards. Hence, an internal 45 degrees taper is provided inside the gripper as a support. With this change in design, the execution was quite reliable.

6.3. Cardholder

The cardholder (Fig. 2) was also modelled using SolidWorks. Since it was required that the cards have to be viewed clearly and attractiveness was also a concern, the final model of the cardholder is 45 degrees truncated cylinder. There are 8 rectangular openings provided to locate the cards. Most importantly, beneath each opening, a box with the magnet is provided. These boxes (Fig. 3) were also 3D printed and pasted to form a complete assembly.

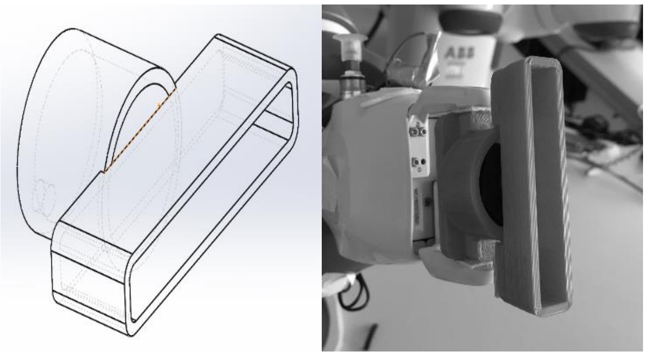

Fig. 1. Design and 3D Printed Gripper

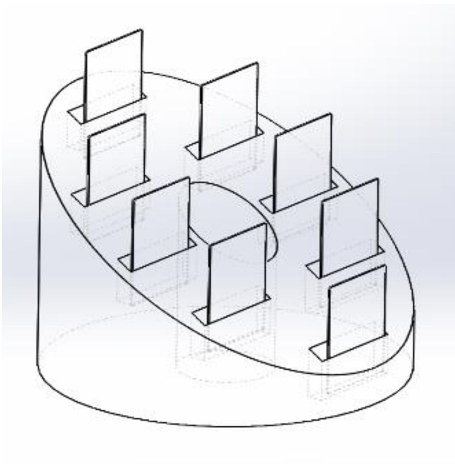

Fig. 2. Card Holder

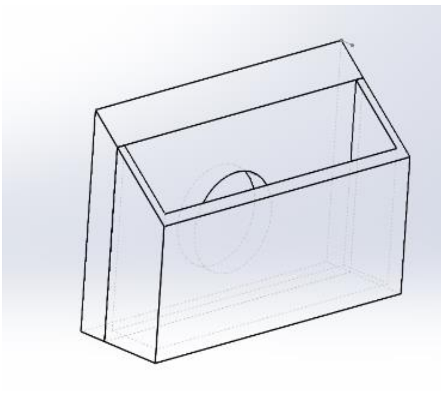

Fig. 3. Design of Box for Magnetic Surface

7. Strategy to Pick and Place

On player's command, in order to continue with the card trick, shuffling of the cards are necessary. However, this can only be done with YuMi© with special considerations. We decided to use the magnetizing effect in order to pick and place the cards, as this method would be much convenient compared to grabbing the cards and placing them in preferred positions.

7.1. Cards

Although regular playing cards have been used in this project, due to utilizing the magnetizing effect the cards have to be supported with a metal surface. Hence, we used a metal plate of thickness 2mm that was cut to the size of the card and attached on the backside of the card. Now, when the gripper moves in to pick the card, the 2mm surface comes in contact with the solenoid.

7.2. Solenoid

YuMi's 24V digital output is extended to power a 24V solenoid, which periodically sends a signal as per the RAPID program. This means, the signal enables the solenoid in the gripper to magnetically attract the card and the magnetic effect is retained until the card has been placed in the desired position. After which the digital output signal will be turned off (Fig. 4).

Fig. 4. Electromagnetic Solenoid

7.3. Rotation

Simply put, the cardholder will be facing the player when an input is required to further proceed with the trick (the player input is given through the special interface we have designed, the interface will be explained in the software section). During shuffling, the cardholder will be faced towards the YuMi©. To achieve this, each cardholder is supported with a servo motor. A simple microcontroller Arduino MEGA has been used to achieve the rotation of the cardholder [7]. It is necessary to rotate the cardholder by an angle of 180 degrees. This begins with a 24 V from Yumi© as a digital output, then it has to go to Arduino as a digital input to run the servo motors. To do that, we have to regulate the voltage from 24 V to 5 V using a voltage divider or voltage regulator, after that, once Arduino receives Yumi's signal, Arduino starts to send a signal to the servo motor controller to rotate from 0 to 180 degrees port (Fig. 5).

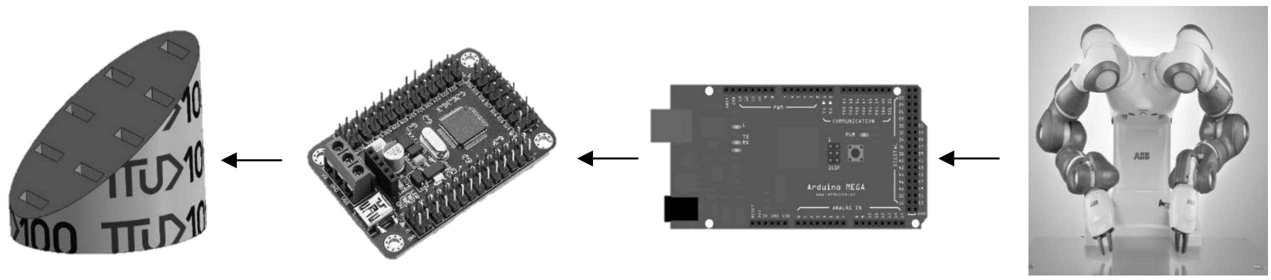

Fig. 5. Rotation Workflow

8. Software Scheme

8.1. Interaction between player and YuMi© robot

Attractiveness is the major concern in our project. Since C# provides features to design creative User Interface (UI), we utilized this option to design our UI using C# by specific algorithm (Fig. 6).

The UI (Fig. 7) prompts the player to identify the position (in which cardholder is the chosen card present) of the chosen card in three iterations. The appearance of this program includes 8 Panels changed in different steps. In each step, the defined data which is related to the selected circle by the player will be sent to RobotStudio by TCP/IP [8], our communication method between C# and RobotStudio. For this communication, we used Thread function in C# that enables to have parallel loops in our program [9], one for getting and analysing input data by the player and another one, for sending needed data to RobotStudio.

8.2. Rotation of cardholders

To achieve the controlled rotation, we used Arduino Mega which enables us to control the exact angle of servo motors. Arduino is coded to rotate the cardholder by 180 degrees in order to execute the next iteration.

8.3. YuMi© Robot Programming

In this stage, we are dealing with different input data from Arduino and C#. When the player prompts with the provided UI, the signal is sent to Arduino to rotate the card holders 180 degrees. Then, YuMi© executes the shuffling in every cardholder. In the first instance of the iteration, 5 cards will be shuffled. Subsequently, in the second iteration, 3 cards will be shuffled. And finally, in the third iteration, only one card will be shuffled. On completion of every iteration after shuffling, YuMi© sends a signal to Arduino to execute the rotation, such that the cardholder faces the player.

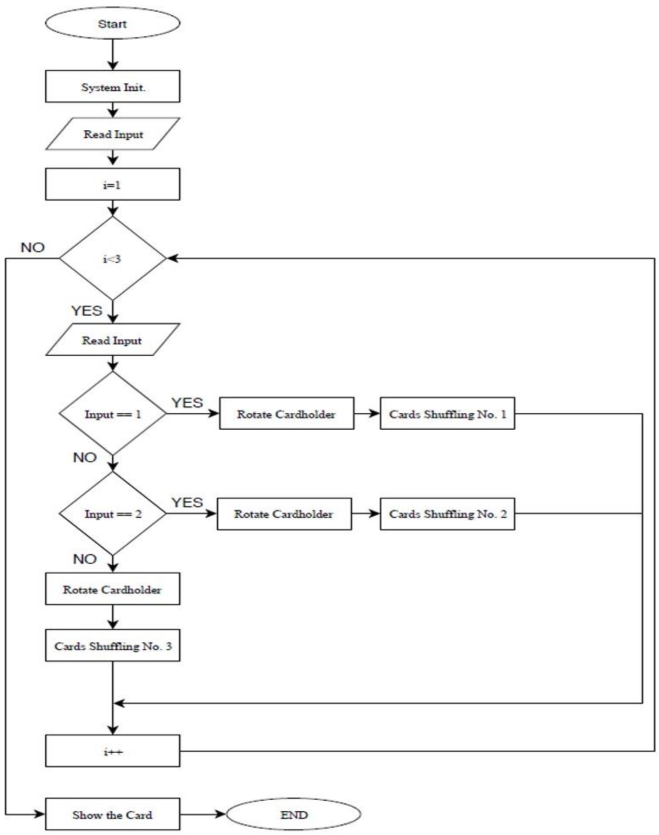

Fig. 6. Software Flowchart

Fig. 7. User Interface

9. Conclusion

To conclude, we implemented our own cards holder design using the available materials in the lab as well as using the CNC machine and 3D printer also we attached metal sheets to the cards to be able to magnetize them whether from the top or the back side. The gripper design was implemented using 3D printer after finalizing the design on solid works and it was sufficient enough at this stage but not efficient for the long-term that is why it needs to be improved or changed to another design.

We made an interface between YuMi© robot and the user using C# visual studio and established a TCP communication between both of them to send and receive the commands from the interface device to RAPID program and vice versa. The time for the whole round will be approximately 5 minutes and each movement need 30 seconds. The actual speed will be 25% of the whole speed of YuMi robot and this can be improved by reducing the errors of the cardholders like fixing the motors with bearings to avoid bending and to get an accurate angle from the motor also, increasing the cups chambers to have more ability to insert the card into the cup.

The thickness of the metal sheet attached to the cards was not enough to let the solenoid grab the cards and this happened mainly because of two reasons. First, the force of the magnet inserted inside the cup is larger than the solenoid force so we need to replace the magnets with smaller ones. The second reason is that the solenoid's force which is available in our laboratory has 25 N which is not enough for gripping the cards perfectly. Instead of having a complex mechanism, we used 3 servo motors each one attached underneath each cardholder for rotating them from 0 to 180 degree and back from 180 to 0 degree using Arduino to control that after getting a signal from the robot.

10. Improvement

To improve the project, we mainly need to focus first on the cardholder by having a well-manufactured cardholder that will eliminate the errors we faced i.e. inaccurate position, Non-stability, holes not aligned etc. The gripper design should be modified by reducing the printed edges inside or even changing it to grab from the back side instead top and the solenoid needs to stronger than the one we have i.e. 50 N.

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