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Agent-based control system methodology for Reconfigurable Bending Press Machine

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Abstract

In the present day technology creation, automation is a promising technology towards the achievement of constructive, innovative and sustainable designs and products in industry 4. The control system of machines that involves the application of mechatronic objects or intelligent units which are envisioned as building blocks for design of the systems are rather configured than being designed. In order to meet dynamic customer needs, within minimal time frames, thereby achieving short-time-to-market. The crucial element in this scenario is that the customer drives the pace and direction of the manufacturing entity. The reality of the matter is that the manufacturer needs to produce customer-centric designed products, and this may be achieved through the use of machinery and a system configured to satisfy the need. Realizing this scenario, in this article, an automated agent-based control system methodology (ACSME) has been proposed for Reconfigurable Bending Press Machine (RBPM) application due to ongoing research. The proposed methodology will help manufacturer of RBPM to address the need for more flexible control systems and to demonstrate their industrial flexibility in several reconfigurable machines applications.

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1. Introduction

The potential to meet the future challenges in control systems cannot be over-emphasized as it provides conceptual models and implementation architectures for goal-based decision making as well as negotiation and coordination of goals and actions, as pointed out by [1]. Bussmann et al., posited that recent applications of agent technology shown that there is no universal design of an agent-based control system that can be re-used for every control problem. The lack of a universal design for agent based control systems, thus implies that for the envisaged control system of machines that involves the application of mechatronic elements or intelligent units which are envisioned as building blocks for design of the systems are rather configured than being designed. The intensity of the information that one has to work with in arriving at an optimal control systems with more dynamic machines designs, and to provide greater flexibility and autonomously to changing situations necessitates an agent-based control system methodology (ACSME). This recurrent design effort, however, hampers the exploitation of the agent-based control systems technology in industry, because to date this design effort does not requires the designer of a control system to be an expert in agent technology: designing agent-based control systems is still a research activity. According to Bussmann et al., a control engineer thus cannot be expected to specialize in agent technology (and also not economically reasonable to install specialists for this design aspect because these would only be required in certain phases of the development). Consequently, to facilitate the use of agent technology, there must be design methodology that allows a non-expert in agent technology to design an agent-based control system given the specification of the control system.

The purpose of this article is to propose an automated agent-based control system methodology and present the simulation results for agent communication information consensus problems in RBPM networked systems. The paper

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maintains its argument in the preceding section where the literatures were reviewed. Section 3 expands on the methodology of using modified Gaia approach with the platform communication model and test bench results for proposed RBPM are presented in section 4.

2. Agent-based Methodology Review

Agent-based control techniques applications, however, have also shown that there is no universal design for an agent-based control system, [1]. The required design of a control system may vary significantly depending on the product to be produced and the reconfigurable requirements of the machine process. But no matter how important, agent-based control is only one aspect in the design of an industrial production control system, which includes the design and optimization of: machining and robotic control programs; transportation device and buffer programs; human worker integration; performance and quality monitoring systems; and material supply and conditioning processes [2, 3]. The most important design criterion for developing an agent-based control system is to find a set of agents that is able to achieve the reconfiguration goals, and thus to solve the production control problem, these agents can then be decomposed into the construction of a set of component modules and how these modules should be made to interact. Author [4] propose an agentification method for manufacturing (i.e., a method for identifying agents in a manufacturing system). Siissmann et al. [5], therefore proposed "proxy" agents for aggregating physically dependent agents. This creates a hierarchy of agents in which the dependencies decrease towards the top of the hierarchy, but Siissmann et al. could not provide criteria for when and how to perform the aggregation. Authors [6] and [7] also proposed a methodology for the analysis and design of agent systems based on the abstractions of roles and responsibilities. Wooldridge et al. model an agent-based system in terms of agent roles, each role is characterised by three attributes: responsibilities, permissions and protocols. Gaia only models individual roles assigned to a single agent. Author [8], therefore proposes in his Societies in Open and Distributed Agent spaces (SODA) methodology to distinguish between individual and social roles. Authors [9], add three organisational abstractions to the Gaia methodology: organisational rules, organisational structures and organisational patterns. Authors [10], proposed the elaborated Multiagent and Systems Engineering (MaSE) methodology that derives the agent roles from the goals of the application. Most role-based methodologies, however, require that the designer is able to identify directly the roles in an application, as it is for example straightforward in a (human) organisation, or to derive the roles from the goals in an application [11]. Author [12], proposes a design methodology based on multiple views representing different features of a multi-agent system. Authors [13], proposes an analysis methodology for the development of agent-oriented systems in the Eurescom Project MESSAGE (Methodology for Engineering Systems of Software Agents). Tropos is an agent-oriented software engineering methodology that covers the software development process from requirements engineering to detailed design according to [14]. Padgham and Winikoff [15] in 2002 stated that their concept of functionality is similar, but not identical, to the concept of roles used in many other methodologies. With respect to control design, system-oriented methodologies (including methodologies like or PASSI [16] or ODAC [17], suffer from the same weaknesses as the methodologies. Authors [18], propose a design methodology, called Agent Interaction Analysis (AIA), which derives the necessary interactions from a goal and preference analysis of the system requirements. Authors [19], propose a methodology for identifying manufacturing agents based on the object-oriented approach and the PROSA framework. The designer then selects the objects in this model which should become agents, even though the methodology does not provide any criteria for identifying suitable objects. Finally, the agents are classified in the PROSA framework by aggregating and specialising agents.

3. Agent-based Control Systems Methodology for RBPM

Agent-based Control System Methodology (ACSME) phases and products for the RBPM defines a software development process and presents some key concepts synthesizes for previous methodologies that have successfully been applied in agent methodology development such as Gaia [9], Tropos [14] and MaSE [10]. According to Bresciani et al. 2014, the Gaia methodology is inspired by the roles model method fragment with minimal effort through the use of case and role models for analysis and design of multi-agent systems (MASs).

3.1. ACSME Analysis Phase

The ACSME analysis phase of the agent-based control system methodology (ACSME) recognises the actors, their goals and interactions in its approach. It is an extended Unified Modelling Language (UML), specification version 1.4.2 of the international organisation of standards (ISO/IEC 19501), which refines the actors to roles as case diagrams and the capabilities to achieving them as the goals. Figure 1 shows the hierarchical structure from the societal level that focus on the actors, roles and agent types and the different part modules of the identified controller agent which is the line between the different levels. It's defined as the levels of abstraction in the phase and demonstrates the increase in decomposition of the movement from the society level to the capability level. The methodology being developed adopted the distinguished software development process using SPEM (Software Process Engineering Metamodel) of the six different phases as proposed for the Agent-Oriented Software Engineering Methodologies by FIPA Methodology Technical Committees 2; it is design for the system developer to iterate the phase movement for one to another and vice versa, the output of the design phase is describe in a platform independent format, while the product of the implementation phase is described in platform specific format. The platform specification format is introduced in this paper for the interaction protocol between the identified controller agent in ACSME analysis phase, which is in line with the recently