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Procedia Manufacturing 21 (2018) 749–756

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

15th Global Conference on Sustainable Manufacturing

Virtual Prototyping Technologies Enabling Resource-Efficient and Human-Centered Product Development.

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Abstract

In modern production environments employees work progressively closer together with autonomous robots and vehicles. Besides the technical specifications, the development of these products focuses on the human-machine interaction. Within the federally funded Project FOLLOWme an automated guided vehicle (AGV) for intralogistics that follows and interacts with the user is developed using virtual reality based prototypes. The benefits in comparison to using only physical prototypes are on the one hand specific user feedback regarding ergonomics and trust. On the other hand the validation of navigation and collision avoidance algorithms and optimization of technical parameters is achieved considering complex environmental conditions. This paper focuses on the latter in detail and deals with the optimization of a fuzzy logic controller using the game engine Unity3D to create the required virtual setup. This approach saves valuable time at early project stages and allows the optimization of a larger number of parameters compared to just physical tests. Furthermore it reduces resources like occupied physical infrastructure and improves the comprehension by using virtual reality.

Peer-review under responsibility of the scientific committee of the 15th Global Conference on Sustainable Manufacturing (GCSM).

Keywords: Resource Efficiency; Human Factors; Virtual Prototype; Automated Guided Vehicle; Obstacle Avoidance; Fuzzy Logic Controller; Unity3D

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2351-9789
Peer-review under responsibility of the scientific committee of the 15th Global Conference on Sustainable Manufacturing (GCSM).
10.1016/j.promfg.2018.02.180

1. Introduction

The complexity of new and innovative products is increasing due to the growing number of mechanical and electrical parts as well as the amount of software code. Customers are demanding reliable, cost efficient and smartly featured products that are developed in a short time period. Product development for human-centered products is even more complex compared to solely task focused products. Not only the product itself, within its environment but also the interactions with the user are demanding designers, developers and engineers to cover a wide range of demands during the product development process. Virtual prototypes can significantly increase the development speed at early product development stages especially considering the stated issues [1].
Being successful in product development first and foremost means being quick to decide on design and engineering issues based on a good prediction on the product behavior. In contrast hand calculations and physical testing quickly reach their limitations (complexity or time and cost consuming) within competitive market settings [2].

Simulations and user studies on the basis of virtual prototypes however can benchmark and improve these products regarding the human-machine interface and interaction design based on early investigated behavior and specific user feedback. Therefore the virtual prototyping technologies in general are not just capable of testing if a product behaves like it is intended, they can furthermore optimize its behavior based on earlier achieved results [1].

This paper shows a variety of evaluated issues, concentrating on optimization of algorithms for path tracking and obstacles avoidance at early stages of an interdisciplinary research project developing a human-centered automated guided vehicle (AGV).

2. Definitions and Focus

A general understanding of virtual prototypes is given with Wangs definition: "*A virtual prototype, or digital mockup, is a computer simulation of a physical product that can be presented, analysed and tested by concerned productlife cycle aspects such as design/engineering, manufacturing, service, and recycling as if a real physical model. The construction and testing of a virtual prototype is called virtual prototyping"* [3]. In the scope of this paper that definition is narrowed to virtual prototypes as computer simulation models that are visualized with virtual reality technologies using stereoscopic views, allowing a 1:1 scale representation and interactive user input.

Depending on the evaluated features of a prototype (e.g. haptic, shape or mechanical use) it is built to test certain constraints or parameters and therefore is not fully covering every aspect compared to the real product. Although virtual prototyping is proved to be a valid alternative to physical prototyping considering the evaluation of usability and user interfaces it still has some drawbacks [4]. Depending on the hardware system, especially the latency based on tracking input data and rendering process, and the users constitution are crucial factors. Some users might experience fatigue, require more time to get used to, or even experience some discomfort [5]. Therefore the technical setup and interaction design of the virtual prototype itself are determining the success of the evaluation.

3. Design of Virtual Prototypes

Considering common principles of human-centered design according to the standard ISO 9241-210 [6] and participatory design [7] the end-user and other stakeholders should be involved in the engineering and design process [1]. A suitable way to get professionals and decision makers involved is to let them interact within the virtual environment rather than simply evaluate simulation results, CAD-based design and product features on a desktop monitor. Crucial features and design aspects need to be considered at a 1:1 scale prototype. This could be a physical mockup but also a virtual one.

Depending on the critical issues that need to be considered with virtual prototypes the test setup and workflow differs from case to case. In the existing use case of this paper an autonomous AGV that strongly interacts with workers during commissioning tasks is developed within the framework of an interdisciplinary project. Virtual prototypes are being used during early development stages to evaluate ergonomics, human-machine interface and technical parameters of possible concept studies. To achieve the greatest gain from these user-orientated surveys the following workflow is used (see Figure 1).