

Animation in Robotics with LabVIEW Instrumentation

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Abstract—Animation in Robotics is one of the most important problem to be solved because with animation will be possible to obtain the best results to control the working space of robots in a space application, to control the Forward and Inverse Kinematics (FK, IK) algorithms, to control the singularity points in applications with one or multiple robots, in different cases: parallel, serial or complex robotic disposeure. In the paper are shown the state of art in this field, the general algorithm used for animation and some usual cases for some type of robots like: Gun, Scara, Portal, Arm, Leg, serial, parallel or complex multi robots applications. The paper shown also the constraints for parallel robot structures and how could be animate this types of robots or the human robots like multi robot application. For all these cases were designed some LabVIEW virtual instruments (VI) what work on-line and by using the remote control or the external files or the front panel buttons, we can do some moving in the space of all robot's bodies to validate de FK and IK, to construct the parallel robot structure. The used algorithms, the cases that were studied, the applied methods and cases of animation open the way to optimal solve the complex problems in robotics.

Index Terms—Forward kinematics, inverse kinematics, animation algorithms, virtual instrumentation, parallel robot structure, multi robot applications, human robots.

I. INTRODUCTION

DART (Dynamic Animation and Robotics Toolkit) [1] is a collaborative, cross-platform, open source library created by the Graphics Lab and Humanoid Robotics Lab at Georgia Institute of Technology. The library provides data structures and algorithms for kinematic and dynamic applications in robotics and computer animation. DART is distinguished by its accuracy and stability due to its use of generalized coordinates to represent articulated rigid body systems and computing the dynamics of motion. DART gives also full access to internal kinematic and dynamic quantities, such as the mass matrix, Coriolis and centrifugal forces, transformation matrices and their derivatives. DART has applications of animation in robotics for control and motion planning.

The paper [2] presents the development of the animation of robots in virtual reality environments, whose mechanisms can be coupled: the movement relies on mechanical

principles; and uncoupled mechanisms, i.e., the degrees of freedom are controlled independently with remote control unit. Additionally, the present phases to transfer the design of a robot developed in a CAD tool to a virtual simulation environment without being lost the physical characteristics of the original design are showed, for which it is considered the various types of motions that the robot can perform depending on the design.

Human-robot interaction (HRI) [3], [4] systems are spreading as a new form of human-computer interaction. In these systems, the concept of "computer" can expand into several integrated devices such as a robot, touch devices, or perceptual devices like cameras or microphones. In order for that to be possible, and to keep on par with the state of the art technology created at universities and research facilities, the HRI community must get together and establish standards, common platforms and reusable tools that can encompass all the different needs of a system that is as heterogeneous as the HRI ones. On this paper we describe the SERA ecosystem: a model and tools for integrating an AI agent with a robotic embodiment, in an HRI scenario. SERA provides both a recyclable model, and reusable tools that were developed with consideration for both technical developers (e.g., programmers) and also non-technical developers (e.g., animators, interaction designers, psychologists).

Catia, SolidWorks, 3D Robot Animation, Xemo Robot Simulator, DeepMotion, RoboAnalyzer, RobotStudio, Solid Edge, Microsoft Robotics Developer Studio, RoboLogix, AnyCode, WeBots, RoboGuide, MotoSim, RobotExpert, RobotSim, Workspace, WorkCellSimulator, AxOnDesk, RoboWorks, Blender, Gazebo, Simbad, LpzRobots, EzPhysics, V-Rep, Easy-Rob, AristoSim, Morse, Eureka, Anvel, STDR, are some of the most known software for animation in robotics [5]-[38].

DeepMotion [5] is a pioneer in the emerging field of Motion Intelligence. We are building tools for lifelike graphics using physical simulation and artificial intelligence. DeepMotion's contents train digital actors motion skills like dancing, athletics, martial arts, and more.

RoboAnalyzer [6]-[9] was developed in the Mechatronics Lab, Department of Mechanical Engineering at IIT Delhi, New Delhi, India under the guidance of Prof. S.K. Saha. The need for a robotics software to teach robotics has motivated the IIT Delhi team to develop RoboAnalyzer. Virtual Robot Module (VRM), which is a part of RoboAnalyzer software, is now made available as a COM Server. Using this version, one can have interactions between VRM and other software applications such as MATLAB, MS Excel, etc., which have a COM interface.

As of RTB Version 9.9, the visualization for robot motion was done using skeleton models in MATLAB. To have more realistic animation, VRM-RTB integration can be used on CAD models of some of the robots. Moreover, if a student/researcher/faculty has some algorithm for kinematics,

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motion planning, etc., and want to see the motion, VRM can be used for animation purpose. This helps in concentrating more on the research than worrying about animation functionality. Some examples of animation with RoboAnalyzer and Virtual Robot Module we can see on the Figs.1-5.

RobotStudio [10], [11] is the development environment/execution system for robot software that supports the robot's human communication capability. Its components are based on the mechanisms and knowledge that we have gained from R&D into the personal robot. RobotStudio is an industrial simulator tool developed by ABB. The software allows you to develop realistic simulation scenarios for ABB industrial robots as well as real robot programs and configuration files. RoboStudio is composed of: (i) workers (components) including the speech and face image recognition functions that can be used in a real environment; (ii) a robot virtual machine that is composed of the messaging mechanisms between the scenario interpreter and the components; (iii) a development tool for robot-dedicated application called the scenario/motion tool; (iv) a database processing function that supports communications.

Microsoft Robotics Developer Studio (MRDS) [11] is a free 3D simulation software designed by Microsoft with support for a wide range of sensors and other robotic platforms. The platform is compatible with all Windows OS versions and it could be used with C# Visual Studio 2010.

RoboLogix [11] is a 3D industrial simulation software developed by Logic Design. The platform was designed to be used in real-world emulation for robotics applications with five-axis industrial robot. The program installed on the robot can be developed and tested in a wide range of practical applications. The platform offers support for a wide range of industrial robots including ABB, Fanuc and Kawasaki.

Anycode [11] is a 3D simulation software with support for service robots. The tool can run on Windows and Linux operating systems, and offers a high-level of reality. In the interface are available a wide range of sensors and actuators with real properties to be used in simulation. The platform can be used in educational purpose as well as researchers or by engineers.

Webots [11] is 3D simulation platform developed by Cyberbotics and used in service and industrial simulations. The tool offer support for Windows, Linux and Apple platforms, and is one of the most used simulation software in education or research purposes. Any robot can be modeled, programmed and simulated in C, C++, Java, Python, Matlab, or URBI. The software is compatible with external libraries like OpenCV.

RoboGuide [11] is a software developed by Fanuc and fully compatible with Fanuc robots. The platform was designed to be used to simulate in virtual environments the behavior of Fanuc industrial robots. The tool is 3D compatible, while the program can be downloaded in the physical model of the robot.

MotoSim [11] is a 3D industrial simulator dedicated to Motoman industrial robots. The simulator was designed to be used for an industrial optimization process for Motoman robotic arms used in industrial applications.

RobotExpert [11] is a 3D simulation tool designed to simulate in an accurate environment the Siemens industrial

robots. Is an intuitive program used to design and modeling workcells as well as robots and mechanisms.

RobotSim [11] is a virtual development tool designed by Cogmation Robotics able to run on Microsoft Windows XP. This is a 3D program with support for a suite of software developed by the same company. The RobotSim is a powerful tool to design and build service robots.

SimplyCube [11] was designed to provide realistic 3D simulations for service robots. Using a 3D editor, the user can develop rich 3D scenes to simulate the robot behavior.

Workspace [11] is a 3D compatible software for industrial services simulations developed by WAT Solutions. The platform support programming languages for a wide range of industrial robot manufacturers including ABB, Fanuc, Mitsubishi, and many others.

WorkCellSimulator [11] is a 3D industrial simulation software developed by IT Robotics SRL from Italy. The tool can be used in simulation for at least packaging, sorting, or laser cutting applications.

RoboWorks [11] is a 3D simulation tool developed by Newtonian. The software can be used to simulate in a virtual 3D world the behavior for industrial and service robots. RoboWorks offer support for 'C/C++', C/C++ interpreter Ch, VB, VB.NET, LabView, etc.

Lpzrobots [11] is a 3D physically realistic robot simulator designed in the labs of Leipzig University. Fully compatible with Linux OS, the tool can be used especially in education and research purposes.

Any technology has its advantages and disadvantages. In the advantages area I can include a lower cost, while all of the simulation tools offer the possibility to simulate the robot in different scenarios, the programming code can be tested to determine the compatibility with the specifications required, robot design can be modified without costs; any robot part can be tested, in a complex project, the robot can be simulated in different stages, a complete simulation can determine if the robot meet the specifications, almost all simulations software are compatible with a wide range of programming languages. Among disadvantages there are the programming problems that cannot cover all the scenarios of the real world. All shown software are not possible to be used in the complex serial multi robots applications like Portal with Arm type robots, or parallel structure of robots with platform and three arm type robots and without the target in the virtual model [36]-[38].

The Genetic Algorithm GA [12]-[30] is a probabilistic search process. The GA operates on a population of individuals that undergoes a process of simulated evolution. The individuals are each an encoded representation of a potential solution to the search problem, the equivalent of the genetic material of a natural individual to solve the Path Planning problem.

A new path planner for a point robot moving among circular obstacles in a two dimensional space is presented [16]. This is a relatively simple problem that would be most effectively solved by using a tangent graph but it allows the development of GA elements that may then be extended to the general n dimensional space. The GA uses a population of potential solution paths each individual representing a path between the start and the goal configurations.

In robotics [15]-[38] an essential component of robot

motion planning and collision avoidance is a geometric reasoning system which can detect potential contacts and determine the exact collision points between them.

II. ASSISTED RESULTS BY APPLYING ROBOANALYZER

The assisted research of the results with RoboAnalyzer was necessary to show the disadvantages of this soft and the novelty of the proposed animation method.

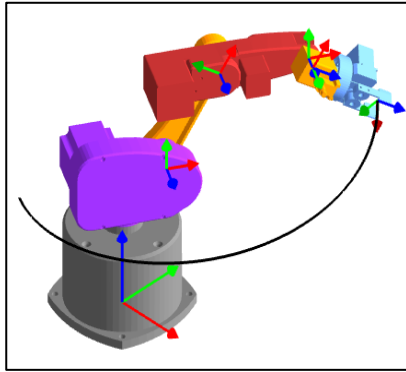


Fig. 1. The RoboAnalyzer robot of the MTAB Mini with file control.

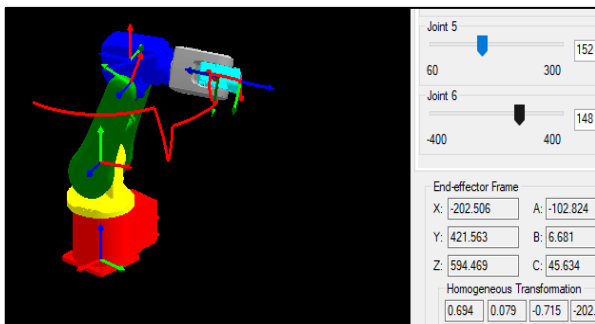


Fig. 2. The robot from ABB IRB120 in virtual robot module platform with simulation of the space trajectory.

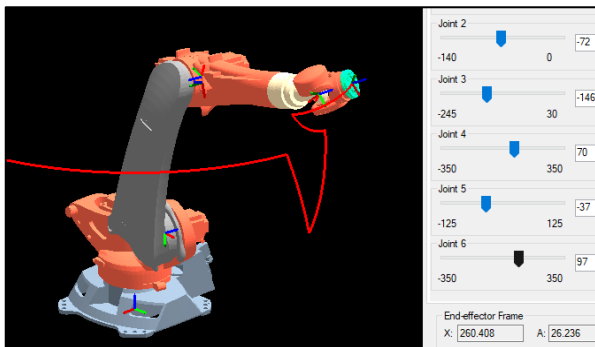


Fig. 3. The robot from KUKA KR10Ultra in the virtual robot module with remote control of the movements.

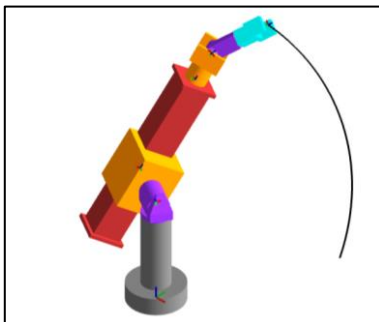


Fig. 4. The robot from Stanford in the RoboAnalyzer with control file of the movements.

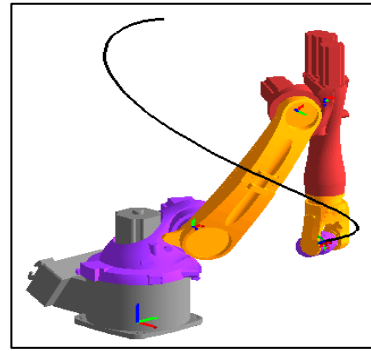


Fig. 5. The robot from KUKA KR5 in the RoboAnalyzer with control file of the movements.

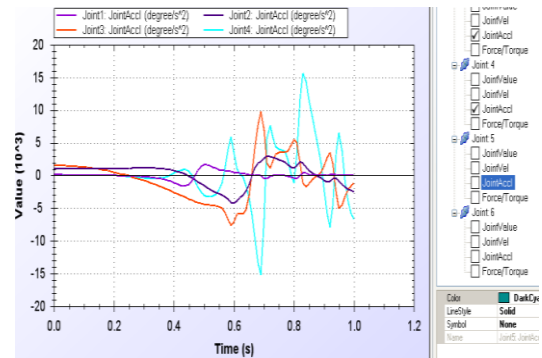


Fig. 6. Accelerations analyze.

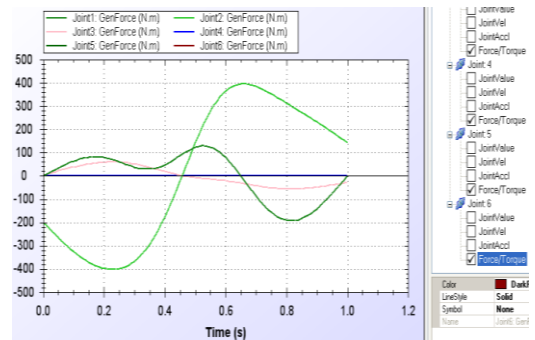


Fig. 7. Torques analyze.

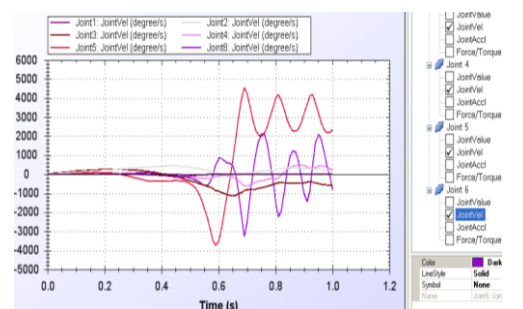


Fig. 8. Velocities analyze.

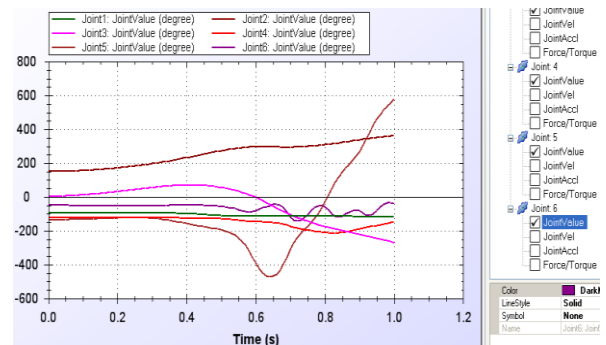


Fig. 9. Positions analyze.

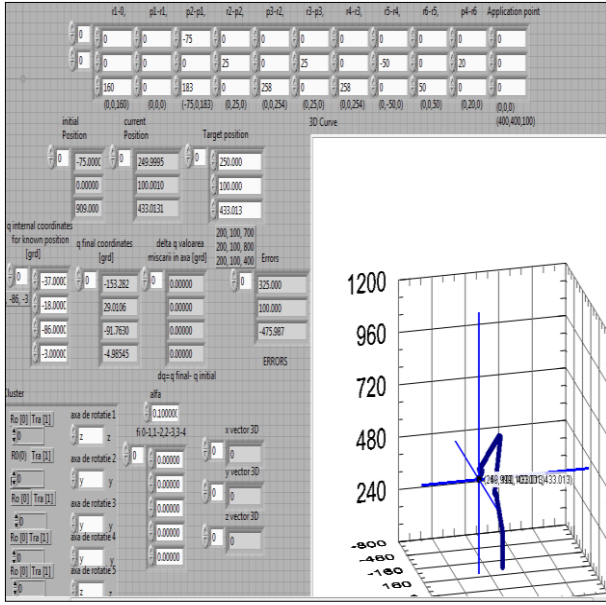


Fig. 10. The front panel of the LabVIEW VI-s for the animation of the arm type robot.

After analyzed the results by applying the RoboAnalyzer soft [6]-[9] we can do the following remarks: (i) the animation offer one real image of the robotic application but without possibility to check the target point and the obtained errors; (ii) the base application point is not used and for that isn't possibility to analyze the optimal position of the robot base and also to use the robot in multi robots application; (iii) the solving of the inverse kinematics problem (IK) used the multi solutions way; some of them is not applicable because touch the singularity points or some obstacles; for that, the user must choose himself the good solution from multiple possible solutions; (iv) the VRM not used the possibility to animate together some of the joints, like in real applications; (v) RA and also VRM not offer one solution for the animation multi robot application in serial, parallel or complex configuration.

III. THE PROPER ANIMATION ALGORITHM

A. General Algorithm

A general algorithm of animation of the movement of all robot's joints contents some mathematical model to obtain the remote control of all joints by the bottoms from the LabView front panel, see Fig.10.

Fig.10 The front panel of the LabVIEW VI-s for the animation of the arm type robot

The algorithm contents the following:

- Definition of the application point of the robot's base;
- Definition of the relative position of all robot's joints vectors included the off-set vectors:

$$r_i^{i-1} = (f(l_i)); \quad (1)$$

- Definition of the home position for all internal relative coordinates:

$$(q_i); \quad (2)$$

- Solve the forward kinematics (FK) that contents:
- Define all types of robot's joints: Translation or
- Rotation, T, R ;
- Define the rotation or translation axes, x, y or z ;

- Determine the translation matrices for all joints:

$$D_i^0 = D_1^0 D_2^1 \dots D_{i-1}^{i-2} D_i^{i-1} \quad (3)$$

$$D_i^0 = (f(q_i)). \quad (4)$$

- Determine the absolute positions of all robot's joints:

$$r_i^0 = r_{i-1}^0 + D_{i-1}^0 r_i^{i-1} \quad (5)$$

$$r_{p_i}^0 = r_i^0 + D_i^0 r_{p_i}^i. \quad (6)$$

- Iterative determination of the absolute positions of all robot's joints:

$$r_i^0 = \begin{cases} r_{i_x}^0 = r_{i-1_x}^0 + idx_i \\ r_{i_y}^0 = r_{i-1_y}^0 + idy_i \\ r_{i_z}^0 = r_{i-1_z}^0 + idz_i \end{cases} \quad (7)$$

where i is the iterative count; dx -the increment of the body i ; r_i - the position vector; D_i -the translation matrix; q_i -the internal relative coordinate; N -the number of the incremental segments for the animation of robot's bodies.

$$\begin{aligned} x_i &= x_i - x_{i-1} \\ y_i &= y_i - y_{i-1} \end{aligned} \quad (8)$$

$$\begin{aligned} z_i &= z_i - z_{i-1} \\ dx_i &= x_i / N \\ dy_i &= y_i / N \\ dz_i &= z_i / N \end{aligned} \quad (9)$$

Concatenation of all values of the robot for x, y, z in a column matrix:

$$[x_i], [y_i], [z_i]. \quad (10)$$

B. How Algorithm Was Transformed in the VI-s

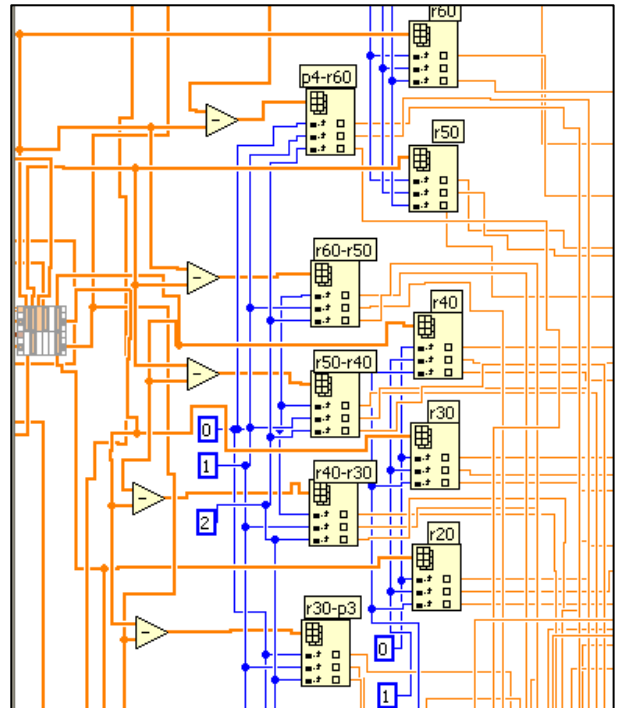


Fig. 11. The part of the block diagram of VI-s animation- module of the determine the position in the space of each robot's body

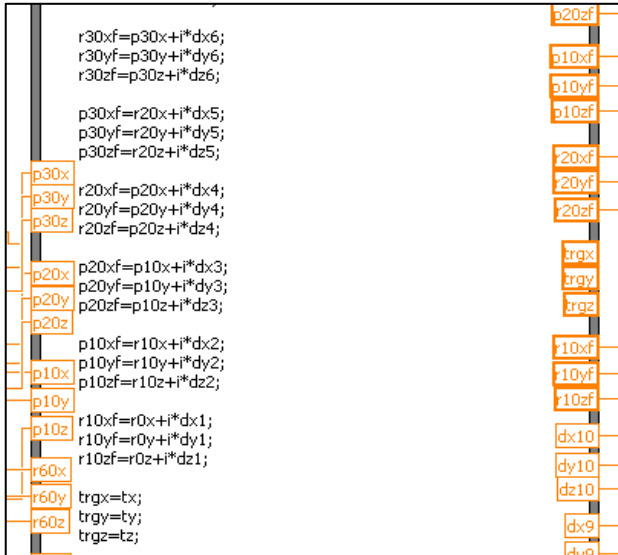


Fig. 12. The part of the position vectors calculus node in the VI-s

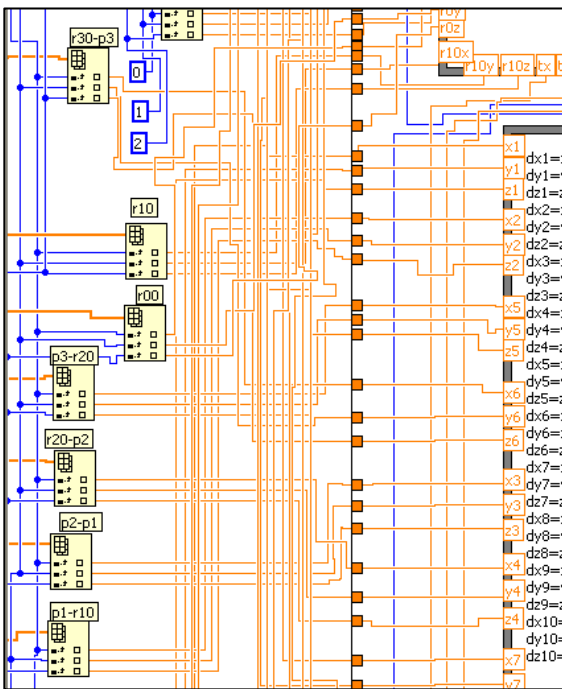


Fig.13. Block schema of the matrix form of calculus of the difference between the joints points for the increment calculus.

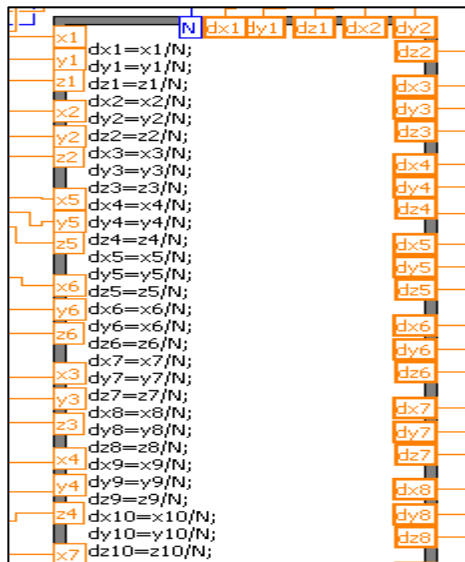


Fig. 14. Calculus node of the animation increments.

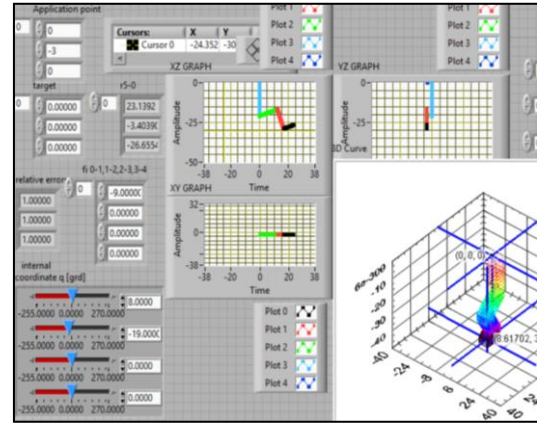


Fig. 15. Front panel of the LabVIEW VI-s for the animation of the remote control of the movements of the leg type of the robot's joints.

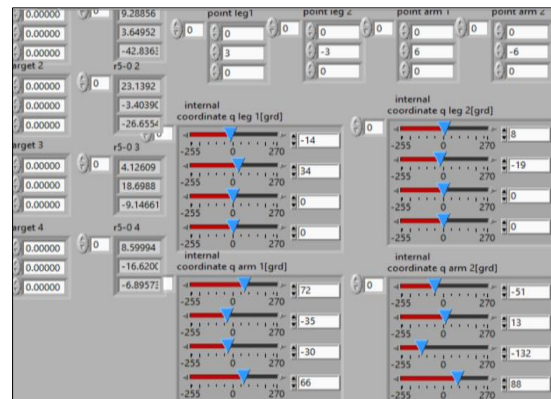


Fig.16. Front panel of the LabVIEW VI-s with the input data of the human robot with two arms and two legs.

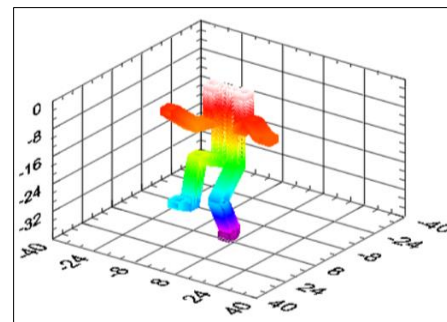


Fig.17. Front panel of the LabVIEW VI-s to simulate the remote control of the human robot's joints: arms and legs.

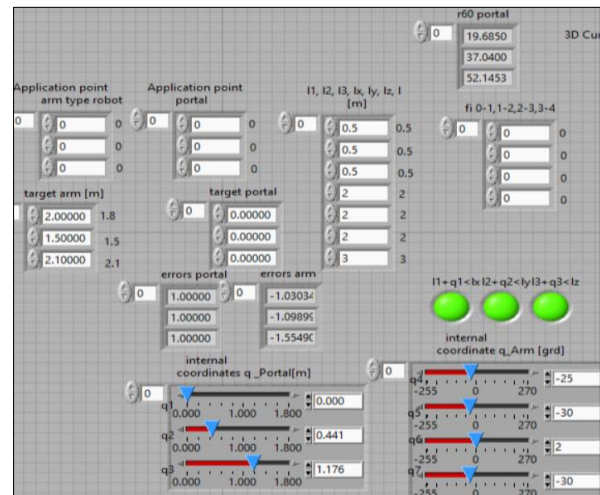


Fig.18. Front panel of the LabVIEW VI-s for the simulation of the remote control of the movements of one complex serial multi robot application: portal and arm type robots

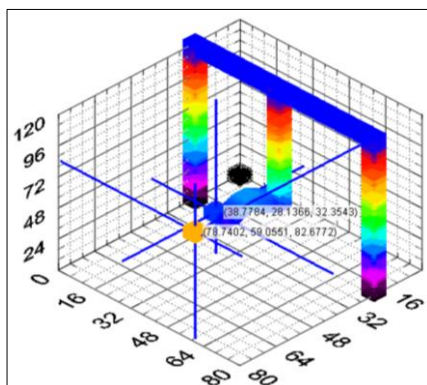


Fig. 19. Front panel of the LabVIEW VI-s (the robotic schema) for the simulation of the remote control of the movements of one complex serial multi robot application: portal and arm type robots.

The proper LabView instrumentation designed for the robot animation contains the following: (i) the remote control of the movement of all robot's joints; (ii) design of the complex multi robots structure by define the different application points of all robotic components; (iii) check the touching target points by using the input data of the IK results; (iv) control of all movements of robot's end- effecters to be inside of the working space and to avoid the singular points; (v) control the automation movement from one application, by using the input data of the file with all internal relative coordinates for all multi robots from application and to see if all geometrical constraints were accomplished; (vi) control the application points of all robot's base in the robotic cells; (vii) choose the better location of the robotic components by checking if all target points were touched by the end-effecters; (viii) the VI-s have some leads that can be used to signal the touching of the constraints limits; (ix) some of the robot's bodies could be changed after the animation; (x) all VI-s show the errors to touch the target- that could be used to design the parallel robotic structure.

IV. CONCLUSION

The paper show state of art in the field of Robots animation, the advantages and disadvantages of all known animation methods and the proper algorithm used in the animation of the movement of robots in a conventional form of all bodies with the LabView soft. The proposed method and algorithm open the way to the researchers in the field of animation to cover proper needs in the simulation of movements, design some characteristics, develop some multi robot applications, controlling the working space of all robots or avoid the collision points to obtain the optimal design of the robot application.

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