CONTRIBUTION TO AUTOMATIC SYNTHESIS OF FORMAL THEORIES OF PRODUCTION SYSTEMS AND VIRTUAL ENTERPRISES

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INTRODUCTION

The first principal objective of the project is validation of two scientific theses concerning the problem of automatic synthesis and use of Formal Theory (FT) of Production Systems and Virtual Enterprises (PS/VE):

1) It is possible to automatically generate a valid FT for PS/VE systems and subsystems; and
2) FT provides more efficient design process than usual intuitive "ad-hoc," informal or only formalized design solutions. These theses will be validated through evaluation of the design process and outputs (solutions) of the traditional design processes in comparison with the specifications obtained by the automatically generated FT (of the corresponding real-life PS/VE).

The second principal objective is development of a corresponding software tool for synthesis of the Formal Theory based on machine inductive inference algorithms (machine learning) of specific formal grammars, namely, the Graph Grammars, with attributes, as the Formal Theory model representation class, in order to achieve the first objective.

STATE-OF-THE-ART AND OBJECTIVES

Concerning the "state-of-the-art" of the development of a FT of PS/VE, there is no consistent and rigorous approach towards the FT of PS/VE, except the initial results in the FCT Interdisciplinary Centre of Production Technologies and Energy (CITEPE) at the University of Minho, through one PhD project (Sousa 2003) and one MSc project (Rosas 2000), and a number of papers, (Putnik and Sousa 2006), (Sousa and Putnik 2004), as well as at the UN University, Macau, (Janowski 2000).

The objective of the project, which is the automatic synthesis of FT, will be limited to relatively smaller systems that in reality represent the "real-life" production systems, or VE, subsystems or some specific aspects, e.g. manufacturing cells and FMS (Flexible Manufacturing Systems) as a "real-life" production systems subsystems, and their functional and physical structures and specific aspects (e.g. spatial structures, processes structures, control and organizational structures, VE organizational structures, and similar). It is important to mention that the Formal Grammars and Abstract Automata (FG/AA) are a FT rigorous models (Minsky 1967), which is a strong base for the proposed PhD project, as the FG/AA theory is a well formed and validated theory (in computer science).

Finally, this project represents continuation of the fundamental research on the topic in the FCT Interdisciplinary Centre for Production Technologies and Energy – CITEPE, UMinho.

METHODOLOGY

The above theses will be validated through an analysis of consistency of the "real-life" cases and specification(s) by the automatically generated FT (of the corresponding manufacturing cell, or FMS, class).

The FT generation process, as well as the production system, and VE, design process, metrics will be defined based on the processes complexity analysis (time and space complexity) as well as on the "learnability" concept (Valiant 1984), i.e. evaluating the error of the generated FT, as well as some "traditional" system performance metrics.

For the comparison and validation of these theses, a prototype demonstrator of Ubiquitous Manufacturing System (UMS) is developed, with functionalities of a typical manufacturing cell with CNC machines and network communication among several such cells and distant users, thus forming building blocks for creation, and basis for validation, of another demonstrator of Automatic Synthesis of Formal Theories of PS/VE.

FORMAL THEORY MODEL (FORMAL GRAMMAR) FOR MANUFACTURING SYSTEMS

An example of a networked system of computer controlled manufacturing cells FT presented in a formal grammar as the representation class is given below.

In Figure 1(a), a Formal Grammar with attributes for design of Virtual Enterprises, in conformance with the BM_VEARM (BM_Virtual Enterprise Architecture Reference Model) (Putnik 2001) and in Figure 1(b) an example of thus generated formal model of manufacturing system architecture part according to the BM_VEARM model architecture are shown.

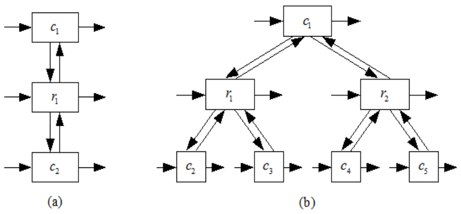
$$G_{BM} = (V_T, V_N, S, R) \text{ com:}$$

$$V_T = \{c_1, \ldots, c_{n_c}, r_1, \ldots, r_{n_r}, s_{eq}, \equiv, \downarrow\uparrow,), (\}$$

$$V_N = \{S, A, B\}$$

$$\begin{aligned} R = \{\, & S \rightarrow c_i(\downarrow\uparrow A) \equiv s_{eq}, \\ & A \rightarrow r_i(\downarrow\uparrow B), \\ & A \rightarrow AA, \\ & B \rightarrow c_i(\downarrow\uparrow A), \\ & B \rightarrow BB, \\ & B \rightarrow c_i \;\} \end{aligned}$$

Figure 1 (a): A Formal Theory (BM_VEARM) in the Formal Grammar representation class, for BM_VE control, or processes, architectures



$$S \Rightarrow c_1(\downarrow\uparrow r_1(\downarrow\uparrow c_2)) \qquad S \Rightarrow c_1(\downarrow\uparrow r_1(\downarrow\uparrow c_2 c_3) r_2(\downarrow\uparrow c_4 c_5))$$

Figure 1 (b): Examples of BM_VE model architectures generated by the BM_VE FT (BM_VEARM)

A physical installation of a Manufacturing Cell at University of Minho is shown in Figure 2.

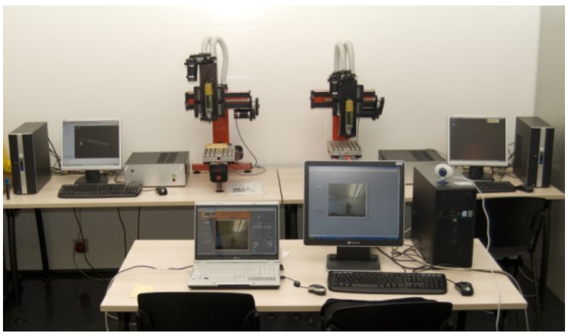


Figure 2: A Manufacturing Cell with CNC machines: the building blocks of the UMS

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