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Interdisciplinary Communication and Comprehension in Factory Automation Engineering - A Concept for an Immersive Virtual Environment

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Abstract: In engineering of factory automation systems, understanding and discussing complex systems is important for a competitive development process. Understanding complex connections within these systems while working with interdisciplinary teams scattered around the globe can be a very challenging task. An intuitive way for comprehension and communication within this environment would be beneficial. For this reason, we propose a concept for a virtual environment for gaining a quicker understanding of complex systems and their connections, as well as a way for presentation and discussion using the concept of virtual reality. This is approached by using an immersive way of visualizing and interacting with complex information. The environment itself as well as different ways of immersing in it are presented. To highlight the properties of the approach, an application example is given.

Keywords: Factory automation, systems engineering, complex systems, communication environments, human factors, information analysis, man/machine interaction, virtual reality

1. INTRODUCTION

During the development process of complex factory automation systems, the involved engineers face severe problems in comprehension and communication. Due to fast engineering cycles and dynamic team structures, engineers are confronted with a vast amount of complex information which they have to comprehend in a very limited amount of time. In addition, the developers are experts in their specific domain, e.g. mechanical construction, electrical engineering or computer science, but lack an understanding of the tasks performed and complex information created by the other domains. While their specific expertise is necessary to create a competitive, high tech product, the integration of the different domains is imperative for reaching a working end result. Therefore, it is necessary to gain a deep mutual understanding when facing difficulties or conflicts, e.g. when solving problems or making design decisions. This situation being already difficult to solve, the development teams often are located in different locations around the globe. Explaining design decisions, complex problems or goals is even more difficult being restricted to web conferences or phone calls. As development cycles of these systems shorten while getting more complex at the same time, these problems intensify as there is less time to communicate and comprehend. This situation would be greatly improved by a mean of comprehension and communication that allows a more natural and intuitive way of understanding, conveying and discussing complex information.

The concept presented in this paper is to approach the problem of a mutual understanding of complex engineering information through a virtual environment which supports the visualization of and interaction with complex information. This is to instil a mutual understanding of engineering artefacts and their connections among development teams stemming from heterogeneous domains and working in different locations.

2. STATE OF THE ART

Complex information in factory automation engineering mostly stems from complex connections between elements of engineering documents. These connections often span across different documents within or even between different engineering domains. Examples for this kind of connection could be data flow connections of parts of a control program with ports of a bus system and relating mechanical parts (sensors and actuators) of the machine translating to a physical movement. Changes of single elements in this connection chain could have effects on other elements and should therefore be discussed with other involved stakeholders.

Systems Engineering approaches the problem of a mutual understanding of complex interconnections within and across the different involved domains, e.g. by creating models that define interfaces and connections between the domains. Many of these works in production automation engineering rely on semi-formal modelling languages such as the SysML (Vogel-Heuser et al., 2014). The main problems of these works is that the models need to be created manually and rely on modelling languages initially unfamiliar to all involved domains. These shortcomings are softened by re-using these documents for automatic generation of further artefacts or automatic analyses. An example for the former are code generation from design documents (Schütz et al., 2014), the latter is regarded in works automatically identifying inconsistencies (Feldmann et al., 2015). Another problem is

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that the information, namely complex interconnections within these models, is becoming increasingly hard to handle with a growing system size. The user quickly loses the ability to trace these interconnections across multiple hierarchies and at a macro scale.

There are ways to visualize such complex interconnections, e.g. directed graphs, specifying connections between elements. Extensive research has been done in the field of visualizing these types of graphs. A good overview over typical ways of visualizing 2D- and 3D-graphs is given by Herman et al. (2000). These approaches focus on displaying the connected information in a suitable way by avoiding occlusions and revealing hierarchies. In many cases, a perfect layout cannot be achieved as there are too many cross connections. In addition, static layouts also tend to get confusing once too many nodes and edges are present. In these cases, interaction with the graphs has proven to be useful. Different techniques, such as structure-based clustering (Roxborough and Sen, 1998) or content-based clustering (Wattenberg, 2006), or specific viewing tools such as the hyperbolic tree (Lamping, 1995) have proven to be useful. Even though these techniques of layouting and interaction are approaching the problem, in many cases the information can get so complex that new types of visualization and interaction should be explored.

In many historic works, it was investigated that displaying certain types of connected information in an integrated view can possess positive properties as the user can quickly relate this information in his mind (Wickens and Andre, 1990). In recent works, this approach was investigated for displaying complex information in process monitoring in 3D (Pantförder et al., 2009). It was found that in scenarios that increase the sense of involvement of the operator by allowing interaction with the 3D scene, increased the ability to spot problems more accurately compared to regular modes of displaying information in this field.

Recently, virtual reality has been rediscovered by the gaming industry as it increases the sense of presence. Presence is largely influenced by the sense of immersion and involvement, where immersion is the feeling of physically being present in a non-physical environment and involvement is the ability to focus on a task or a subject (Witmer and Singer, 1998). With virtual reality, the subjects are secluded from the world when using a headset and are able to completely immerse into the digital world. Translating head and even body movements to the virtual world can appear to be more real compared to interacting with it using a mouse and keyboard. Thus, the interaction feels more natural. An overview over important properties of the sense of presence in virtual reality is given by Schuemie et al. (2001). Immersion has shown to be useful in a number of scenarios, such as operator training and data set analysis (Raja et al., 2004) as it can reduce information clutter for example, yet not every task profits from a high degree of immersion, e.g. tasks with a low degree of spatial information (Bowman and McMahan, 2007).

In virtual product development and design, modern display techniques, such as stereoscopic large screen displays, projection techniques or even CAVEs (Creagh, 2003) are already being used to a great extent. This is due to the increased sense of presence which in turn facilitates imagining the real product. In addition, modern tools of interaction are used such as head tracking to allow changing the viewing angle in an intuitive way. The information displayed in these visualizations on the other hand quite often does not possess complex interconnections and does not include connections to other domains, which is the focus of our work.

3. CONCEPT

The concept in this paper can be summarized as a virtual environment in which individual or multiple members of development teams can enter and meet to understand, present, explain and discuss complex information within a development process involving different domains. Different modes of immersing into this environment allow a wide variety of usage scenarios including remote access to this environment. In addition, different modes of visualization as well as interaction with this complex information are presented.

3.1. The Virtual Communication Environment

The virtual environment (see Fig. 1) is to be designed in such a way that it is not distracting from the task to be performed, while remaining relatable to real environments to allow for a high degree of involvement and immersion. Thus, in its basic state, it is designed as a non-distracting open infinite plane in which the subject of discussion is located in the middle. The discussion partners can enter this environment and move around on this plane while being displayed as human avatars. The users can view the complex subject and interact with it to gain a deeper understanding of the interconnections.

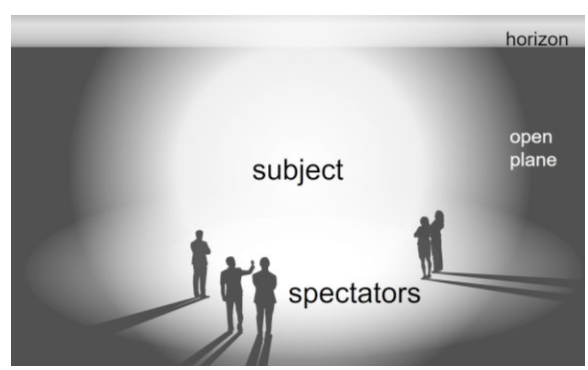

Fig. 1. The basic structure of the virtual environment

To emphasize the focus on the subject, it is highlighted with intensified lighting in a substantially darker environment.

The subject can be viewed from different angles by walking around it. To analyse details of the subject, the user can move closer or view the whole subject by moving further away. This type of interaction possesses many similarities to natural interaction with a subject in real live and therefore increases the intuitiveness of the visualization of the subject and subsequently increases the sense of presence. In case this