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# Consistency check of the functional solution model in special purpose machinery

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**Abstract**

Individual customer demands and increasing technical complexity are placing an even greater importance on the engineering process for special purpose machine manufacturers. To support the engineering process the Manufacturing System Dependency Model (MaSDeM) was developed. The basic idea of the MaSDeM concept is to install a cross-domain solution model at the beginning of the engineering process representing the principle solution. The building blocks for this model are functionally categorized automation components. However, since the resulting system is more than the sum of its components, the links between the elements need to be examined. In this paper a consistency check for the MaSDeM cross-domain solution model is proposed. This involves the identification of the different types of links between the components. The features of the links and the component categorization are used to build up a knowledge base for the consistency check. Thereby the static and procedural structure and the process functionality of the solution model can be verified. Moreover, the links can provide further engineering information. A profound principle solution is hugely important for the engineering process, and thus the consistency check is a vital contributor to increasing the efficiency of the engineering process in special purpose machinery.



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*Keywords:* Engineering; Consistency; Model; Special purpose machinery

## 1. Introduction

Manufacturing in Europe is under a great pressure from structural changes in the global economy [1]. Providers of manufacturing systems must face two major trends. The first trend is brought about by the consumer market which demands individualized products and shorter product life cycles [2]. This creates the need to produce a large number of varieties on a manufacturing system and the need to quickly adapt the system to new products [3,4]. The second trend is the technical progress and the integration of information and communication technologies into manufacturing systems [5]. Whereas in the past manufacturing systems used to be characterized by the mechanical basic structure that was supplemented by several electrical components, nowadays innovations are mainly based on the cooperation between the domains mechanical design, electrical design and software [6].

In view of these trends, the challenge of engineering is to manage the complexity of individualized special purpose machines with a cross-domain engineering team. Hence engineering is becoming more and more important and its efficiency is a critical factor for success [7]. Three performance parameters are used to rate the efficiency of the engineering process in special purpose machinery: time, cost and quality [8].

In order to improve the cross-domain cooperation in special purpose machine manufacturing and thus to increase the efficiency of the engineering process, the Manufacturing System Dependency Model (MaSDeM) was developed [9]. The basic idea of the MaSDeM concept is to introduce a cross-domain solution model at the beginning of the engineering process. This is the stage during which the principle solution is created and thus most of the features are defined and fixed. As the cross-domain solution model forms the basis for the


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engineering process, it must be easy to understand for all participating domains and the consistency of the model must be guaranteed.

This paper presents an approach to verify the consistency of the MaSDeM cross-domain solution model by identifying contradictions in the interlinking of components and using the model to gather information. Therefore an overview of the MaSDeM concept is given in the next section which can be seen as the framework for the model checking approach that is presented afterwards.

## 2. Basics of MaSDeM

Special purpose machine engineering is a cross-domain challenge and entails a need for cooperation to reach the optimal mechatronic solution. Each domain brings its specific expertise to the process and contributes to making the system operational [10]. The customer has the specific knowledge of the product to be manufactured and the manufacturing process. In order to realize the process in a special purpose machine the engineering is assigned as appropriate to the domains mechanics, electrics and software. The mechanical design determines the geometrical structure of the system as well as the selection of the automation components. The wiring and communication infrastructure is within the responsibility of the electrical design and the software determines the logical sequences and implements the controller code. [11]

However, several problems can occur during the cross-domain cooperation. Each domain has specific engineering tools and models which hamper the exchange of information between the domains. That is why the domains mainly execute their tasks autonomously, leading to misunderstandings, errors and suboptimal overall solutions. [12]

Breaking down the walls between the domains by introducing a cross-domain solution model at the beginning of the engineering process is the basic idea of the MaSDeM concept. This cross-domain solution model is used as the common platform to discuss, harmonize and optimize the solution with all participants in the engineering process. [9] That is why the cross-domain solution model is very important as the basis for the engineering process and has a crucial influence on the engineering efficiency.

In addition to defining the cross-domain solution model, the MaSDeM concept also includes the integration of the solution model in the overall engineering process, but this part is beyond the scope of this paper.

### *2.1. Cross-domain solution model*

The cross-domain solution model consists of three tightly interconnected levels (Fig. 1). The process model contains the description of the manufacturing process for the product and all the customer requirements. In the layout model the realization of the manufacturing process is divided into single units, called stations, and the material flow between the stations is defined. The third level is the detail model. For each station the detail model represents the principle solution of how the process step can be realized within this station.

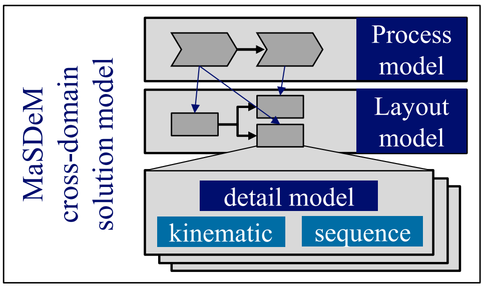


Fig. 1. Structure of the MaSDeM cross-domain solution model

The detail model consists of a kinematic model and an associated sequence model (Fig. 2). The kinematic model determines the geometrical structure of the solution. It is composed of automation components that are linked, creating a kinematic system and representing the active structure of the solution. Each automation component brings certain skills into the system. These skills are the basis for the associated sequence model which defines the succession in which the skills are executed. Thus the detail model represents the component-based solution that performs the station's defined process step. [9] In the example of Fig. 2 a handling system with two linear axis and a gripper is shown. The simplified sequence for this handling process involves opening the gripper, going down, gripping the workpiece and going up again.

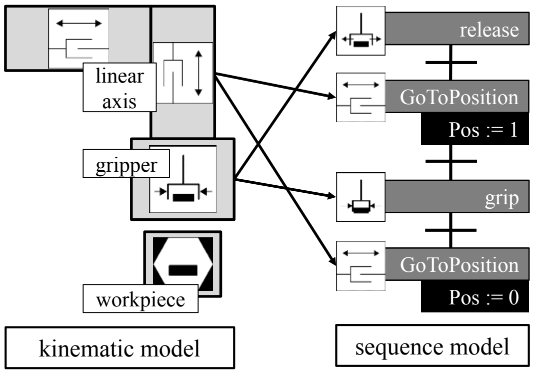


Fig. 2. Detail model representing the principle solution

The automation components and their associated skills are the building blocks to model the system's principle solution. That is why a well-defined description language needs to be installed.

### *2.2. Functional categorization of automation components*

The description of the automation components in the cross-domain solution model has to be understood beyond the borders of the participating domains mechanical design, electrical design and software. That is why the function of a component is used as abstraction layer for the representation of automation components. [13] The function of a pneumatic