

# Optimal management of reconfigurable manufacturing system modeling with Petri nets developed three-dimensional - RPD3D

F Teodor, V Marinescu and A Epureanu

“Dunărea de Jos” University of Galați, Faculty of Mechanics, Manufacturing Engineering Department

E-mail: [theo.florin@gmail.com](mailto:theo.florin@gmail.com)

**Abstract:** Modeling of reconfigurable manufacturing systems would have done using existing Petri net types, but the complexity and dynamics of the new manufacturing system, mainly data reconfiguration feature, required looking for a more compact representation with many variables that to model as accurately not only the normal operation of the production system but can capture and model and reconfiguration process.

Thus, it was necessary to create a new class of Petri nets, called RPD3D (Developed Petri nets with three dimensional) showing the name of both lineage (new class derived from Petri nets developed, created in 2000 by Prof. Dr. Ing Vasile Marinescu in his doctoral thesis) [1], but the most important of the new features defining (transformation from one 2D model into a 3D model). The idea was to introduce the classical model of a Petri third dimension to be able to overlay multiple levels (layers) formed in 2D or 3D Petri nets that interact with each other (receiving or giving commands to enable or disable the various modules together simulating the operation of reconfigurable manufacturing systems). The aim is to present a new type of Petri nets called RPD3D - Developed Petri three-dimensional model used for optimal control and simulation of reconfigurable manufacturing systems manufacture of products such systems.

## 1. Introduction

The necessity of new manufacturing systems has emerged as a feedback to the globalization of the economy, generating complex applications for producers (a variety of products that meet the quality and low price special).

The concept of reconfigurable manufacturing system involves including the capability to change the physical structure of the production system (repositioning resources, changing their functionality, etc.) to process new pieces of the same family of parts or new families.

The concept of reconfigurable manufacturing system (RMS) and composition of resources (Reconfigurable Manufacturing Machines - RMT, transportation systems parts and semi-finished industrial robots, storage, etc.) have been proposed in 1999 at the Center for Systems Research Reconfigurable Manufacturing (ERC / RMS) at the University of Michigan by Prof. dr. Koren Yoram



known in the scientific world as the "father of RMS".

He defined as the RMS modern manufacturing systems, it has precisely the required production, just when it is needed. *This means that the manufacturing system adapts in real time to the point of manufacturing requirements by reconfiguring processes that can be grouped into several classes, as follows:*

**R1** – Initial setup of all elements RMS - manufacturing workshop (building the list of resources available and the choice of which will be included in a synchronization RMS on technical characteristics of the resource and technological operation to be performed);

**R2** – Reconfiguring all the factors RMS by opting for a technological flow or another (FT - order of achieve technological operations and relations of dependency between them);

**R3** – RMS reconfiguration to ensure system stability (capacity calculation positions RPD3D variables associated RMS Petri net so this is viable, stable and without jamming);

**R4** – RMS manufacture reconfiguration during simulation by changing states of RES resources (either an RES becomes available at some point, or becomes unavailable because of failure or the need to use it in another RMS);

**R5** – RMS reconfiguration under changing production specifications (changing the number of copies made of a particular product, in or out of the manufacture of a product);

RMS's aim is therefore to achieve an overall manufacturing orders or family of parts in a number of samples while maintaining optimal configurations the available resources according to the chosen criteria (minimum production time, maximum productivity) in terms of system stability.

Reconfigurability's RMS must be based on economic factors that will ensure that the benefits obtained outweigh the costs and production losses reconfiguration for this operation.

We assume that this condition is satisfied in all cases and suppose that reconfiguration time is as small (eg R3 and R5 time should not exceed the time necessary to manufacture a one product). Also, the reconfigurability to be atomic - is carried out in a single operation to reconfigure then be re-evaluated RMS's condition.

## 2. The idea

Modeling of RMS would have done using existing Petri net types, but the complexity and dynamics of the new manufacturing system, mainly data reconfiguration feature, required looking for a more compact representation with many variables that to model as accurately not only the normal operation of the production system but can capture and model and reconfiguration process.

If any products to manufacture enough to have a workshop with some machine tools, industrial robots, intermediate storage of parts and tools to make several technological operations, then we can modularize the whole process by associating each resource and generic RPD3D each technological operations, they differ only by working parameters and status. These can be predefined generic RPD3D are editable and are stored as modules, parameter values so that individualized product or its manufacturing process technology being stored in the database.

Shaping extremely simple to manufacture a product (5-6 technological operations on 2-3 machine tools supplied by an industrial robot and equipped with deposits of semi-finished and finished parts, plus inter-conditionings and error correction subnets) with a classical Petri net we get a model that will contain dozens of positions and transitions and hundreds of links between these elements will have a development model prevailing in the vertical relationship between the two dimensions may have values of  $6 \div 20$ , the network obtained is hardly noticed as a whole.

For a more complex product manufacturing (tens of technological operations, dozens of machine tools, industrial robots, elements of the transport and storage, several members of the product family, the whole assembly being able to reconfigure dozens of other manufacturing systems) we get a classical Petri

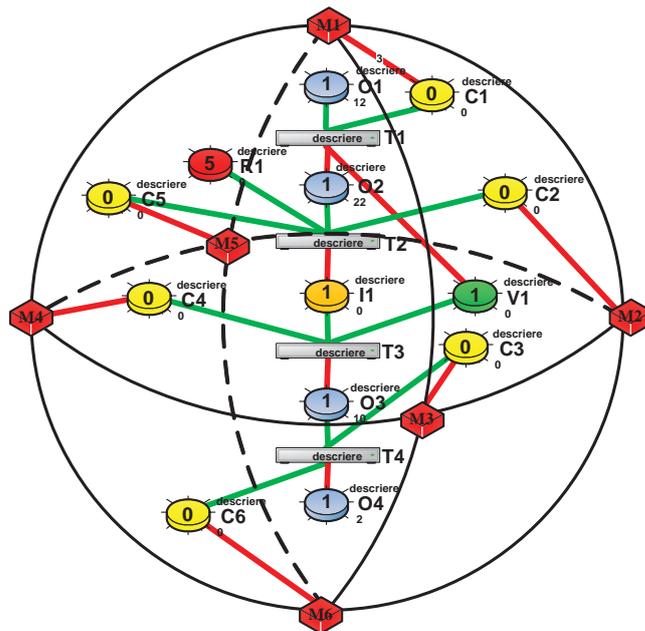
network of thousands of elements linked by tens of thousands of links. Such a network would be represented in the form factor represented and viewed almost impossible, but adding a third dimension Petri net can obtain a compact representation, even beautiful, which will also resolve the difficult problem of tracking a link type feedback (reset) of one of the last transition to one of the top positions commonly used type of connection.

In nature the deoxyribonucleic acid has a 3D structure of double helix just to save space, not influence function as essentially a 'ladder' right is functionally identical to the one of a double helix.

### 2.1 Analysis of the state of resources

During operation of RMS, a resource can be in one of the following six states: Ready (R), Work (W), Damaged (D), Pause (P), Error correction (E) or IntoRMS - built into RMS (I) - the resource is ready but requires time to be entered in RMS. During operation of RMS, a resource can be in one of the following six states: Ready (R), Work (W), Damaged (D), Pause (P), Error correction (E) or IntoRMS - built into RMS (I) - the resource is ready but requires time to be entered in RMS.

The transition between a state and the other resources can be automated (P to W, W to R, E to I, E to W) or may be subject to state one of the six markers (ON - marking is active, thus allowing change of status OFF - the mark is inactive and blocks the change of state (see figure 1).



**Figure1.** RPD3D network that models the operation of RMS module

### 3. Developed three-dimensional Petri RPD3D - presenting the model

To create and simulate the operation of RMS with RPD3D author created an application called SODRMS (System to Optimal Driving for RMS) based on the NetBeans8 IDE development platform in tandem with a MySQL database and graphics were made with Java3D interface.

Note that all programs used and related documentation (NetBeans, MySQL, Java3D) are available free on the Internet, so long as they are not used for commercial purposes, so they are easily available to anyone who would like to create work environment for application SODRMS. Like any Petri net, RPD3D consists of two main elements: position (represented by spheres) and transitions (represented by



activities and start counting the number of cycles controlled and controlling position at the exit end of the last transition of operations to control and count the cycles of activities for each subsystem type of machined parts in the system. In this model are transitions that represent the beginning or end of an operation - O-transitions and transitions that trigger subnets for error handling are E-transitions.

As a novelty, the colors used to represent positions and transitions were differentiated for easy viewing in 3D space and understanding RPD3D operation: operational positions - red (O), fixed resources positions - green (R), position variable resources - blue (V), intermediate positions - Gray (I), control positions - yellow (C), operational transitions - blue (TO), transitions, input / output of subnets - yellow (TE) (see figure 2).

Each position RPD3D may contain one or more marks (or chips). Representation in classical RP was achieved by points that were added or removed from the circle symbolizing the position, but in the transition to three-dimensional representation, marking positions to be adapted and opted for a numerical representation placed on the outside of the sphere that symbolizes the position.

The graphical representation of the elements is a ball-type position (diameter 0,5 - 1 - 2 or 3 units), and the type of transition elements is a parallelepiped with dimensions of length and 0.5 x 3 units section 0.5 units - 3 being colored according to the convention above.

Positions and transitions have some metadata displayed graphically, the others being stored and handled only by RMS related MySQL database. Four position description are shown (top right), titled (right) mark (middle range) and execution time (bottom right) and the transition name (right) and description (middle).

#### 4. Presentation tables in the database for the main elements RPD3D

Table POZ – type stores data items in a module position RPD3D how a resource can be associated to a workshop production or technological operations of a manufacturing flow of a product, data like: *ID position* - number generated by the database, incremental, used as the primary key of the table (sorting, unique records), *name position* - like O25, *description* (interpretation) position - remained formulating grammatical descriptions used in the definition of RP-D model [1], *marking* the original position, *the coordinate of the center* position, *scale* position - which is the position size (0.5X, 1X, 2X and 3X), *the maximum allowable execution modeled operation* position ( $T_{max}$ ) in seconds, *visibility* -1 (ON) and 0 (OFF) and *timestamp* - when inserting position as a 10-character numeric sequences; The insertion type Timestamp field value is automatically calculated and can be used to reconfigure the RMS (you can compare the current time with TSTP and find out bond or 3D object is more recent or older. Ex: 1256953732 = Sat Jul 23 02:16:57 2005

Table TRZ – stores data items in a module type transitions RPD3D, how that can be associated with a resource or a workshop production of a technological operations manufacturing flow of a product, data like: *ID transition* - number generated by the database, incremental, used as the primary key of the table (sorting, unique records), *the name of the transition* - the type TOnnn, TCnnn, where nnn is a number of 8 characters, *the description* (interpretation) transition - remained formulation grammatical descriptions used in the definition of RP-D model [1], *the coordinate of the center the transition*, *initial error code* of the transition, *scale transition* - the size of which is the transition (0.5X, 1X, 2X and 3X), *visibility* transition-1 (ON) and 0 (OFF), *timestamp*- timestamp of transition – transition time of insertion as a 10-character numeric sequences;

Can thus be defined  $10^5$  error codes, enough for any module RPD3D each error code with a description and a way of resolving the error, even if for most of these error codes, solving resource is switching state D (Damaged) and excluding it from the RMS's analysis.

Links between elements are oriented (sense) and are carrying information about the manufacturing system reconfiguration.

Table LEG – stores data items in a module type connected RPD3D how that can be associated with a resource or a workshop production of a technological operations manufacturing flow of a product, data like: *ID link* - number generated by the database, incremental, used as the primary key of the table (sorting, unique records), *the name of the connection*, *name position*, *name transition*, *meaning the link* (0-direct, 1-reverse), *the weight of the link* (probability of extinction of that links to a possible reconfiguration), *description of the link* (optional, in particular for the weights 1 and 2), *TTB\_LEG* - TimeToBuild - information, in numerical form (seconds), which is the length of materialization or selling link in the process of reconfiguration, directly proportional to the weight of the link, *visibility of link* - 1 (ON) and 0 (OFF), *timestamp link* - hold when inserting links as a 10-character numeric sequences; useful to compare the connections between them by their age (maintenance required reconfiguration process).

The weight three is given arcs of the elements constituting modules RPD3D, weight 2 is given RPD3D arcs between modules on the same level and the share of one of the modules is given arcs RPD3D located on different levels.

The link thickness indicates durability link, weakest link indicating a higher probability of extinction of that links to a possible reconfiguration of RMS, the share of the three strongest and the weakest one. Data links between modules (share 1 and 2) will be noted in Table CON.

In addition, in the RPD3D model, easy to make the connections between the different modules of the RMS, placed on the same level or on different levels, it adopted a third type of element, called connector, represented by a red cube with sides equal to the diameter of the sphere which is a position connectors are arranged on a sphere circumscribing RPD3D compact (obtained after compaction operation). The based connections are six, are placed in the points where the axes intersect the sphere which includes RPD3D compact and are referred to as M1 (y +), M2 (X +), M3 (z +), M4 (x-), M5 (z-), M6 (y-). Outside the module, the six connectors are connected by arcs of weight 1 or 2 other connectors and inside the module, they are connected by arcs of 3 weight control positions which they convey different commands given from higher hierarchical levels (ie : beginning or end of OT, transfer the number of finished parts made, changing the state of RES). Connectors does not affect the operation or its associated RPD3D analysis but were only meant to send it to and from the upper levels commands will result in the reconfiguration or RMS's operation.

Table CON – connector type stores data items in RMS: *ID connector* - number generated by the database, incremental, used as the primary key of the table (sorting, unique records), *RPD3D module ID* which includes, *name connector* - type M1 (means M1 connector module 23 associated with the RMS), *description connector*–optional, fields *X\_CON*, *Y\_CON* and *Z\_CON* are the coordinates of the connector relative to the center of the sphere circumscribed, *PLI* - internal liaison position (inside the module ex: "C2"), *PLE* - external link position (another connector module ex: "M1\_MOD\_23"), *weight* - leg. between RMS modules are on different levels are value 1 and leg. between modules of the same level are value 2, *STARE\_CON* (active / inactive) that transmits the activation signal to another module or not, *visibility Connector* – (1 ON and 0 OFF), *visibility of link* -1 ON and 0 OFF, *timestamp*- hold when inserting links as a 10-character numeric sequences; useful to compare the connections between them by their age (maintenance required reconfiguration process) și *timestamp position* - when inserting the connector as a 10-character numeric sequences;

As a novelty, it will be able to use the zoom in levels - the number of items displayed on the page (visible) will be chosen depending on the zoom level. This feature uses zoom levels of visibility of items in the RPD3D, switching from one zoom level to another leading to enable or disable the visibility of certain elements.

Also, all the new element was introduced feature scale (representing the same type of item 0.5 of normal size or 2x or 3x).A greater representation of an item RPD3D suggests greater importance given that item (robots, other important resources).

Thus: which models resource positions (fixed or variable) will be represented at 2x or 3x scale positions and operational transitions (those of processing, assembling, etc.) at 1x scale, control and intermediate positions will be represented at the scale 0.5 x.

Since we started from the premise that RPD3D RMS modeling the operation's resources look the same regardless of size, for leaders or materials involved, which leads to a standardization of these networks, they can be built, it will create the basic forms RPD3D resources, the rest can be created when it will be needed.

## 5. Conclusions

Just as DNA is essential to the identity of any body, so RPD3D is suitable mathematical model to describe the process of reconfiguration of reconfigurable manufacturing system, the combination and interaction of the modules RPD3D inspired by way of combining DNA elements whose sequence determines the diversity of individuals of the same species.

Taking on the comparison of genetic identity and modeling of manufacturing systems can be said that the method of differentiation of individuals of the same species by a minor modification of the combination of the DNA could be used to create a procedure to enable the manufacture of entire families of parts per same RMS adjustments (reconfiguration) minor. This can be compared with the reconfigurability of RMS temporal evolution of a species nearing RMS sites more than any other previous production systems can integrate into manufacturing of bioengineering features.

## References:

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