International Journal of Industrial Ergonomics 44 (2014) 368–373

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

journal homepage: www.elsevier.com/locate/ergon

Axiomatic design principles in analysing the ergonomics design parameter of a virtual environment

Zahari Taha [a], Hartomo Soewardi [b,c,*], Siti Zawiah Md Dawal [b]

[a] Faculty of Mechanical Engineering, University Malaysia Pahang, 26600 Pekan, Pahang, Malaysia
[b] Centre for Product Design and Manufacturing, Department of Engineering Design and Manufacture, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
[c] Department of Industrial Engineering, Faculty of Industrial Technology, Islamic University of Indonesia, 55584 Yogyakarta, Indonesia

ARTICLE INFO

Article history:
Received 11 September 2012
Received in revised form
2 November 2013
Accepted 27 November 2013
Available online 13 March 2014

Keywords:
Axiomatic design
Ergonomics
Design parameter
Virtual environment

ABSTRACT

One of the negative side effects experienced by users when interacting with virtual environment is visual symptoms. This paper explores the ergonomics design parameters of the virtual environment to minimize such negative side effect by applying axiomatic design principles. Axiomatic design is a method to provide a systematic way for designing products and large systems. The independence axiom is used to map customer domain (CAs) to functional domain (FRs) and physical domain (DPs). A paper based survey was conducted to identify and define customers' preference in the virtual environment. A virtual robot manufacturing system was developed as a case study to explore ergonomic design parameters that satisfy the independence of FRs and CAs. Results of this study shows that the ergonomic design parameters of virtual environment identified (DP_{161}-DP_{162}-DP_{121}-DP_{111}-DP_{131}-DP_{141}-DP_{151}-DP_{152}) have satisfied the independence functional requirement and desired visual comfort for users. By uncoupling the design it provides an efficient and effective sequence of design activities FR_{161}-FR_{162}-FR_{121}-FR_{111}-FR_{131}-FR_{141}-FR_{151}-FR_{152}.
Relevant to industry: Result of this study contributes a guide for designer in implementing the design parameter to design the virtual environment.
Crown Copyright © 2013 Published by Elsevier B.V. All rights reserved.

1. Introduction

Virtual environment (VE) can be defined as a computer generated three dimensional model environment in which a user feels as if he/she is present in it and the user can interact intuitively with objects contained within it (Wilson, 1999). While being advantageous in experiencing new environment without having to build the real thing, the experience comes with some side effect for some. When interacting with VE through output and input devices, it has been reported that some users experienced negative side effects by being immersed into the graphically rendered virtual world. One of the side effects is known as cyber sickness i.e. especially affecting the vision (Stanney et al. 1998; Barret, 2004). Stanney et al. (1998) further mentioned that for VEs to be effective and well received by their users; while avoiding unwanted side effect, human being's limitation needs to be considered during the VE design stage. It is highly essential to ensure that advances in VE technology will not be at the expense of human well-being.

Ergonomics is a branch of science that is concerned with the achievement of optimal relationship between workers and their work environment (Tayyari and Smith, 1997). Since human being's limitation is crucial in the design process of a virtual environment, implementation of ergonomics will bring about an optimal VE experience for users. Good design incorporating ergonomics consideration will enhance the communication between the user and the virtual world. Since several ergonomic factors contribute to good VE design, there is a need to investigate what are the critical ergonomics design parameters.

Ergonomics research related to virtual environment has been conducted in the past, but the focus of the research is only on the use of VE as a tool in ergonomics analysis (Shaikh et al., 2004; Colombo and Cugini, 2005; Pappas et al., 2005; Dukic et al., 2007; Hu et al., 2011). Shaikh et al. (2004) studied on participatory ergonomics using VR and found that VR system will help towards designing better workplaces. Colombo and Cugini (2005) researched on virtual humans and prototypes, evaluating ergonomics and safety. While Pappas et al. (2005) investigated on

* Corresponding author. Centre for Product Design and Manufacturing, Department of Engineering Design and Manufacture, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia. Tel.: +60 3 79677625, +60 169048312; fax: +60 3 79675330.
E-mail addresses: hartomo@siswa.um.edu.my, hartomo@fti.uii.ac.id (H. Soewardi).

0169-8141/$ – see front matter Crown Copyright © 2013 Published by Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.ergon.2013.11.007

ergonomic evaluation of virtual assembly tasks. Other researchers such as Dukic et al. (2007) researched on the evaluation of ergonomics in a virtual manufacturing process and Hu et al. (2011) presented preliminary experimental results on the relationship between ergonomic measurements in VE and RE for some typical "drilling" tasks.

It is noted that no research on ergonomics design parameter for designing a virtual environment has been reported. To create a design of the virtual environment that is acceptable from the ergonomics point of view, Suh (2007) stated that the functional requirements (FRs) and constraint related to ergonomics issues must be identified and defined from the beginning of the design process where the design parameter (DPs) must be determined to satisfy the FRs independently. Axiomatic Design (AD) constitutes a formalized methodology that can be used to represent a variety of design problems (National Academy of Engineering, 2002). This method provides a scientific basis and logical and rational thought process for the ergonomics design (Suh, 2001).

In recent years, there have been quite a number of researches on the application of AD in ergonomics whether theoretical or empirical studies. In a theoretical study, Helander (1995) had conceptualized the use of AD procedures in ergonomics. Suh (2007) proposed the application of AD and complexity theory in ergonomics design to improve the robustness and efficiency of design. In an empirical study, Quill et al. (2001) applied AD to design visual information. Helander and Lin (2002) introduced AD as a foundation in ergonomics design where they designed an ergonomics microscope workplace and biomechanical design of hand tools. Lo and Helander (2007) conducted a study to analyse the complexity in human-machine system and develop a methodology for eliminating the couplings. Helander (2007) also conducted a study to identify the sources of couplings and proposed new design parameters that uncoupled the design in human-machine interaction.

However, there have been no researches on the application of AD to the identification of ergonomics design parameter of a VE. Thus, the objective of this study is the identification of the ergonomics design parameter for designing a Virtual Environment using axiomatic design.

2. Research method

Three main activities were undertaken in this study to explore the design parameters of a virtual environment based on ergonomics principles using axiomatic design theory. The following research activities are:

Activity 1: Investigating the major attributes that a customer is looking for in the virtual environment through a survey.
Activity 2: Performing an empirical study to analyse the effect of VE attributes on visual symptoms.
Activity 3: Applying Axiomatic Design to the design of a virtual environment based on the data collected and analysed in activities 1 and 2.

2.1. Survey

A questionnaire was developed and deployed to respondents who are familiar with the virtual world. It consists of three parts that are the personal background (part A), user criteria of the VE design (part B), and user criteria of the VE's hardware used. A paper based survey was conducted in a period of 3 months to identify attributes that customer are looking for in a VE. It is called the voice of the customer. Over one hundred questionnaires were distributed in the survey. The required sample size is determined as minimum valid feedback responses. Descriptive non-parametric statistical analysis was also applied in this study.

2.2. Empirical study

The objective of the empirical study is to analyse the effect of virtual environment attributes on visual symptoms. The experiments were conducted at the ergonomic-virtual reality laboratory. Eight university students participated in the study where none of the participants suffered from any vestibular and visual dysfunction and were not taking any medication during the experiments. The mean age was 21.7 years old (aged 19–23 years). A sitting position was adopted with the subject sitting at a distance of 15–25 cm from the back edge of the table to complete the task. The activity is to operate a virtual robot in the VE using an infrared mouse (wireless mouse) with the motion observed on the wide screen display. The virtual stimulus system used is a virtual robot manufacturing system. It presents a virtual robot activity for storage loading and unloading (SLU) process (shown in Fig. 1).

A qualitative assessment was conducted through the use of questionnaire. The questionnaire was developed to identify the visual symptoms of the virtual environment variables/attributes investigated. The questionnaire consists of two principal parts. The first part contains the question with seven response option. This is aimed to identify the visual problems experienced during or after interacting with the VE. The second part contains questions to identify the level of symptoms experienced based on the answers of the previous part. The answers to the questions in the second part were of the ordinal data type.

Non parametric statistical analysis was implemented involving descriptive statistic and statistical binomial test. The tests were on hypotheses about the effect of each attributes or variables of the virtual environment on the incidence of visual symptoms. The hypotheses developed were:

- H1: Colour of background has effect of visual symptoms among immersive environment users
- H2: Virtual lighting has effect of visual symptoms among immersive environment users
- H3: Contrast ratio has effect of visual symptoms among immersive environment users
- H4: Field of View (FOV) has effect of visual symptoms among immersive environment users
- H5: Flow rate (FR) has effect of visual symptoms among immersive environment users
- H6: Speed of virtual object motion has effect of visual symptoms among immersive environment users

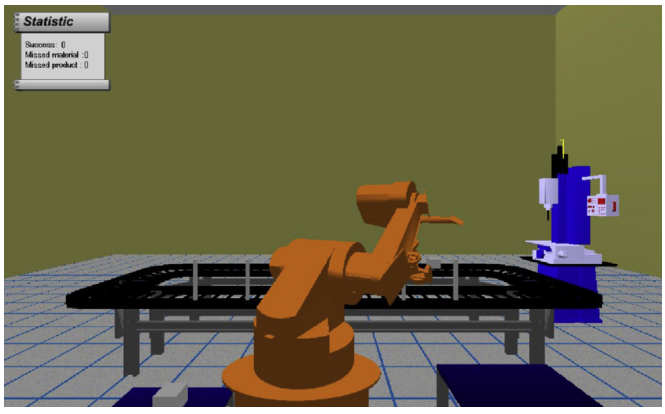

Fig. 1. Snap shot of Virtual Robot Manufacturing System.

Download English Version:

https://daneshyari.com/en/article/1096098

Download Persian Version:

https://daneshyari.com/article/1096098

Daneshyari.com