Advances in Dynamical Systems and Applications (ADSA).
ISSN 0973-5321, Volume 16, Number 2, (2021) pp. 441-455

https://www.ripublication.com/adsa.htm

GUI Elements and Windows Form Formalization Parameters and Events Method to Automate the Process of Additive Cyber-Design CPPS Development

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Abstract

This article presents a method for formalizing parameters, GUI elements and Windows Forms events for the development of Cyber-Physical Production Systems based on object-oriented programming languages cybernetic component HMI additive cyber design. The proposed method will allow to automate the HMI CPPS development process by setting a unique "Lingustic Variable" which refers to "Container Solution" containing a piece of program code that must be implemented in accordance with the requirements of the technical specifications. The developed method allows to reduce the time for creating an additive cyber design, which will increase the efficiency of managing new and old CPPS modernization development.

Keywords: Industry 4.0, Industrial Internet of Things, Cyber-Physical Production Systems, Digital Twins, Additive Cyber Design, HMI, GUI.

1. INTRODUCTION

Modern production is not possible without Industrial Internet of Things (IIoT) concepts usage, which allow you to create a Digital Twin of real production and implement them in Cyber-Physical Production Systems (CPPS) as a complex synthesis of physical and cybernetic components into a single information space [1]-[4]. One of the difficult tasks in the CPPS creation is the cybernetic component implementation, which not only displays current information about the parts production technological process, but also carries the functions of monitoring, analysis and making intelligent decisions [5]. Analyzing the work of Uwe Schleinkofer, Jorge F. Arinez from General Motors Company (GMC), Xin Ma, Marco Rodrigues, we can conclude that the development of HMI for additive manufacturing is a complex task that must take into account the multifactorial nature and specifics of equipment, technological process and production in general. and correctly display information at all levels of SCADA, MES, ERP [5]-[11]. As a result, articles by Jeremy A., Achraf Skander, Harley Oliffa, B. Ahmad, Seung Woo Lee & Jai-Kyung Lee consider experimental and theoretical approaches for HMI implementations within Micro Smart Facture (MSF) [12]-[16]. Nikolaj Borisov conducts research on the HMI interface launched on a mobile device and comes to the following conclusions that this approach is the most promising for future interactive systems in the automotive industry for the selected stage of production [17]. During a critical analysis of existing approaches to the HMI development, it can be concluded that at the moment the CPPS cybernetic component development the is based on HMI existing analogs empirical experience and prototyping [18]-[23]. As a result, the task of creating new approaches to the development of the CPPS cybernetic component arises – as the additive cyber design based on GUI elements for object-oriented programming languages development automation.

2. DEVELOPMENT OF GRAPHIC ELEMENTS PROPERTIES AND EVENTS FORMALIZATION METHOD FOR OBJECT-ORIENTED PROGRAMMING LANGUAGES

Additive cyber design – this is an HMI developed on the basis of high-level object-oriented programming languages using GUI elements. As a result, it can be argued that the developed additive cyber CPPS design (P), is a collection of *Windows Form* *(* $Form_n$ *)* and GUI elements sets the number and connections of which are determined by the technical tasks requirements. Let be P as CPPS additive cyber design cyber component, therefore, multiple visual windows (*Windows Form*) $Form_n \subseteq P$, if each element of the set $Form_n$ is a set of P.

Theorem 1. $Form_n = P$ if and only if simultaneously $Form_n \subseteq P$ and $P \subseteq Form_n$ i.e. $Form_n = P \Leftrightarrow Form_n \subseteq P$ and $P \subseteq Form_n$. We denote the condition $P(Form_n)$ defined in this way: not one element exists $Form_n$, which would satisfy the condition of Theorem 1. For example, $P(Form_n) = \{Form_n \neq P\}$.

In the context of this condition, we can say that all elements $(Form_n PE, CF_n) \in Form_n \neq P$. Based on this, under this condition, it can be determined that the set P does not contain a single common element $(Form_n PE, CF_n) \in Form_n$ denote as the empty set $\varnothing$. In this study, this will mean that the set $Form_n$ has no $\xrightarrow{\Xi}$ in the set P and this set is considered redundant and, therefore, $Form_n = \varnothing$.

To prove the fulfillment of the conditions of union and intersection of the proposed sets included in P, it is necessary that they satisfy the following properties:

- commutability 2 and $2'$;
- associativity 3 and $3'$;
- distribution 4 and $4'$.

Theorem 2. Let $Form_n$, $Form_n PE$ and CF_n are arbitrary sets of properties and parameters that are included in the P set. Then they have the following equalities:

$$
\begin{aligned}
&1.\ Form_n \cup Form_n = Form_n;\\
&2.\ Form_n \cup Form_n PE = Form_n PE \cup Form_n;\\
&3.\ \begin{aligned}&(Form_n \cup Form_n PE) \cup CF_n =\\ &= Form_n \cup (Form_n PE \cup CF_n)\end{aligned};\\
&4.\ \begin{aligned}&(Form_n \cup Form_n PE) \cap CF_n =\\ &= (Form_n \cap CF_n) \cup (Form_n PE \cap CF_n)\end{aligned};
\end{aligned}
\tag{1}
$$

$$
\begin{aligned}
&1'.\ Form_n \cap Form_n = Form_n;\\
&2'.\ Form_n \cap Form_n PE = Form_n PE \cap Form_n;\\
&3'.\ \begin{aligned}&(Form_n \cap Form_n PE) \cap CF_n =\\ &= Form_n \cap (Form_n PE \cap CF_n)\end{aligned};\\
&4'.\ \begin{aligned}&(Form_n \cap Form_n PE) \cup CF_n =\\ &(Form_n \cup CF_n) \cap (Form_n PE \cup CF_n)\end{aligned}.
\end{aligned}
\tag{2}
$$

Proof. Each assertions of these properties follows from the operations definition on sets and Theorem 1. For these assertions, it is necessary and sufficient to prove the 4th property. The rest of the operations properties are proved similarly. To simplify mathematical notation, we denote by the left and right sides of equality 4. Let us show that both conditions of Theorem 2 are satisfied. To do this, we first prove that