# Impact of Force Feedback on Computer Aided Ergonomic Analyses

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**Abstract.** The objective of this study is to test the correlation between a Physical Task and a Digital Task through integrated sensory feedback mechanism in Virtual Build Methodology. The research question posed regards whether the pressure feedback mechanism in Virtual Build Methodology proposes high fidelity for push-pull tasks. There are many research studies that have been done on DHM, MOCAP, VR and Haptic interfaces individually, but integrating those with a tactile feedback mechanism is still challenging. While being increasingly used, the Virtual Build Methodology has not been studied regarding its human integration through a multi-sensory feedback system. It may seem intuitive, but disregarded many times, that the tactile feedback mechanism is essential for product design and development practices. This study aims to fill this gap by introducing a pressure based sensory feedback system to provide a higher fidelity in virtual product design practices.

**Keywords:** Computer Aided Engineering (CAE), Ergonomics, Virtual Build Methodology (VBM), Digital Human Modeling (DHM), Motion Capture (MoCap), Haptics, Force Feedback, Product Design, Healthcare Engineering.

## 1 Introduction

Traditional product design and production planning techniques are insufficient to manage dynamic product development and customization (in contrast to mass production) needs [1]. Technological progress, especially in the past two decades, sped up the design and manufacturing process and reduced costs of product development through digital design/production techniques [2]. The use of computer aided ergonomics tools minimize the need for excessive physical prototyping, limit the number of design iterations, reduce design/manufacturing costs, and decrease the lead time to market [3][4].

Poor ergonomic practice may result not only in physical injuries but also significant financial and reputational loss for companies. Although ergonomic problems in manufacturing and production domain may result in significant financial losses, problems in healthcare could be more severe. Most manufacturers do not regard Human Factors Engineering (HFE) principals during medical product design [5]. Many times,

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there is a lack of fundamental interest paid to HFE principles when compared to mechanical engineering or software programming and the functional aspects of product development. However, if manufacturers had employed a better design practice through HFE and followed a human-centered design approach, failures due to poor design practice would have been reduced [5].

Because of the increasing trends in US healthcare costs and medical product design related challenges, a code cart is selected to demonstrate the practicality of force feedback integrated VBM in design and analyses of concept products.

## 2 Sensory Feedback Integrated Virtual Build Methodology

There are many research studies that have been done on assistive CAE tools (i.e. DHM, MOCAP, VR, and Haptic interfaces) individually, but an integration of those under a global design method is still not well established. While being increasingly used, the Virtual Build Methodology has not been studied with multi-sensory feedback system integration.

Although vision and audition are among the most important human sensations and are engaged in most human-machine interface applications, research about systems that introduce tactile feedback (touch and proprioception) is not a focus of many CAE systems. A tactile feedback mechanism is essential for product design and development [6][7][8][9].

## 3 Components of the Integrated System

### 3.1 Motion Capture (MoCap) System

The MoCap system STT Motion Captor, used in this study is composed of six infrared cameras and linked computers to capture and store data. The system is set up with 60 frames per second and assigned to a 19-marker human configuration template.

### 3.2 Code Carts

The concept code cart was developed through a yearlong collaboration between students and faculty from the following Purdue University affiliations – Regenstrief Center for Healthcare Engineering, College of Engineering, School of Nursing, and College of Management [8][10].

Efforts of developing a better code cart are focused on eliminating problems observed by current carts and adding features to increase efficiency of response.

A lightweight, versatile, maneuverable, ergonomic, and organized cart with increased safety is designed and introduced to healthcare practitioners. The concept code cart model provides a combination of features different than the current code carts (i.e. bi-directional transparent drawers for ease of access and viewing, an adjustable handle, 360° rotating platform for a defibrillator, oxygen tank housing, biohazard

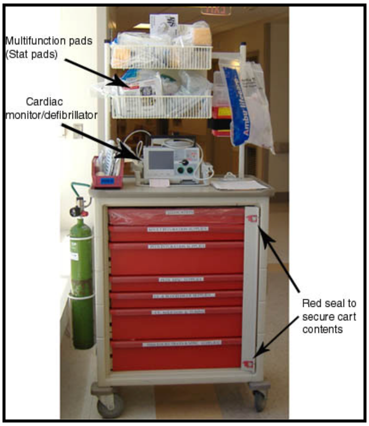


**Fig. 1a.** – Current Cart model [7]

**Fig. 1b.** – Concept Cart model [8][10]

bin, IV pole, rounded corners, biocide exterior surface, retractable power cord, and AC outlets.) (Fig. 1a and Fig.1b shows current and concept cart model.).

### 3.3 Sensory Feedback Mechanism

The feedback system introduced in this study is composed of a pressure pad device integrated with the Virtual Build system. It was seen from literature that humans lose some perception in the Virtual Environment compared to a real environment, where assistant feedback would be helpful to improve subjects' performance in the VE. In addition to this, the sensory feedback integrated VE, including collision detection and hybrid immersive-VR, would provide an additional sense of reality to the human that could lead to improved task performance. [10][11][12].

The pressure pad system is activated by a 5V power supply (~ .5amp). The capacitance system that is located inside the pressure pad outputs analog signals when pressed/depressed. The output signals are collected in and distributed from the suppliers (Pressure Profile System – PPS) circuit board. Each voltage value, analog signals between 0.25V to 4.5V, corresponds to a standardized pressure value from 0 psi to 10 psi provided by PPS [13].

National Instruments' (NI) LabView 8.2 software is used to analyze real-time data coming from pressure pads. A special code is written to interpret the analog data. The code initiates a pre-recorded video after the specific pressure threshold (value which is required to initiate a movement on a physical cart) is reached. The prerecorded video mimics what the subject would be seeing if she/he is pushing a real cart.

### 3.4 Design and Analyses Software Packages

Digital code carts are designed in Dessault Systemes' parametric CAE package called CATIA V5 R16. UGS Tecnomatix JACK will be used to stream the data from MoCap to perform ergonomic assessments.

## 4 Proposed Methodology

Each subject is required to perform a push task on two different code cart designs (market available cart design vs. prototype cart design) in both the actual MOCKUP (Physical Task Experiment with actual code carts) and corresponding identical VE (Virtual Task Experiment with virtual cart video). Simultaneously, the subject's movements are captured through the motion capture system. (See Fig.3)

One major difference between the Virtual Task Experiment and the Physical Task Experiment is that a pressure pad device is used as a sensory feedback mechanism. This device assists users in initiating a pre-recorded video on LCD display which mimics a forward push movement when a threshold pressure force value is reached. Captured motions are input into UGS Jack to drive the digital human model. These mimic the movement of the subject working on push-pull posture. Then, embedded static ergonomic analysis tools in UGS Jack are used to analyze the subjects' initial and final posture in both experiments under varying load conditions (Fig. 2 shows VE task.).

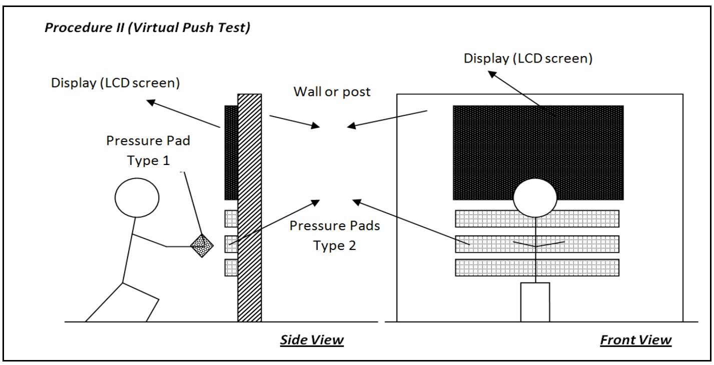


**Fig. 2. –** Virtual Push Task and Pressure Pads

## 5 Data Collection and Analysis

At least 24 subjects will complete the tasks and evaluate the code carts under varying loading conditions (0 – 40lb). A code cart from Purdue University School of Nursing will be used as the "current code cart" and a developed prototype will be used as the "concept code cart." See Fig. 1a and 1b for an example of the carts to be tested.

Differences generated by subjects' different performance (difference in posture) between MOCKUP and VE are the main focus of the experimental design. These differences can be measured through certain posture variables (shoulder abduction torque and elbow torque). Then, the correlation between these variables in MOCKUP and VE will provide information about the degree of fidelity.

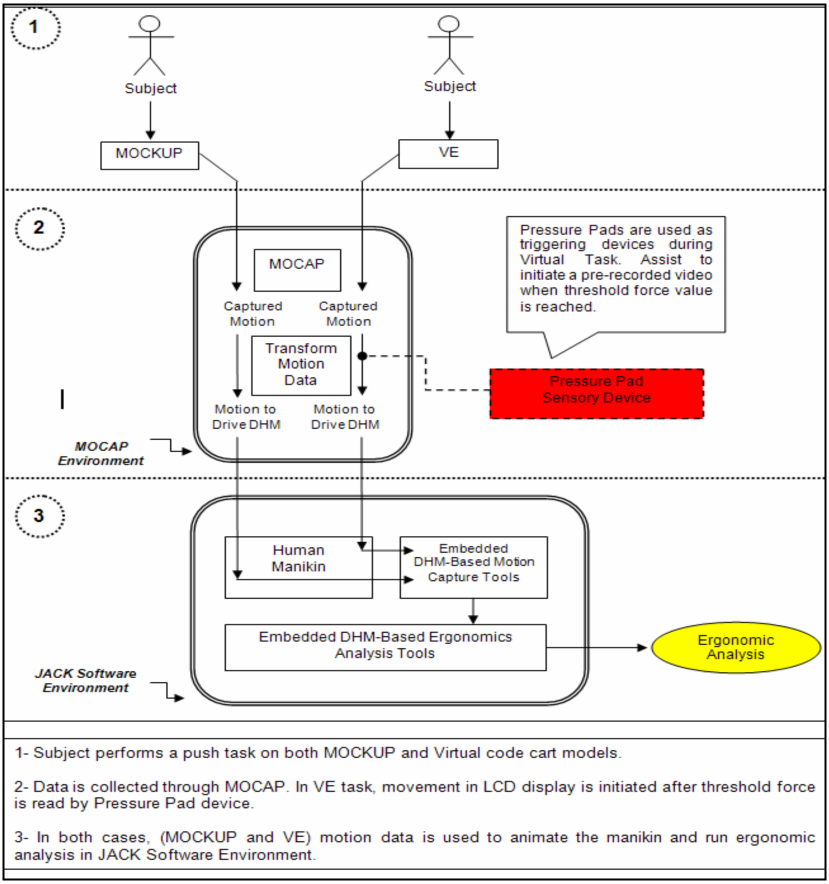


**Fig. 3. –** Experimental process and procedure

## 6 Discussions

It was observed through literature review and from the on-going study that the Virtual Build Methodology proposes a suitable environment to incorporate computerized technologies with a tactile feedback system, where users can interact with digital products/environment during the design and evaluation phases. The success of this study may provide a testbed for concept products. This could include a reduction in time and financial costs of the design cycle and minimize the design errors by systematically applying HFE design principles.

Future work could include evaluating current or different concept products. Advance immersive technologies and haptic devices such as CAVE, Head-Mounted-Diplays and real-time/dynamic DHM tools such as the Lumbar Motion Monitor (LMM) could also be considered.

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