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KINEMATIC MODEL OF INDUSTRIAL ARTICULATED SELF ROOTED ROBOTS FOR TRAJECTORY PLANNING USING KBS ALGORITHM

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Abstract. *The paper presents a method for determining the workspace of an industrial robot using an approach consisting in integration a 3D model of an industrial robot with a virtual control system. The robot model with his work environment, prepared for motion simulation, was created in the "Motion Simulation" module of the Siemens PLM NX software. In the mentioned model components of the "link" type were created which map the geometrical form of particular elements of the robot and the components of "joint" type mapping way of cooperation of components of the "link" type. In the paper is proposed the solution in which the control process of a virtual robot is similar to the control process of a real robot using the manual control panel (teach pendant). For this purpose, the control application "JOINT" was created, which provides the manipulation of a virtual robot in accordance with its internal control system. The set of procedures stored in an .xlsx file is the element integrating the 3D robot model working in the CAD/CAE class system with the elaborated control application.*

1. Introduction

The dynamic development of systems of the CAD/CAE class allows creating motion simulation of 3D models of technical systems with a complex structure of the kinematic chain. Motion analysis may involve alike mechanisms characterized by the closed and open kinematic chain. In works [1,2,3] are presented examples of the use of the system of the CAD class, Siemens PLM NX, for motion analysis of technical means. Determination of positions that could be reached by the robot in the analyzed work environment is important taking into consideration the correct implementation of the conducted technological process. Therefore it should be ensured that the workspace of the analyzed industrial robot allows achieving specific positions determined in the technological process. Ensuring itself the possibility that the robot achieves the given position is a necessary condition but not sufficient to be considered that the robot correctly fulfill its functions in the analyzed technological process. Additionally it must be ensured that reaching the given positions by the robot is realized without the occurrence of a collision between the robot and the elements of its environment. The use of the CAD/CAE class systems allows simulating operation of the analyzed industrial robot within the framework of the given technological process. Basing on the virtual tests it is possible to determine the robot workspace and to predict the collision of robot elements with other elements of the system. It allows eliminating such events like collisions at the stage of designing the given robotized technological process. Such approach requires creating a 3D solid model both of an industrial robot and of elements of its work environment. The process of creating the 3D model of a technical system could be based on different methods. In works [4,5,6,7,8,9,10,11,12,13] are shown different methods of designing the technical means.

2. Robot model preparation for motion simulation in the PLM Siemens NX system

In the analyzed system (figure 1) the kinematic chain of a robot represents the group of open kinematic chains and consists of 7 kinematic pairs of the V class, which represent a rotational motion (one degree of freedom - rotation about the selected axis) and one kinematic pair of V class which represents a reciprocation motion.

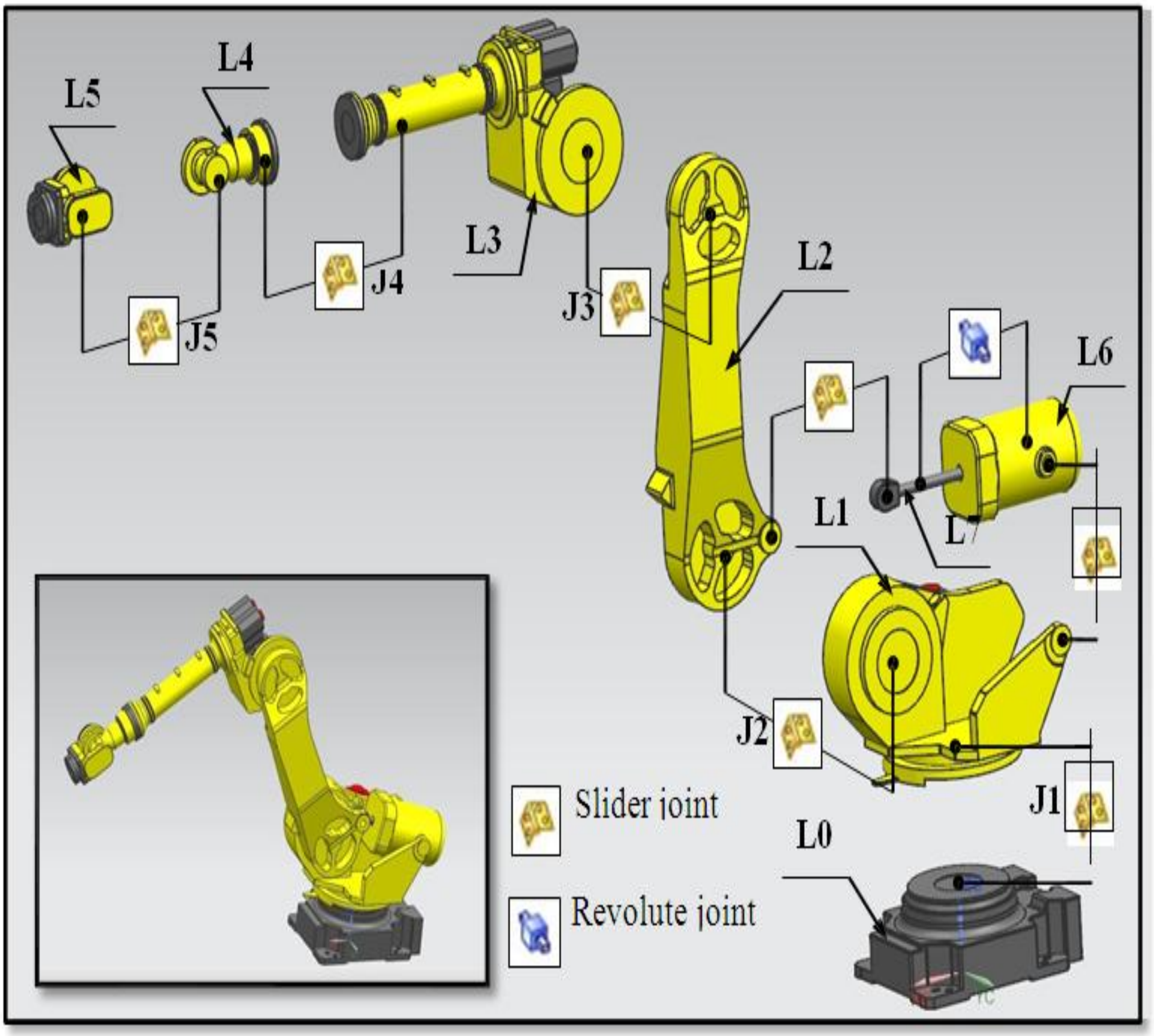

Figure 1. The model of FANUC R-2000iB R-30iB robot prepared to the motion simulation.

Preparation of a solid model of an industrial robot for motion simulation consists of:

- Creation the components of the "link" type L0, L1 to L7. It should be noted that all elements being a part of the component of "link" type does not change their position in relation to each other during motion, and the whole component is treated as a rigid body.
- Creation the components of the "joint" type J1, J2 to J7 determining the possible movement in relation to each other between the components of the "link" type.
- Creation the components of the "joint" type (fixed) preventing displacement of the component L0 for proper operation of the system.

The next stage of creation the model prepared to motion simulate was associated with the imposition of constraints on the individual axes of the robot manipulator (figure 2). Imposed constrains allow faithfully reflecting the ranges of motion performed by the robot manipulator in its internal layout. This allows narrowing research area. The range of movement has been reflected on the basis of the documentation robot FANUC R-2000iB R-30iB manufacturer: axis J1 -180° to +180°; axis J2 -90° to +46°; axis J3 -200° to +112°, axis J4 -360° to +360°, axis J5 -125° to +125°.

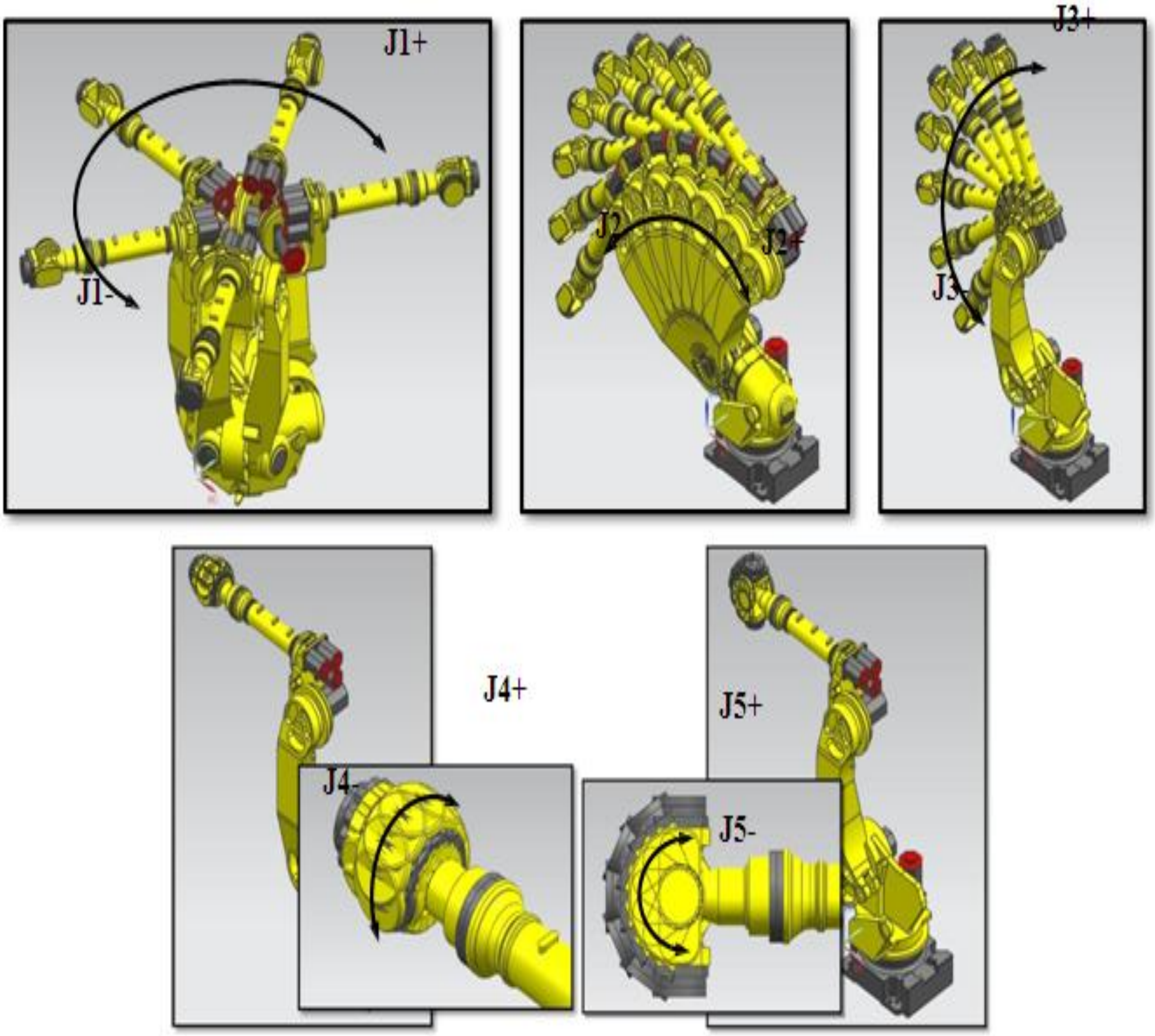

Figure 2. Implementation of movement ranges for particular kinematic pairs of an industrial robot using the PLM Siemens NX system.

Then, such prepared model of the robot has been implemented as a component of a robotized production workcell. It should be noted that the subject of implementation was elaborated robot model, prepared for motion simulation with components of the "link" and "joint" types and not only its geometrical form itself. The production system, analyzed in the paper, was designed for pressure welding of elements using an industrial robot. It consists of the following major subsystems (figure 2):

- Fanuc R-2000iB (1) robot model.
- Model of a turntable, on which are situated welded elements (2).
- Model of a floor panel (3).
- Model of a control cabinets, fencing and elements of a process control interface (4).

Because of the transparency of an environment area, in which the robot moves, it was hidden parts of the fencing (figure 3). Analysis of work space of the robot is important in order to ensure the proper course of the welding process of joined elements. The location of the robot, in the analyzed production system, must provide proper cooperation between him and the turntable on which are located the elements for welding - what is the most important from the point of view of the primary task of the designed system. It should be also examined the possibility of a collision between the moving executive system of the robot and elements of its environment. This information is important because of the implementation of the algorithm designated to control the robot. Analysis of the position held by a suitably positioned tooling, mounted on the robot wrist, requires defining six values of the angular displacements (for each axis - a kinematic pair) of the robot.

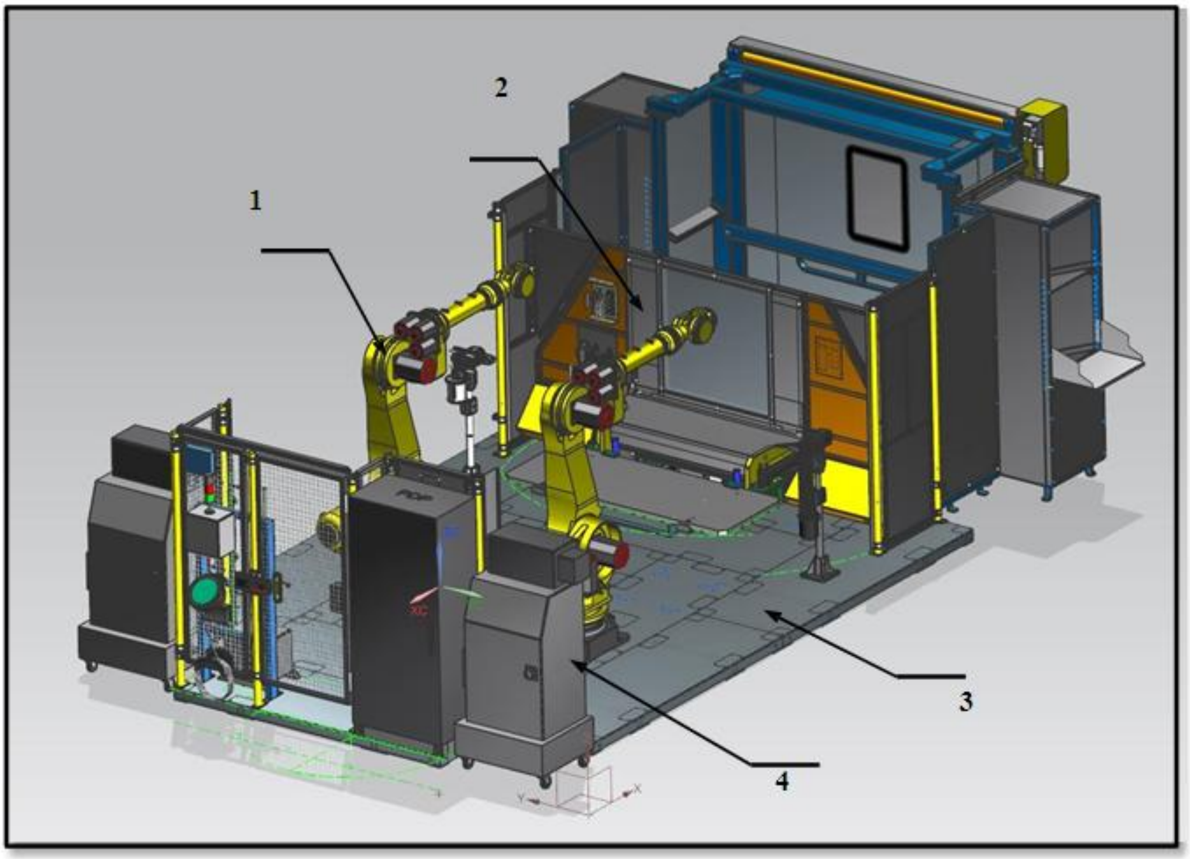

Figure 3. The model of the robotized production workcell.

Control in this way the robot work realized in the system of the CAD/CAE class is a time consuming process and is non-intuitive deviating from the control of a real robot using a real control panel.

3. Integration of the model prepared in the CAD/CAE class system with a virtual controller

The process of integration of different systems supporting engineering works using Dynamic Data Exchange (DDE) is described in next papers [14,15,16,17,18]. For the purposes of the process of intuitive manipulation of the executive system of the industrial robot FANUC R-2000iB R-30iB, used in the robotized workcell, it has been created the virtual control panel shown in figure 4.

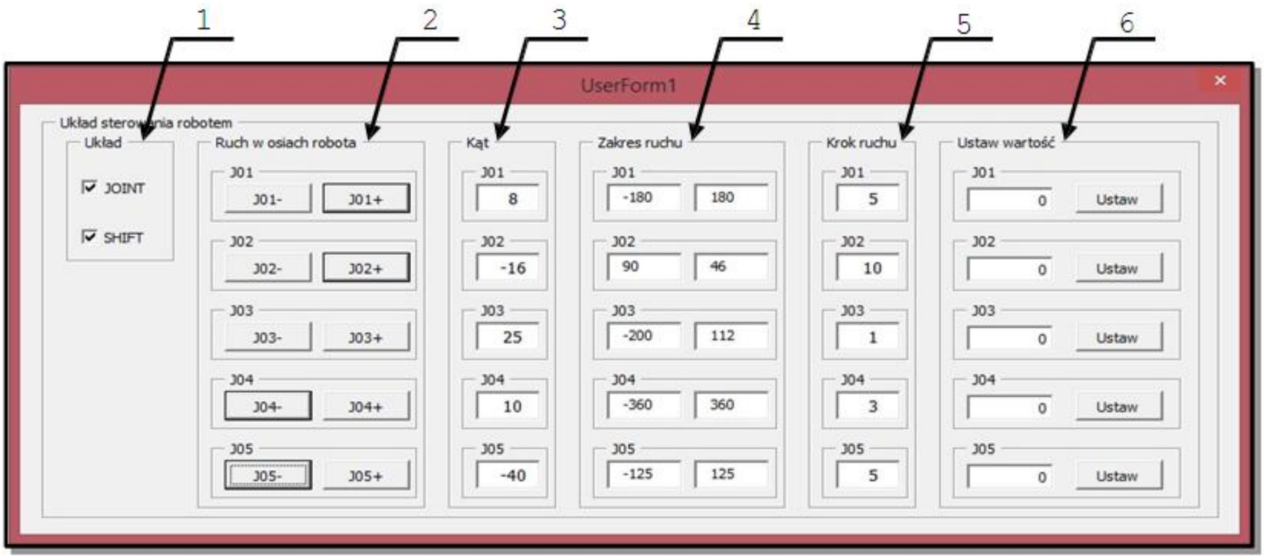

Figure 4. Virtual control panel designated for the robot control.

Within the virtual control panel it could be recognized the following areas:

- Area connected with the approval of the coordinate system in which the manipulation of the executive robot system is realized (1).
- Area connected with the manipulator control of in its particular axes (2).
- Area in which is displayed the current position of the elements of robot arm in each of its axes (3).
- Area in which is defined the range of movement of the manipulator (4).
- Area in which is defined the step of movement in each manipulator axis (5).
- Area in which it is possible to enter the desired position which should be reached by the manipulator (6).

The created virtual control panel allows controlling the virtual model of the robot manipulator in its machine system of the JOINT type. The control is possible, as is the case of controlling using the real control panel, only when the type of a coordinate system of manipulator work is selected and the "SHIFT" key is pressed (1). Using the keys J0i- and J0i + (i = 1, ..., 5) it is possible to control the movements of the individual axes of the robot (2), in accordance with the given step of movement (5) in the permitted range of motion (4). The current value of the angular position of each axis is displayed in the area "ANGLE" (3). In the case, in which the desired position of the manipulator is known, it is possible to enter it in the field "SET THE VALUE FOR EACH AXIS" (6).

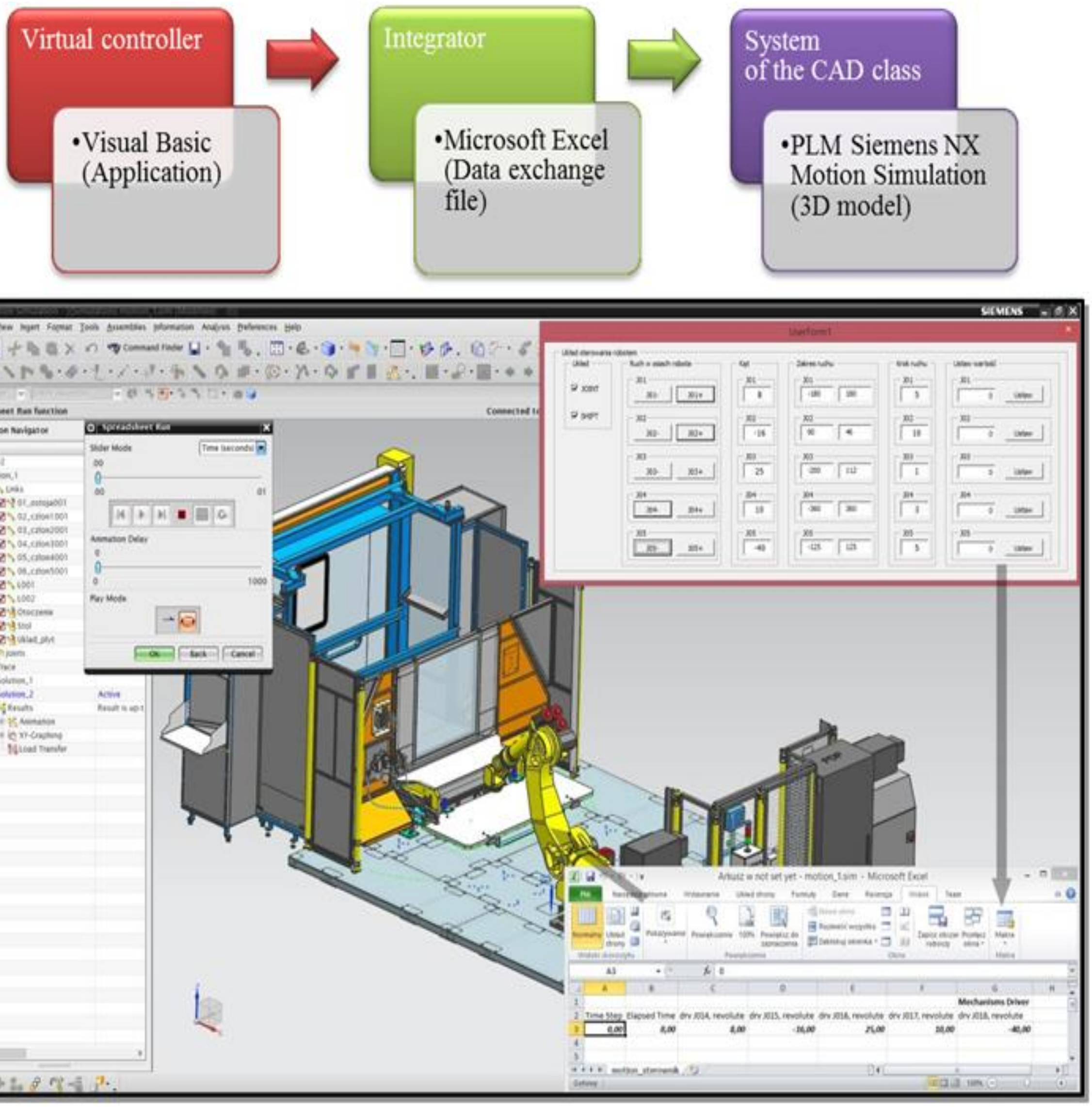

Figure 5. Integration of the virtual control panel with the motion simulation in PLM Siemens NX.

In order to integrate created the virtual control panel of the robot manipulator with the model of the robot manipulator, prepared for motion simulation in the adopted work environment, it was created a swap file for data exchange basing on Microsoft Excel program (figure 5). In the described case, the angular positions on each axis are transferred using Dynamic Data Exchange (DDE) from the virtual control panel to the appropriate cells in the Microsoft Excel application, from where they are downloaded by the PLM Siemens NX system. These values are automatically implemented to the appropriate joints of the model that is prepared for motion simulation. Such a solution of the problem of control the virtual model of the robot manipulator, in the adopted work environment, allows mapping the operation of a real system in a virtual environment.

4. Motion simulation basing on the integration of the CAD/CAE class system with the virtual control system

Basing on the used method of integration of the model prepared for motion simulation in the CAD class system with the virtual control panel was carried out the process of controlling the virtual robot in its work environment (figure 6).

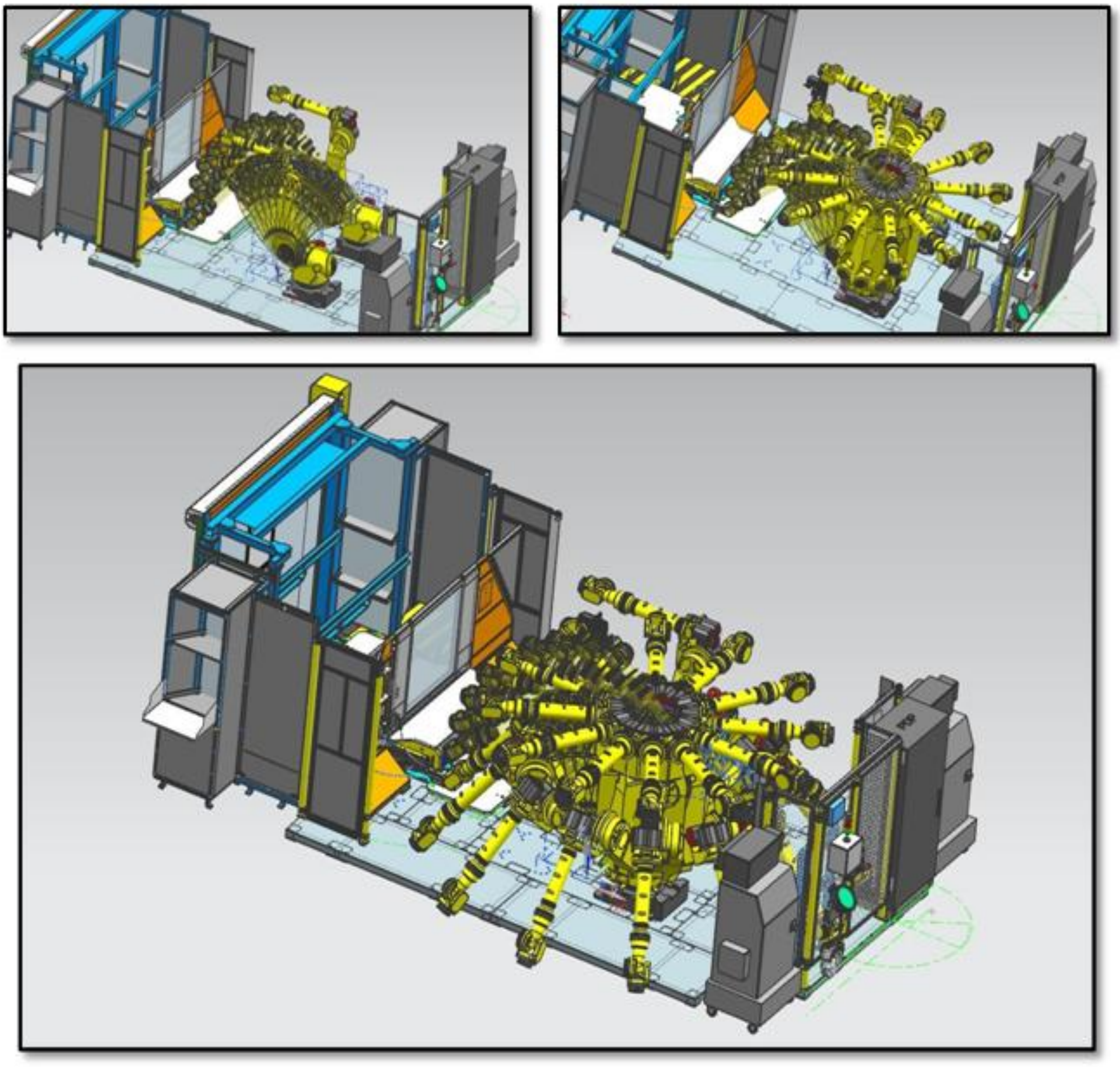

Figure 6. Visualization of the movements ranges of the robot manipulator in the axles J1 and J2.

Figure 6 shows the selected position of the robot in axes J1 and J2 to illustrate the possibility of controlling by the elaborated control panel. On the basis of conducted analyzes (of manual control) the correctness of positioning of the robot manipulator in the adopted robotized production system was stated. The robot placement position in the system, designed for pressure welding allows free accessing to the turntable on which components are respectively arranged and prepared for welding. Another considered issue was the problem of the collision occurrence between the robot performing the technological process and elements of the production workcell. For this purpose, the capacity of the CAD/CAE class system PLM Siemens NX, in analyzing the collisions of systems being in motion have been utilized. It was assumed that the individual system components are in a collision when its volume or surface area, at the given moment of time, occupy the same position in the stationary (immovable) reference system. Table 1 presents the selected angles of robot motion chosen to minimize the risk of occurrence the collision between the robot manipulator and other elements of the robotized production workcell.

Table 1. Determined range of movements of the analyzed manipulator of the industrial robot

Axis number	Movement range (°)
J1	-30 to +30
J2	-90 to +46
J3	0 to 112
J4	-360 to +360
J5	-125 to +125

It should be emphasized that the specific ranges of movement are the preliminary one and should be treated as narrowing of the field of possible moves when programming the robot motion within the real robotized system.

5. Conclusion

The elaborated method of determining the robot work space using integration of the CAD/CAE class system and the virtual control one allows specifying the location of the robot in the previously determined work environment because of the ability to implement the established technological process and to minimize the risk of collision occurrence at the designing stage of the real robotized system.
The created model of the robot manipulator, prepared for motion simulation, is the independent system and it is fully controllable using the virtual control panel and it could be used in any robotized production system.
The presented control method could be adapted, for control purposes, to solid models of industrial robots of any class that are created in the CAD/CAE class system PLM Siemens NX.
The motion analysis of a model of a robot is carried out in the CAD/CAE class system, while the control operation is realized through the virtual control panel. This control method lets to combine the capabilities of the CAD/CAE class systems, regarding to motion simulation and the intuitive control process of a real robot using the real control panel.
The developed method of integration of the CAD/CAE class systems and virtual controls ones could be adapted to simulate the movement of any solid models of robotized production systems.

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