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Overview of the KUKA robot language-based intelligent algorithms on industrial robots for multifaced medical and engineering applications: A modern approach to automation

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***Abstract*---**Industrial robots have been in use for about fifty years. Typical applications of industrial robots include biomedical, painting, palletizing, welding, assembly, and material handling. As healthcare robotic systems for diagnostics, surgical treatments, or rehabilitative services: Robotic technologies seem to be very well with a broad array of applications in automation medical advancements. Apart from medical, an algorithm is designed to play electronic musical keyboards with the help of an industrial robot. The algorithm is implemented on the KUKA KR-16 industrial robot. The robot plays an electronic musical keyboard according to the keyboard notes of the desired song.

The algorithm is designed to make the input of musical notes simple and easy. The design algorithm is further developed with KRL (KUKA Robot Language). The proposed algorithm results show that the KUKA KR-16 can play the specified notes.

***Keywords*---**industrial robot, electronic musical keyboard, algorithm, KUKA KR-16, KUKA robot language.

Introduction

Industrial robots are usually designed for specific applications and are available with a wide range of configurations, drive systems, physical sizes and payloads [1-3]. They are often employed to do tasks such as welding, assembly, and packaging. Most of these tasks are repetitive, dull and boring for manufacturing processes [1]. For this purpose predefined sequences and positions usually have to be stored in the robot's built-in controller memory. But nowadays, robots are very autonomous and can perform tasks other than the typical industrial jobs. The development of the service and entertainment robots is changing the concepts about the industrial robots. In recent years, entertainment has become an important issue for robot applications [2-5]. Although number of special piano playing robots have been designed and developed, but in this paper, a new solution is proposed for playing an electronic musical keyboard with a robot. Instead of creating a special musical keyboard playing robot, an algorithm is designed to play electronic musical keyboard with the help of industrial robot. The main focus is on implementing the algorithm on the KUKA KR-16 robotic arm. KUKA is a German manufacture of industrial robots and solutions for factory automation. As a pioneer in robotics and automation technology, KUKA Robotics is one of the leading manufacturers of robotic systems worldwide [6]. KUKA offers a unique and wide range of industrial robots and robot systems, covering all common payload categories and robot types [6].

Comprehensive overview on KUKA KR-16

KUKA KR-16 is a six-axis low payload industrial robot weighing 235 Kg, with jointed-arm kinematics for all point-to- point and continuous path controlled tasks [6]. The robotic arm has a rated payload of 16 Kg and is suitable for small scale activities such as component testing, assembly of small parts, grinding, polishing and bonding. Fig.1. illustrates utilization of KUKA industrial robots in this modern era of industrialization and modernization [7]. Fig.2, 3 and 4 shows the various components, mechatronics design, assembly and kinematic modeling of KUKA robot control system [7]. Fig.5 shows the KUKA KR-16 robotic arm [11].

Fig 1. Modern KUKA industrial robots [7]

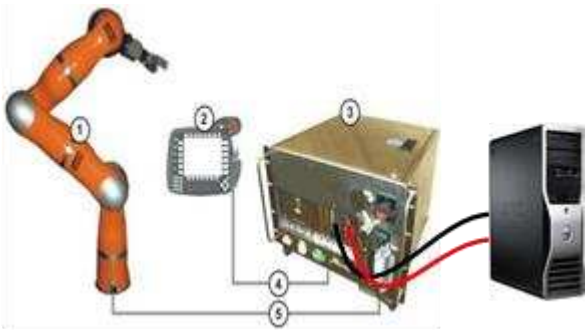

Fig 2. Overview of the KUKA robot control system [7]

- Light Weight Robot (1);
- KCP teach pendant (KUKA Control Panel) (2);
- KR C2 lr (KUKA industrial controller) (3);
- KCP cable (4);
- Power and SERCOS data connection cable (5);
- a workstation running real-time Linux (RTAI) and Orocos software;
- one real-time connection and one non-real-time connection with the KR C2 lr; both ethernet-based;
- (not shown) an input/output module connected to the KR C2 lr (Device Net);
- (not shown) many peripherals, including a JR3 force- torque sensor, electric and pneumatic grippers, a touch-sensitive handle, camera's and laser distance sensors [7].

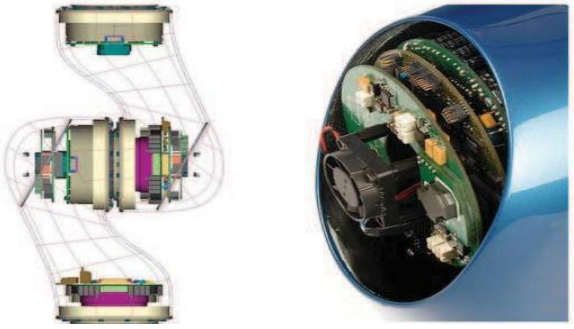

Fig 3. Mechanical design of KUKA robot with seven degree of freedoms, brushless DC motors, absolute encoders, torque sensors (strain gauges) on each joint [7]

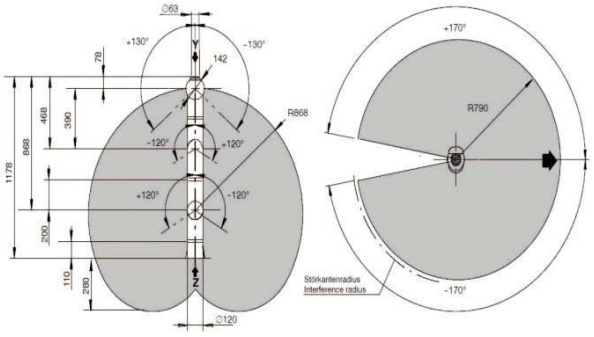

Fig 4. Kinematic model of the KUKA LWR [7]

Fig 5. KUKA KR-16 Robotic Arm [11]

The main parts of KUKA KR-16 are:

- Base frame
- Rotating column
- Link arm

- Arm
- Wrist

The rotating column turns about a vertical axis on the base frame along with the link arm, arm and wrist. Mounting flange is provided on the wrist for attachment of end effectors [6, 11]. The volume of working envelope of KR-16 robot is 14.5 m^3 with maximum reach of 1610 mm. The repeatability is less than ±0.05 mm and the maximum speed of the robot is 2 m/s [6, 11]. The robotic arm comes with a controller and an integrated teach pendant. Teach pendant is also known as KCP (KUKA Control Panel). The KCP has all the display and control functions that are necessary for operating the robot and for programming it. Fig. 6 shows the KUKA KR C4 controller [12].

Fig 6. KUKA KR C4 Controller electronic musical keyboard [12]

Electronic musical keyboard is one of the most familiar musical instrument. The beauty of this instrument is that it produces a particular sound when a specific note key is pressed for a specific amount of time. Keyboard typically contain keys for playing the twelve notes of the Western musical scale, with combination of larger, longer keys and smaller, shorter keys that repeats at the interval of an octave. Depressing a key on the keyboard connects one or more circuits, which triggers tone generation in an electronic sound module. Fig. 7 shows the Casio SA 21 mini electronic keyboard which is used in this project to play songs with the help of KUKA KR-16 [8, 10]. The size (W x D x H) of the keyboard is 612 x 176 x 61 mm and has 13 black keys and 19 white keys for a total of 32 keys. It also has 5 drum pads, 32 patterns (Rhythms: 13, Super Accompaniment patterns: 13), 5 built-in tunes and 100 built-in preset tones. The voltage rating of the keyboard is DC 7.5V and power rating is 1.6W. To operate, it requires either 5 AA-size batteries or AD-1 AC adaptor [8, 10].

Fig 7. Casio SA 21 Mini Electronic Keyboard proposed algorithm [8, 10]

The task of playing the electronic musical keyboard by KUKA KR-16 robot can be breakdown into following steps: Motion of the robot by PTP (Point-to-Point) motion command from the "HOME" position to a point near the electronic keyboard. Orientation of the pen type end effectors which is used to play the keyboard, nearly at an angle of 45 degrees. Motion of the robot by LIN (Linear) motion command to move the pen tip above the centre of the keyboard. Execution of the control algorithm to actuate the desired key of the keyboard according to the keyboard notes of the desired song. Motion of the robot back to the "HOME" position.

Control algorithm

Fig. 8 shows the flowchart of the designed algorithm to play the desired song on the electronic musical keyboard with the help of KUKA KR-16 robot. The program begins by declaration of the single dimension arrays and variables. In the initialization section, assign the distance between the centre of two consecutive white keys, distance between the centre of two consecutive black keys and distance between the centre of the last black key ('A' sharp or 'B' flat) of the group of three black keys and the centre of the first black key ('C' sharp or 'D' flat) of the group of two black keys to the variables declared in the declaration section. Fig. 9 shows the various keys of Casio SA 21 mini electronic keyboard along with the musical note represented by each key [13]. The depressed position of the first white key and first black key of the keyboard is get by manually teaching the points with the help of KUKA teach pendant. The program control enters a "FOR" loop for calculating the depressed position of the remaining keyboard keys and the preposition of each key, which is at a distance of 12 mm above each key. In the loop, the position of each succeeding key is calculated from the position of the preceding key by incrementing the distance between the centre two consecutive keys. The loop repeats until it calculates the position of all the keyboard keys.

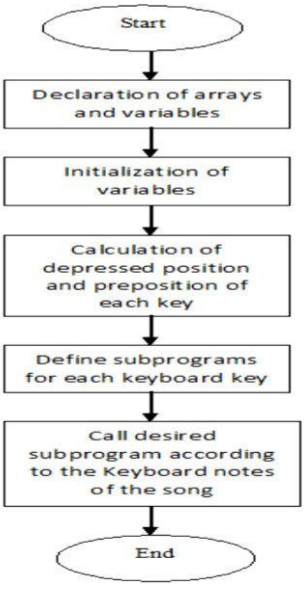

Fig 8. Control algorithm flowchart

Corresponding to each key, the subprogram is defined in the main program. Fig. 10 shows the flowchart of the subprogram defined for each key. The desired wait in seconds after each keyboard note is input as parameter to the subprogram. Point to Point motion is used to reach the preposition and the depressed position of each key. According to keyboard notes of the song, the desired subprograms are called in the main program.

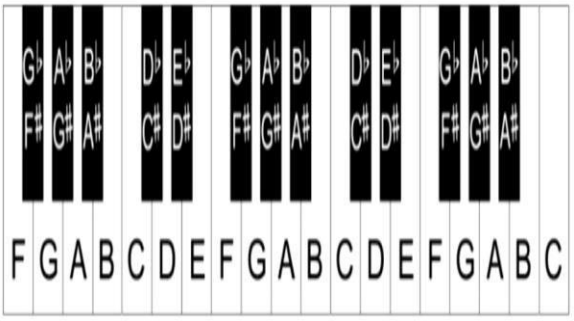

Fig 9. Casio SA 21 Keyboard Layout program execution [13]

The designed algorithm is implemented with the help of KUKA KR-16 industrial robot. For programming the KUKA KR-16, Orange Edit Beta version 2.0.11 from Orange Apps is used. Orange Edit is the programming environment for KUKA robot programs. It allows creating and editing the programs written in KUKA Robot Language (KRL). The program written in the Orange Edit can be easily copied to the KUKA robot controller KR C4 with the help of pen drive. Fig.11 shows the part of keyboard notes of a particular song which are programmed to play the keyboard [9-10, 13]. Fig.12 shows the screen shot of the KRL program

written in the Orange Edit. Fig. 13 shows the KUKA KR-16 playing the keyboard according to the designed algorithm.

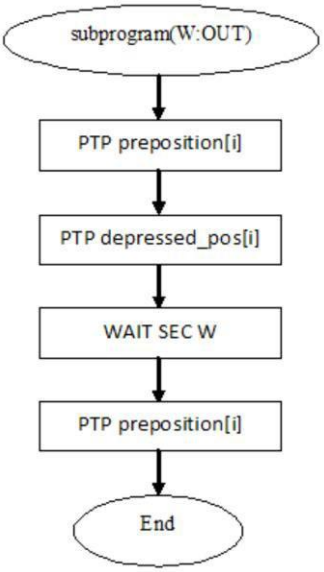

Fig 10. Subprogram Flowchart

Fig 11. Part of Keyboard Notes [9]

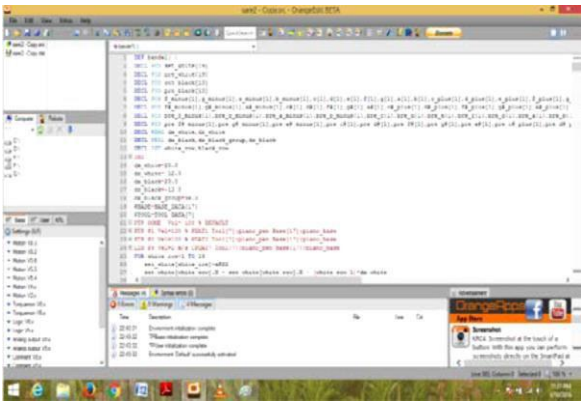

Fig 12. Screenshot of KRL Program

Fig 13. KUKA KR-16 Playing Keyboard

Conclusions

The focus of this paper is to design and implement an algorithm which makes an industrial robot to play any user defined song according to the musical notes of the keyboard. The algorithm allows the input of the keyboard noted for the user to be easier. The beauty of this algorithm is that it can be used to play any user defined song. The designed algorithm is successfully implemented with the help of KUKA KR-16 industrial robot to play the song on the keyboard according to the predefined keyboard notes,. Some of the famous songs like "Sare Jahan Se Acha", "Sun Raha Hai Na Tu", "Bande Hain Hum Uske" were successfully played by the KUAK KR-16 industrial robot.

Future outlook

There are many domains of the algorithm in which the further study can be done in the future. The robotic hand can be used as end effectors to play the keyboard which will increase the accuracy of playing performance. Machine vision can be used to interpret the keyboard notes and simultaneously transform them into motion commands of the robot in real time. Another possibility is in music industry where robot can be used to play keyboard in accompany with the singer.

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