Designing of robotic production lines using CAx software

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Abstract. Present market conditions causes that modern control systems of robotized manufacturing cells should be characterized by the much greater degree of flexibility, self-organization and, above all, adaptability to emerging outer excitations. The phenomenon of information distribution is one of the most important features of modern control systems. In the paper is presented the approach, based on application of multi-agent systems, for supporting the operation of robotized manufacturing cells. The aim of this approach is to obtain the flexible response to outer excitations and preventing situations that might cause the delay of the production process. The presented paper includes description of the concept of an informatics system designed for controlling the work of production systems, including work cells. Such systems could operate independently if it would be equipped with the self-organization mechanism. It is possible in the case of the proposed multi-agent system. The implementation of the presented concept will follow the present analysis of the described concept. The advantage of the proposed concept is its hierarchical depiction that allows integrating different utilized informatics tools in one complex system. It allows preparing the final computer program.

1. Introduction
Delmia is a virtual environment which allows to design fully robotic stations of production line and simulate it work. Program developed by Dassault is based on Catia files which causes that it is able to import any geometry modelled using Catia. Primary functionality of Delmia is graphically offline robot programming. This program belongs to Computer Aided software type and is used by robotics engineers all around the world.

Basic types of files used by Delmia:

• .cgr type - contains only basic information’s about geometry, does not contain any additional information, requires little space in RAM memory;
• CATpart - contains information about geometry and stages of its creation or link to geometry included in other files, allows to storage additional information like frames of interest;
• CATproduct - contains links to one or a few geometries contains in other files, allows to define additional information like frames of interest and kinematic properties;
• process - main type of files generated by Delmia V5, contains location of all parts in station, robots programs and points used during offline programming.

One of the greatest problems during using CAx programs in work on big projects are hardware limitations. Model of robotic station can includes many elements what requires high computing power
and provides slowdown the simulation. To avoid this problem stations should be built from the as great as possible number “.cgr” elements. Additionally most elements can be modelled only by their external geometry, interior can be replaced by empty space or solid. Element which extremely borne the computer and should be mandatory replaced by simpler geometry is thread. Engineers must find compromise between accurate models and labour productivity of the program. Because of that some element like a cables are modelled in a very simplified way and it is possible that simulation of their movement will not be consistent with reality. It is very important to sign that one of the worst problems is a difference between virtual model and a real devices or production hall geometry because of using out of date information. Most of program errors is caused by bad communicate between programmer and a customer or between programmer and designer responsible for tool and external devices design. To avoid this errors programmers should use files included in one compact database which has to be constantly updated by all the users and customer.

Positioning parts into virtual robotic cell, definition their properties and creating robots programs are based on a few types of points. Types are divided into two groups: frames of interest and points stored in process file.

Frames of interest is a group of points which is used to specify properties of models and contains three basic types:

- base – type used during positioning parts or devices in cell;
- designe – allows to define kinematic properties;
- tool – defines tool centre point of appliance;

As shown on the picture 1 blue points on moveable tool parts are connected with points on fixed one. Based on that points programmer set constrains and axes of rotation. Violet one should be used for positional the gripper on model of robot during building a virtual cell. Red frame determines tool canter point of the gripper. Its position was determined by method of positioning manipulated part on the gripper.

Points which is stored in process file is called manufacturing. This type determines point which are parts of program and define following arrangements of robot. Manufacturing points are called tags and collected in tag groups. Programs can use many different tag groups and tags can be used more than once. Tag groups make easier to organize points because of their position in space or program.

![Figure 1. Simplified model of gripper with marked three types of points: blue-design points, red-tool, violet-base point.](image)
membership. Each program contains additional information about tags and divides them on via and process points. Process points defines point in space where operation should be executed of where should it starts and ends. Via points define tool path between process points.

Robotic engineers use most often two of Delmias modules: Device Building and Device Task Definition. First one allows to specify kinematic properties of moveable models, second is used for building cells with prepared elements, robot programing and simulation. As in most of CAx programs, basic element of program Delmia V5 is tool called tree. Tree contains names of all elements of the simulation and relationships between them. It allows to switch between modules by double click on the name of process or resource and modify some properties of resources. Delmia V5 gives a possibility to modify all joint ranges values and joint speeds values in device model so as make it in line with reality even if the robot or other machine has been modified by the customer (figure 2).

![Modification kinematical properties of robot model.](image)

Basic term used during robot programming is tool canter point. This point defined by frame of interest type tool determines place of tool which is the last point robot. Correct definition a TCP significantly simplifies improving tasks in factory. Tool canter point can be defined on physical elements of tool like an electrode or on immaterial parts of geometry like an axis or circle canter. It is very important to notice that movement of tool in critical parts of task should be realized along one of the axis defined by TCP. This fact is very helpful during taking detail from magazine or mounting it into manufactured item.

2. Programming in Delmia V5

Robot programming in Delmia V5 is based on conception of using four profiles:

- tool profile,
- accuracy profile,
- motion profile,
- object profile.

It is recommended to use many different profiles of the same type during robot programming if task requires it. Profiles allow easy patching tasks in factory and correct functionality of programs.

Tool profile contains information about TCP and should be created every time when robot changes its tool or other part of tool becomes the most important during operation. Accuracy profile determines
approximation of the path in specified points (figure 3). Selection high level of accuracy may result robot motion slowdown. It should be emphasized that there is no reason to know exact robot path in many parts of the task, when process does not require it and there is no risk of clash.

![Figure 3](image)

**Figure 3.** Green line represents path with high accuracy of the middle point, orange with low value of accuracy.

Motion profile determines speeds of robot drives during movement. Object profile contains information about local reference system used during points creation. Object profiles should be created for tasks related with external devices like magazines or manufactured products.

For example during mounting some elements into manufactured product, robot should take out part from storage and put it down into product. There is a need to use two different object profiles because process is related with two different objects: manufactured product and external magazine. There is need to know that all elements in real factory has positional inaccuracy of different value. Because of that we should use two different object profile during the task. Movement in different parts of task should be realized with different accuracy and speed. When robot moves near some elements of its scene movement should be slower and accurate because of possibility of clash, in the rest of task we should avoid low speeds and accurate movement to obtain the shortest cycle time. Positioning mounted part during taking it out from storage and mounting it into product can be positional by different parts of a tool, so it is justified to use two tool profiles. Depends on settings Delmia V5 can make possible selection config of the robot during reaching following points, interpolation type and allows to add support external devices. Robot path can be saved in program using points in space or following orientation robot arms saved as known joints values. This feature can be especially helpful if is necessary to reach positions near singularity of the robot to determine its configuration. Singularity is a term describing situation when point in the workspace can be reached on infinitely many ways. It’s possible when axes of two rotary joints lying on the same line and there is an infinite number of combinations their relative positions. Other application of this functionality is predefined position programming. For example position which has no connection with robot scene like transport position or home position. Both of theme should has no connection with environment of the robot.

3. **Communication signals and determination of collisions**

Communication between robots and other parts of the station is realized by signals. Delmia V5 allows to add signals during robot programming and simulate work of PLC controllers. This feature allows to simulate simultaneous work all of station parts using tool named Multi Resource Simulation. For accuracy definition work of all controllers managing robots movement programmer should use additional module named Real Resource Simulator. RRS allows also designation accuracy cycle time and make sure that there will be no collision. It is necessary because of little differences in work between controllers responsible for determination of robot movement developed by different company. Without RRS Delmia gives an approximated path and cycle time and this approximation depends on values set in accuracy profiles.

Collision can be divided into two groups:

- collisions between robots or their tools and unmovable elements called static collisions,
possible collisions between robots during work inclusive collisions provided by unexpected events like delay or stop one of the robots in station. For detection and prevention fist type programmer can use tool clash which can search and indicate time and position in space when clearance between marked falls below specified level. Collisions between robots have to be detected by programmer during program development. Prevention can be realized for two ways:

- by path planning,
- using signals as an interference zone.

Path planning is method programing in such way that robots have to cover greater distance but their paths do not intersect. Interference zone can be understood like a flag or resource. Two robots compete for a flag when enter into hazard zone. If first one occupy interference zone program of the second is stopped to time release the resource. It means that interference zone has no relation with space only a parts of robots programs. Interference zone as other signals should be sent only when all information about state of process are known, especially robots positions. For this reason signals should be sent only when robot stops in point specified with full accuracy. Each stop of the robot results in a lengthening cycle time, so sometimes it is better to send signal much earlier instead add additional stop. It means that one interference zone submitted in space can be different sizes and in different places depending on the robot which it use. Robot programing consist of creation programs for normal work of robots, service tasks enabling tool maintenance or assessment of damage after collision and tasks enabling tool change.

Tool maintenance consist of improving tool geometry or replacing some tool parts.

Service tasks are programs which consist of achievement points on measuring element by a key part of tool. If after start-up service task tool centre point do not achieve established point staff knows that damages are serious and further work of station is impossible until the repair.

Programs can also contain command “call task” (figure 4) which runs other task. This functionality can be used for create main programs consisting of small parts. Each part store information about path in some part of manufactured product. When product has a few types and the greater part of the treatment do not change, it is possible to divide path for main and secondary parts. In that case main program can call main and type paths in desired order.

![R3_Main_Program](image)

**Figure 4.** Main program consisting two “call task” command.

Robot programming using Delmia V5 allows to save a lot of time and many because it is not required to stop production for long time. Delmia allows creation programs even when factory is still being build. One of the greatest difficulties during working use CAx software is need for good
project management. Project lider has to ensure that data on which programmers work are always up-to-date and direct the work of the team.

4. Conclusions
In this article possibilities what is offered by the use of modern CAx software in the design of manufacturing processes was shown. It is also shown as by two programs NX and DELMIA simulation and offline programming of robots can be created. The result of this article - design and simulation of robotic work station on the production line was done. In future articles authors will show presented software tools for modeling car production line and they will try to apply simulation in real industry plant.

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