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Automatized modeling of a human engineering simulation using Kinect

Chanmo Jun[a,b], Ju Yeon Lee[a], Bo Hyun Kim[a], Sang Do Noh[c,*]

[a] IT Converged Process R&D Group, Korea Institute of Industrial Technology, 143, Hanggaulro, Sangnok-gu, Ansan, Gyeonggi-do 15588, Republic of Korea
[b] Department of Industrial Engineering, Sungkyunkwan University, 2066, Seobu-ro, Jangan-gu, Suwon, Gyeonggi-do 16419, Republic of Korea
[c] Department of Systems Management Engineering, College of Engineering, Sungkyunkwan University, 2066, Seobu-ro, Jangan-gu, Suwon, Gyeonggi-do 16419, Republic of Korea

A R T I C L E I N F O

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A B S T R A C T

Many researchers of human engineering seek to enhance work efficiency and to reduce workloads by analyzing worker load, work efficiency, and production using analogue methods, such as checklists. Recent analyses have examined job performance using digital human models created by digitally recording the movements of actual workers through keyboard and mouse-based data input. However, this modeling method has two problems: it takes too much time to model all movements, and accuracy depends on the modeling technician. To solve these problems, this study presents a digital human modeling automation system using Kinect, a Microsoft Xbox data input device, to model human movements. The system is designed to utilize multiple Kinects, and the data model conveys and manages data from these devices to calibrate an algorithm that can be used to create a digital human model. Through this system, it is possible to easily generate a digital human model accurately, inexpensively, and efficiently. The developed digital human modeling automation system is verified using four scenarios, and the results, limitations, and development plan of the study are described.

1. Introduction

As manufacturer competition increases and product life cycles become shorter, manufacturers are making diverse efforts to improve the efficiency of product manufacturing and to reduce costs. Optimization is focused not only on facilities but also on workers, who assemble products by using or operating these facilities. Human engineering attempts to enhance work efficiency and reduce workload by analyzing worker load, work efficiency, and production [1,2]. Previous analyses of human engineering have been carried out using analogue methods based on checklists, but the current analysis is based on a digital model [3], created by digitally recording the movements of actual workers. Previous digital human models were created manually, through keyboard and mouse-based data entry [4], which had two significant limitations: the time required to model entire movements and accuracy being dependent on the modeling technician. To solve these problems, an automated modeling method using a Vicon camera [5] has been suggested to quickly and accurately model movements, although the cost of the camera is high. Thus, studies on model automation have also used Kinect cameras, which are a low-cost gaming device [3] that is less accurate for modeling than the Vicon camera.

In this study, to solve the problem of low accuracy when using one Kinect camera, several Kinect cameras were used for model automation. A data model was suggested to combine data from multiple Kinect cameras, and a system to integrate skeleton data from the Kinect through a virtual reality peripheral network (VRPN) was devised [6]. The integrated data were input as basic information into Jack, a human engineering software package, to analyze diverse actions. The results were verified through a modeling test using the developed system.

2. Research background

2.1. Modeling automation

Two methods for modeling worker movements using digital-environment information have been used: the active sensing method, which acquires movement information through sensors attached to workers' bodies, and the passive sensing method, which uses a camera to analyze movements from a distance [7]. The active sensing method provides accurate information, but attaching sensors to subjects is time consuming. A typical active sensing device is the Xsens MVN made by Xsens Co [8], which accurately records movement using electromagnetic sensors attached to the whole body. The passive sensing approach records movement information using a camera, such as the Vicon, which uses two-dimensional images of a subject with markers attached to joints to record movement [5]. An improvement on this

* Corresponding author.
E-mail addresses: jchm99@kitech.re.kr, jchm99@skku.edu (C. Jun), ljy0613@kitech.re.kr (J.Y. Lee), bhkim@kitech.re.kr (B.H. Kim), sdnoh@skku.edu (S.D. Noh).

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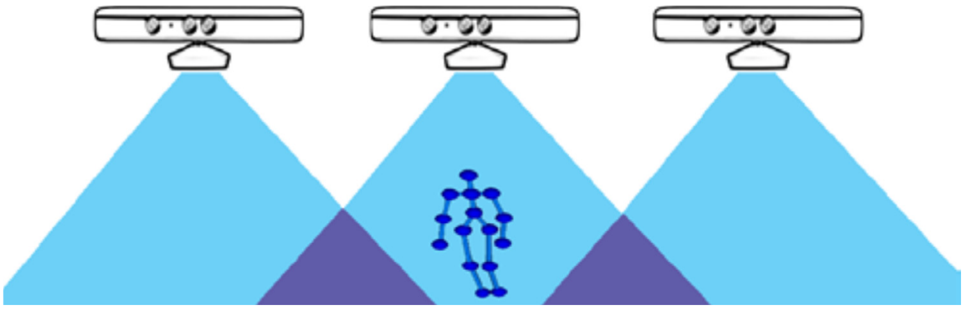

Fig. 1. Human tracking study using Kinect [10].

technology is Kinect, which uses depth sensors without any attachments to record movement [9].

2.2. Ergonomics studies using Kinect

Kinect is a console device for game play developed by Microsoft. Because of its low price and free API for joint extraction, it is widely used for human-engineering studies on tracking, pose estimation, and recognition. For example, Schönauer [10] studied continuous tracking of the movement of a subject in a certain space, as shown in Fig. 1. When several Kinect cameras were used to track the object, the data from the Kinects overlapped, as shown by the purple regions in Fig. 1. To solve this problem, Schönauer gave weight to each Kinect.

Martin [11] used Kinect to measure worker loads in an educational situation and suggested a warning system to indicate loads that are too large. He proved the feasibility of Kinect devices for human engineering by comparing the results from Kinect to conventional human-engineering analyses using occupational safety and health administration (OSHA) and recommended weight limits (RWL). Martin pointed out a number of limitations to comprehensive use of Kinect in human-engineering studies, such as unrecognized joint movement when objects are hidden and the failure of the system when two Kinect cameras are linked together.

2.3. VRPN

The VRPN is a method suggested by Taylor [6] to realize virtual reality through the communication protocols of multiple devices. Diverse input devices, such as gloves, joysticks, and cameras, are used to achieve this virtual reality. This method was suggested to solve problems related to interference and event time while receiving data from devices; independent data-input environments for each device are connected through a network transmission control protocol/internet protocol (TCP/IP) to check the data times from different devices and to integrate data through a simple interface, enabling the use of the information in a virtual environment. Fig. 2 shows the simple architecture of the VRPN methodology, which is composed of input devices, such as a Kinect or joystick, the VRPN server that acquires information from input devices, the VRPN client that integrates this information, and the application that expresses input information after integration. In this study, the experiment environment was created using multiple Kinect cameras and VRPN servers, and the skeleton data acquired from relevant servers were integrated in the VRPN client to present the data through a virtual reality application (i.e., Jack).

3. Multi-Kinect calibration system

In this study, an automated modeling system was developed to carry out a human-engineering analysis using multiple Kinects and a VRPN methodology. To this end, this study proposes a skeleton data model as a framework for exchanging data throughout the system and a calibration algorithm to integrate the human skeleton input data from several Kinects.

3.1. Multi-Kinect calibration system architecture

Fig. 3 shows the architecture of the system designed to receive the skeleton data from multiple Kinects, integrate these data, and send the results to the application. Similar to the architecture in Fig 2, the system is composed of the data input device (i.e., Kinect), the VRPN server, the VRPN client, and the application. The algorithm to integrate the data from multiple Kinects was applied to the VRPN client. Three Kinects were used, but the system was designed to be able to increase the number of Kinects, if necessary. Each Kinect was connected to one VRPN server, which sent skeleton data from the Kinect to the VRPN client through a TCP/IP network. Skeleton data from multiple devices were sent through the network and stored in the form of a pre-defined data model. The VRPN client module received data from each VRPN server, and the transferred data passed to the user after conversion through four modules. The calibration module converted the data received from several motion cameras into a single coordinate system, while the angle-check module calculated the angle between the subject and each camera to assign weights. The length-check module compared the length of each joint to the joint length in the initial setting process to determine whether or not there was an abnormality. Data from several Kinects were converted into one skeleton dataset through a data

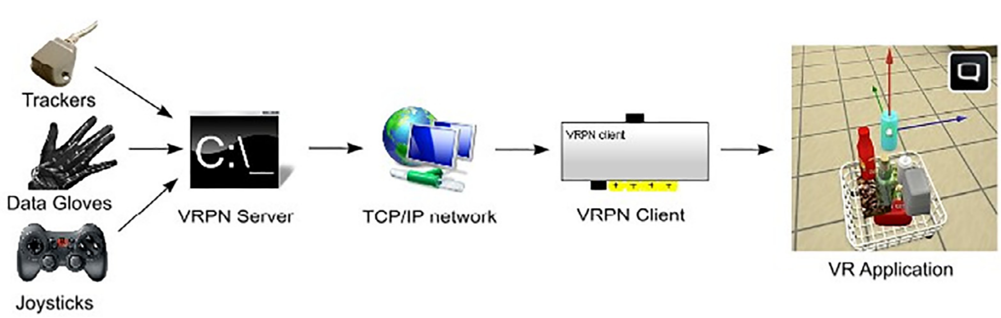

Fig. 2. VRPN architecture [6].