Journal of Trends in the Development of Machinery
and Associated Technology
Vol. 18, No. 1, 2014, ISSN 2303-4009 (online), p.p. 119-122

IMPLEMENTATION OF INTELLIGENT MANUFACTURING ALGORITHMS IN AGILE ARCHITECTURES FOR PRODUCTION: WORLD MODELS FOR SYSTEMS INCORPORATING BINARY AND CONTINUOUS VARIABLES

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ABSTRACT
Building in previous works of the authors, the present paper focuses on the extension of the Algorithms described for the specific case study of binary systems (systems in which each variable can take one out of two values), to cases that also incorporate continuous variables (those which can take any continuous value within a range). This extension of the Algorithms makes possible the incorporation of new possibilities and functionalities for the treatment of the information received by the sensors of the manufacturing systems and in particular reduce the number of variables in which to monitor the states and costs of execution. The Construction of World Models based on this logical theory -that incorporates the knowledge derived from the results of a set of experiments conducted by the system utilizing a set of different algorithms- is applicable to a wide range of production systems topologies, which is also visited in the present work.
Keywords: Agile Manufacturing, Intelligent systems, Algorithms

1. INTRODUCTION
In previous works [1,2], the authors have explored the possibilities of building World Models of a Manufacturing system and its environment in order to succeed in making a specific task without the need of programming specifically all the steps to achieve it; but only to enunciate a task as a defined set of information containing the Initial and Final desired end state. In this way, an Intelligent system is empowered to perform the tasks execution by itself without needing extensive human programming taking into account each and every eventuality that might occur during the systems' performance.
Computers are good for carrying out repetitive tasks and for providing high computing power and better repeatability than they would be able to humans; and so, computers are the best candidates to perform experiments and learn. Lopson and Schmidt [3] developed in 2009 an experimental interface called "Eureka Machine" dedicated to model mathematically the laws of nature by observing the behavior of the world face experiments. The effective implementation of autonomous learning

platforms in agile architectures for professional production, as it is being approached in personal manufacturing systems such as the RepRap case study[4], should make possible the enhancement of a truly deployment of intelligent behavior in industrial manufacturing.

2. DEFINITION OF SYSTEMS WITH CONTINUOUS VARIABLES

The previous binary algorithms presented –i.e.: algorithms for building models in worlds populated only binary variables which only take the values '0 'or '1 '-, are representative for multitude of manufacturing cells and manufacturing automatic systems with repetitive movements such as handlers, conveyors and pistons. However, in certain manufacturing systems topologies and in particular in the case of machine-tools, and other machine architectures such as the additive manufacturing systems, there is the need to control smooth movements along different axis; thus implying a big quantity of variables to be utilized.

In the cases where a specification of continuous movements is required, it can be reached by building a topology with very high resolution. Indeed, by increasing the number of positions in any of the main directions it can be generated a model 'almost' continuous -or at least, continuous in the limit- (*See Figure 1* below).

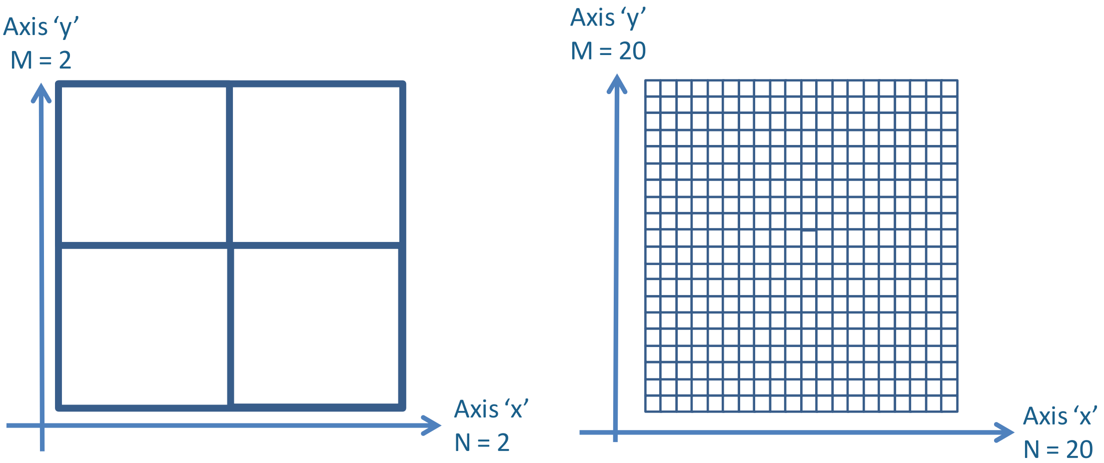

Figure 1. Different levels of resolution for a 2D-reticule. Left 'N'x'M'= 2x2, Right: 'N'x'M'= 20x20.

However, in order to utilise this modelling approach, it is necessary to put many sensors (on in each position for each grid spaces) and so increasing the number of input sensor and variables in the system, in the limit, to the infinity. Moreover, a possible complementary modelling is to use a consequence of the logical model presented by Vivancos and Gomà[1], which determines that the models are not unique in the world. In this way, instead of determining a world using twenty binary variables (for example, in the case of Figure 1 where there is a grid of twenty binary positions) which can only take '0 'or '1' as value, it is possible to model the same situation using a variable, called "continuous" capable of taking a number of values within a range (in the same example, twenty, although with enough computing power could increase to infinity).

This type of modelling can be used to greatly simplify the number of variables to govern as well as the number of sensors contained in the system, thus, only a sensor for each variable is needed. At the physical level, it will also imply to change the sensors utilised respect those used in the binary case, which now will require a much greater range of information acquisition capability (*See Figure 2*). Keeping in mind, though, that this modelling is not a continuous model in the mathematical sense of the term (because there will always be a degree of approximation for the transition to discrete values of the continuous values in the range of job), this situation is not a disadvantage in physical reality because all sensors measuring systems will only be capable of measuring and rounding numbers to a certain quantity of decimal positions; and it will not be needed to reach real infinite resolution.

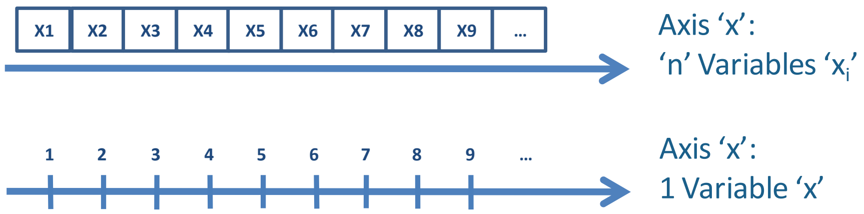

Figure 2. The same controllable machine-tool axis modelled via 'n' binary variables (above) and a single continuous variable (below).

3. IMPLEMENTATION BY MS VISUAL STUDIO®

To assess the results yielded by a continuous implementation, it has been used the same experimental platform (named 'States Space') than it was constructed for the binary case; although this time it has been further developed so to include the treatment of continuous variables. Since the implementation of this test bench in MS Visual Studio® is only intended as a mean of verification of the utilization of the algorithms presented for the binary case in this continuous variables approach, the introduction of the modeling of the continuous variables was performed by incorporating a third axis Cartesian movement 'z' to the head of an hypothetical machine-tool formerly only moving along the axis 'x' and 'y'.

For reasons of simplicity in the graphical representation, rather than adopt a three-dimensional isometric view display to show the trajectories in the three Cartesian axes, the board view remains 2D and the representation of the relative height position of the head and obstacles is an azimuthal projection of the value 'z' in the direction normal to it. When the head is in the position of minimum height (z = 0), the circle drawn in the space provided in the grid has the same diameter as in the 2D case. Similarly, when the head is in the position of maximum height (z = 1), the circle drawn in the space corresponding to the grid is much smaller than the previous one (See Figure 3).

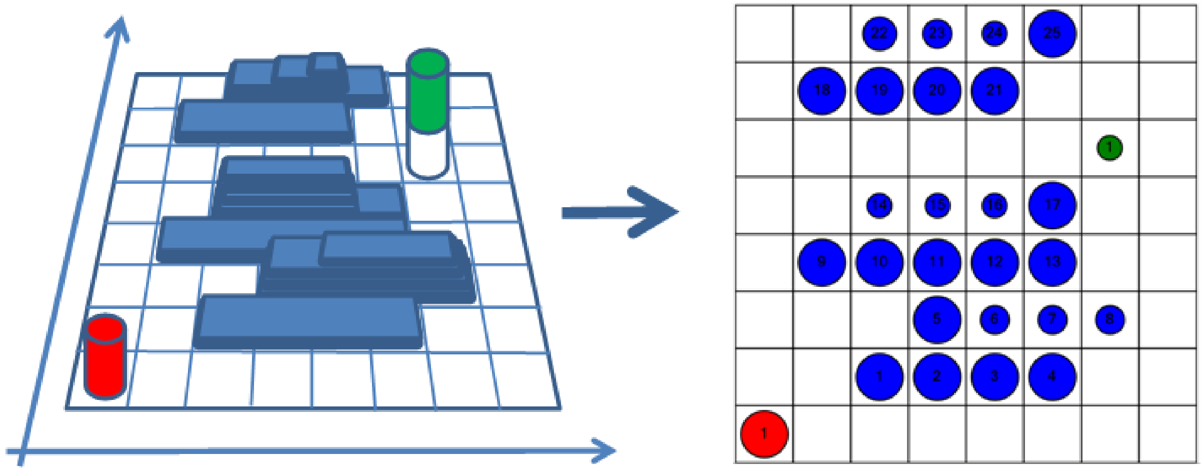

Figure 3. Situation of World three Cartesian axes of movement ('x'-'y'-'z') with obstacles and representation via MS Visual Studio, marking the two positions of the head: the initial state {E_0}-red-, final state {E_f-} -green- and obstacles –blue-.

In this new situation, there is a new variable 'z' can take values between '0 'and '1' with a resolution of one decimal. In the case of the head, this variable represents the minimum lower bound. In the case of possible obstacles, this variable represents its maximum height. Thus, given a specification of initial state and final states {E_0} and {E_f}, the system not only has to find a practicable way taking into account the 2D occupation, but it also has to take into account the height of the obstacles incorporating another controlled axis which is modeled via continuous variables.

4. DEFINITION OF STRATEGIES

In essence, the specification of the algorithms for modeling the world and for executing tasks remains invariant respect those implemented in the binary case. The main difference comes, however, because there is now a new ‘z’ variable that can take values between '0 'and '1' with a resolution of one decimal place (i.e., it can take up to eleven different values: 0 ; 0,1; 0,2; 0,3; ... 1).

Moreover, unlike what happened in the 2D case, in 3D appears a set of variables corresponding to the height of obstacles {θi}. In fact, for each obstacle is introduced into the system, it will be necessary to introduce a variable charge to meet your height. Thus, in contrast to the binary case discussed where the obstacles were all the same type, in this new situation, each obstacle will have its own distinct height variable. In relation to the variables sent to the actuators, it is necessary to take into account the new ones that act on the new system variable. In particular, it has been chosen a forth of 3D inputs that are: {α1} = {0; 0; 0}, {α2} = {1; 0; 0}, {α3} = {0; 1; 0} and {0} = {0; 0; 0,1}, ensuring that the variables have a resolution equal to the definition used for the transition to discrete numbers (in this case 0,1).

The situation presented and the 3D model described is inspired in an additive manufacturing system based on FDM technology constructed in Fundació CIM (See Figure 4). The treatment of states and the methodology for determining the minimum paths remain invariant.

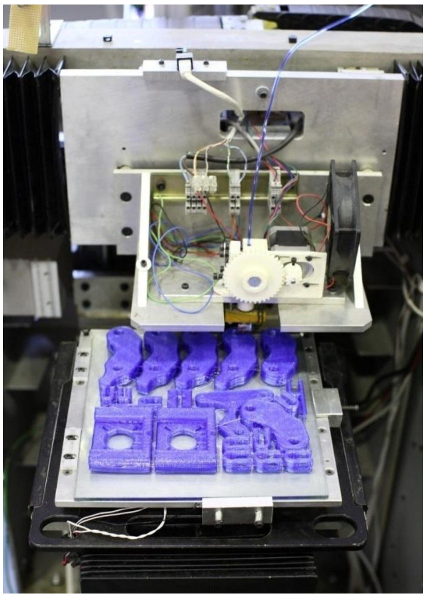

Figure 4. Application case of an Additive Manufacturing system for plastic FDM constructed in Fundació CIM.

5. CONCLUSIONS AND FUTURE WORK

The results achieved move a step forward to the implementation of intelligent production systems, this time being capable of incorporating continuous variables in the frame of testing and analysing World Models and undertaking Autonomous Tasks Execution. Therefore, the presented work for autonomous learning can be applied in more manufacturing systems than the former ones, including machine-tools and additive manufacturing systems architectures. Although the representation view remains a 2D board modeling, indeed, it represents a situation in a cubic space of three dimensions.

The potential scope of application of autonomous learning systems is huge, due to the fact that there are myriad of possible fields of application such as medicine, biology, cosmology, environmental science or even social science. The introduction such systems in agile architectures for manufacturing may suppose a breakthrough in the way to set up and interact with the production systems; making possible for the operators to rely in the knowledge residing in the machines.

6. REFERENCES

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