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Correlations between emergent synthesis classes: Due date based control and planning of job shops

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Abstract

Emergent synthesis classifies problems of artifactual system behavior into three classes depending on the completeness in the description of the system environment and specifications. This paper introduces correlations between the problem classes and their problem solvers. To illustrate the discussed correlations, a job shop model with make-to-order manufacturing environment is presented. The problem frame of the control and planning in the model is shown to be a Class III type problem and approached by using the correlated problem solvers of the three classes. The purpose of the job shop is to evaluate the overlapped space between the specifications of the customers and the capabilities of the manufacturing system and to form the behavior of the system in order to fulfill orders with high accuracy. The structure of the model and the developed solvers indicate that to solve a Class III type problem, various Class I and Class II problem solvers are relevant.

Keywords: Emergent synthesis; Manufacturing control; Production planning

1. Introduction

Emergent synthesis offers a great methodology to handle and resolve complexity in artifactual systems. Harmonizing top-down and bottom-up features in forming the behavior of the system, the approach provides efficient, robust and adaptive solutions to the problem of synthesis [1]. In emergent synthesis related solutions the global behavior of the system is dynamically formed bottom-up through locally inspired interactions between the artifacts attempting to achieve the purpose of the whole system. To verify the emerging global order, top-down features are introduced that are able to modify the order by rendering the global purpose to the artifacts top-down. With taking into account the local and global goals, the artifacts build up their emerging behavior in order to accurately achieve the purpose of the whole system.

Emergent synthesis introduces three types of problem classes and their emergent related problem solvers depending on whether completeness of information could be achieved in the description of the system environment and the specifications of the system. In Class I type problems full completeness can be achieved in both the description of the environment and the specifications. Although all constraints to be taken into account are known, to find a solution satisfying all the constraints leads to combinatorial explosion. Therefore, emergent related methods that can handle combinatorial explosion are implemented in this class. The problem solvers are evolutionary computation methods such as genetic algorithms and evolutionary programming. In Class II type problems the description of the specifications is complete, but the description of the environment is incomplete. The proposition of the system is to cope with the dynamic properties of the unknown

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environment. To deal with this problem, the environmental constraints have to be determined through being in interaction with the environment. Learning and adaptation based approaches such as reinforcement learning and adaptive behavior based methods are feasible to this class of problems. In Class III types withal the incomplete environmental descriptions, the description of the specifications is also incomplete. Besides ascertaining the dynamic environmental constraints, this class has to cope with the iterative determination of the system structure. Emergent properties, such as interactivity, self-coordination, co-evolution and self-reference are essential in this class.

In this paper correlations between emergent synthesis classes are under examination. One correlation can be seen between Class II and Class III as the implementation of the Class II approaches to handle the unknown environmental changes in Class III type problems. In the aspect of the presented research work it is necessary to establish further correlations between Class I, Class II and Class III classes to solve complex problems in artifactual systems. The paper first draws a schematic functional description of emergent synthesis classes and their correlations. Although it is an oversimplified model, it shows, in the same manner, the examined correlations between the classes. Literature review follows the schematic model to support the necessity of establishing the correlations. After the review, a Class III type problem is described as the due date based control and planning of a job shop model with make-to-order manufacturing environment. The developed problem solvers and system structure illustrate that to solve a Class III type problem, various Class I and Class II problem solvers and their synthesis are relevant.

2. Correlations between the problem classes

2.1. Schematic functional model

In Class I problems the description of the environment and the specification is complete. Let E denote the set of environmental constraints, S the constraints of the specification and P the constraints of the human purpose, then the symbolical model of a Class I problem can be seen in Eq. (1)

$$\begin{aligned} & f(E,S) \rightarrow R \\ & \text{subject to } P \end{aligned} \tag{1}$$

In Eq. (1), f function denotes the search method that is able to find optimal or quasi-optimal solutions and R the result of the method as that found near optimal or exact solution for the problem. The main difference between Class I and Class II is the dynamic approach to the problems. In Class I the emergences of the solution is not time related, but in Class II the emerging solution is valid for time periods in between the decision makings where the dynamic environmental constraints need to be considered. To solve a Class II type problem the incomplete description needs to be completed for the decision making and the dynamic property of the environment handled. In Eq. (2), the g function denotes the learning or adaptation based method that converts the environmental changes to determined constraints at any time t. The task of the learning and adaptation method is to signify the non-linear property of the uncertain environment, thus the g function is non-linear by t.

$$g(\Delta E, t_n) \rightarrow E_n, \quad \text{where } n \in N \tag{2}$$

In Eq. (2), t_n denotes the time the decision is requested to be made in the Class II type problem. In case the environmental changes are accurately indicated by g, then with complete description a Class I problem can be defined at any time and a search method can be applied (see Eq. (3)). The Class II problem is approached as a dynamic Class I problem. R_n represents the emerging solution for the decision making that is denoted by t_n.

$$\begin{aligned} & f\{g(\Delta E, t_n), S\} \rightarrow R_n \\ & \text{subject to } P \end{aligned} \tag{3}$$

In Class III problems, besides the incomplete description of the environment the system has to be prepared for incomplete specifications as well. The system interacting with its superiors and collaborators determines goals and specifications to form its behavior and achieve collective and individual purposes.

One can suggest that if superiors and collaborators are considered as environmental factors then in this approach a Class III type problem would not differ from a Class II problem. An architect having created a new design style that inspires other architects to follow did not solve a Class II problem with the design of his first building in the new style. Even if the customer who ordered the building is considered as an environmental factor, he certainly left incomplete specifications for the architect that allowed him to design in the new style. The architect using his creativity rendered these incomplete specifications to individually complete specifications that drove his conceptions. Moreover, his actions have been learned and adopted by the environment. A successful system in a Class III problem is able to perform actions which can drive itself and its environment to a higher level of development without complete specifications.

In the schematic model, specifications are handled as dynamics of the system without considering their externality or internality. Let h denote the iterative method (co-evolutionary, self-organization or interactive) that is able to determine the set of constraints of the specifications at any time t (see Eq. (4)). Note that the function h is also non-linear by t due to the uncertainty of the specifications.

$$h(\Delta S, t_n) \rightarrow S_n \tag{4}$$

In case the specifications become determined, the Class III problem can be approached by the synthesis of a Class II and a Class I problem at time t_n (see Eq. (5)).