Novel Method of Capturing Static and Dynamic Anthropometric Data for Home Design

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Abstract — This paper presents a novel method for capturing and measuring both static and dynamic anthropometric data of people. These data can be then used for barrier-free home design based on a concept of ergonomic design with motion. This new approach utilized a 3D motion capture system as a tool to simultaneously obtain anthropometric information based on body motion analyses. This paper reports the experimental system design, data collection and analysis techniques on body motions.

Keywords — anthropometric data, dynamic information acquisition, ergonomic design, motion analysis.

I. INTRODUCTION

THE number of elderly people is markedly increasing in developed and developing countries such as the UK and China. In general, elderly people will have some biologic and physical degeneration when they become aged. These may result in the loss of physiological function, exercise ability or mobility (such as the body atrophy, reduction in hearing and visual impairment, slow-moving, and reduced range of motion). Moreover, the degeneration may be also caused in various degrees by some diseases, e.g., heart disease, high blood pressure, arthritis and diabetes. With decreasing mobility, elderly people find more and more difficulties in their daily life. Therefore, in order to improve their quality of life, it is very important to investigate home design using ergonomics principles for the handicapped and people with special needs and for the frail elderly [1,2]. For example, in order to make it easy to use bathroom facilities safely and conveniently, we should design these facilities such as bathtub for them in accordance with the their anthropometry and mobility.

To do so, knowledge about human body size and anthropometric data of elderly people is essential, but not alone sufficient for the ergonomic design because the standard anthropometric measures are static. In the real world, human interactions with the physical world include many dynamic features and information. Furthermore, there is, in general, a lack of adequate anthropometric data on the elderly. For example, we only know the standard basic size of human body for Chinese adults (male 18-60, female 18-55) from Chinese National Standard Documents (GB1000-88), while the specific data for Chinese aged people is not available. Although some research [3,4] has shown that the body size of old people can be derived from those of mature adult sizes, we still prefer to have experimental tests to obtain a set of new data reflecting on both body size and dynamic mobility, because the published body size is static data, not reflecting changes in mobility [5,6].

Traditional method to obtain anthropometric data is to survey characterized populations (the use of averages and percentiles). This method has difficulty in measuring anthropometric data against multiple realistic-postures. The 3D scanning techniques (http://store.sae.org/caesar/) have been recently used to capture 3-D data of subjects in realistic postures allowing to extract an almost infinite number and variety of measurements long after the subject has moved. However, these methods can only capture static data.

Thus, it is novel to develop a method for simultaneously measuring both static and dynamic anthropometric data for product and home design applications. This paper describes the method and its experimental system design in Section 2. Section 3 introduces data collection and analysis techniques based on body motions. Some test results for bathing facilities design are discussed in Section 4, and finally, conclusions are drawn.

II. THE METHOD AND ITS EXPERIMENTAL SYSTEM

The human body size and mobility measurement method using a 3D motion capture system includes three stages: measurement scene setting up, marker design and motion capturing, and motion data processing and interpretation. This section introduces first two stages.

A. Measurement Scene Setting Up

The concept of ergonomic design with motion was realized using a motion capturing system by Motion Analysis [7]. It is a 3D optical motion capturing system that measures the movement of objects. The system combines proprietary hardware, software and electro-optical techniques with standard computer and video

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hardware. In our system, 7 Eagle digital cameras were used with the EVaRT 4.2 software to collect motion data. The 7 cameras can be located circularly to let the system to capture body motions within a rough volume about 5m X 8m X 4m along the x, y directions on the ground and the vertical z direction. Motion is captured from reflective markers. The size of marks varies from 6 mm to 25 mm in diameter. Different sizes of markers will affect the size of the volume. After setting up the motion capturing system, a test scene with various 3D references was set up in the centre of the capturing region. For example, an elastic string had been suspended horizontally with the foot of tables (Fig. 1). Its height could be changed easily to test people's motion of crossing the string line (similar to the edge of bathtub). The use of the string can reduce the obstruction of view from cameras. On the ground, we used white paper tapes to mark a base of the 'bathtub'. One foot of the table on the right side is close to the centre, which allows people to use it as an assistance handle if needed. These references were visible, touchable and pressure-sensible.
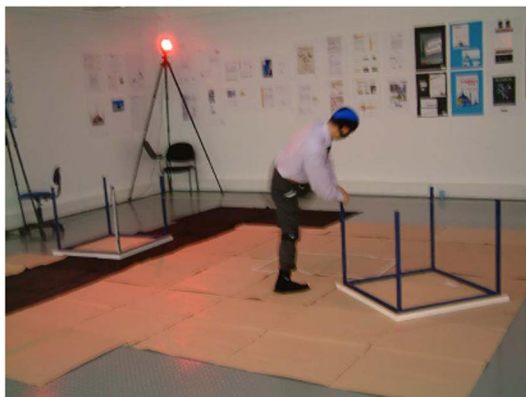

Figure 1. Test scene design

Figure 2. Marker design

B. Marker Design and Motion Capture

In order to measure the body size and mobility correctly, a good marker design is required. How many markers we need depends on applications. For a general purpose, the marker design can refer to Helen Hayes Marker Set

Placement (http://www.lifemodeler.com/ LM_Manual/A_motion.htm) (Fig.2). When a subject wearing designed markers moves in the test scene, the corresponding motion can be captured.

III MOTION DATA PROCESSING AND INTERPRETATION

After receiving motion data captured by the system, the motion was recorded in a Track Row Column (.TRC) file, which contains X-Y-Z position data for the reflective markers. The file is in the ASCII format that can be easily read into a spreadsheet program such as Excel^{TM}. The position data for each marker is organized into 3 columns per parker (X, Y and Z position) with each row being a new frame. The position data is relative to the global coordinate systems of the capture volume and the position values are in the units used for calibration. Missing data is represented as an empty frame of position data.

In a TRC file, the first row will represent a starting pose. Analyzing data extracted from this row against mark settings can result in static anthropometric data such as heights, shoulder widths, lower leg lengths. Table 1 shows an example of 11 people's static data extracted from a motion capture file. Each row represents one person's static dimensions such as heights of forehead, shoulder, elbow, knee, heel and toe.

TABLE 1: STATIC DATA SHEET.

F, Head	Shoulder	elbow	knee	Heel	Toe
1617.613	1361.833	1045.782	497.9818	59.92479	42.55588
1537.54	1242.22	984.1884	526.8735	54.88779	44.83432
1676.67	1397.395	1122.163	466.7862	95.55046	52.81231
1647.7	1442.348	1141.566	468.2026	59.73159	49.43542
1716.527	1420.328	1173.16	504.0228	62.19487	49.68678
1471.483	1240.019	960.6669	440.767	48.93247	47.6213
1699.29	1433.228	1153.37	462.5336	62.38312	47.41731
1433.701	1261.405	1092.011	535.8144	75.24448	18.82006
1540.088	1290.282	985.0888	447.8157	49.77518	40.36644
1680.646	1402.299	1066.349	458.0783	61.4655	59.60952
1610.404	1288.203	1030.523	406.3123	129.0469	122.5929

From motion data, the EVaRT 4.2 software can be used to analyze dynamic information based on the relation of markers and segments (See Fig. 3). Velocity of each marker can be obtained by computing positional displacement per frame. Acceleration of a marker is based on velocity difference per frame. The size of a segment can be measured as a distance between two marks. Included angles between two body segments can be calculated by selecting two lines with 4 (or 3) markers. The velocity and acceleration information can be further interpreted to reflect easiness and confidence of performing a specific task. The included angles also indicate the range of motion required for a task. Their variations reflect changes of mobility. All these dynamic information is very useful

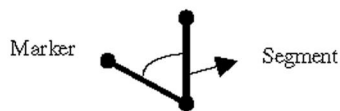for ergonomic studies in product and home design applications.

Figure 3. Relation of markers and segments

IV TESTING RESULTS

In order to test our new method, we randomly selected 20 volunteers with different genders, ages and places of birth. The data collection process was associated to a home design (a bathtub) for the elderly. The goal was to identify dynamic features when people crossed the edge of a 'bathtub' (string).

The test scene was shown in Figure 1. The test heights were set to 400mm, 450mm, 500mm, 550mm, and 700mm. In the test, the volunteers were required to be barefoot. At the beginning of each test, they gave a standard pose (Fig. 2) to show their body size rightly. Then, they were asked to feel free and natural to 'walk' into the bathtub (walking crossing the string) and get out the bathtub (walk back). The whole motion was captured.

Some static data collected from this test has been given in the Table 1. The body sizes were measured correctly.
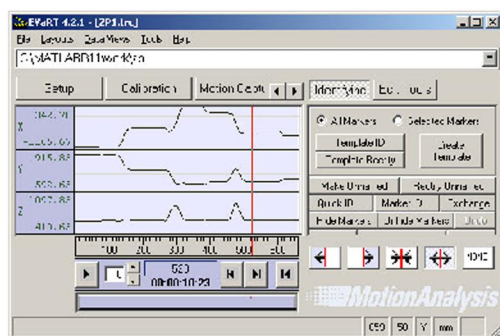

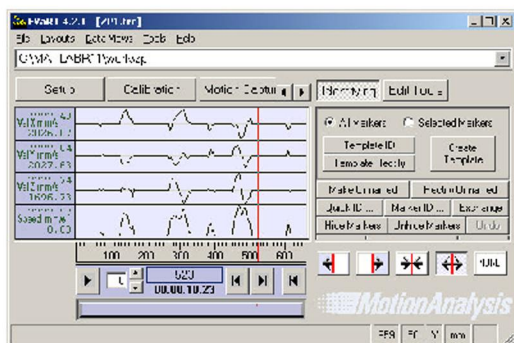Figure 4a. Dynamic information: position graph

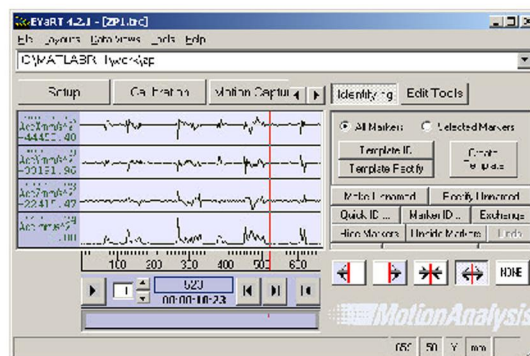Figure 4b. Dynamic information: velocity graph

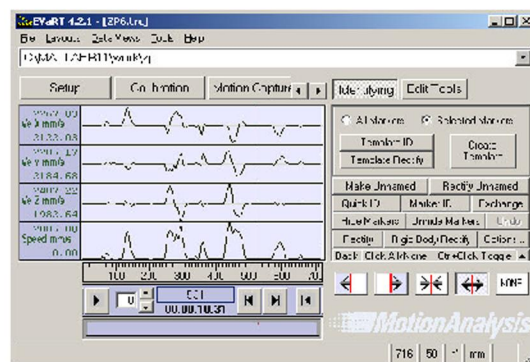Figure 4c. Dynamic information: acceleration

Figure 4d. Dynamic information: velocity graph for another

Figure 4 gives dynamic information with graphs. The figures 4a and 4b indicate the position and velocity changes of a selected marker when a person crossed the string (height=500mm) and came back. The corresponding acceleration graph is shown in Figure 4c. The graph in Figure 4d describes the velocity changes of another person crossing the string (height=700mm). Comparing different people's motion graphs, it is clear that there are some certain patterns corresponding to the crossing motion. By studying the acceleration curves, a force and a moment for crossing the bathtub can be computed later.

In order to compare the performances between two subjects and identify degenerations of aged people, we selected two men with a similar height but different ages to cross the bathtub at the height of 700mm. This setting was lower than the average bathtub height of 750-800mm in China. Figure 4 shows performance curves from a 23 years old subject (4a: position; 4b: velocity; 4c: acceleration). The counterpart's performance from a 50 years old subject is given in Fig 5 correspondingly. From them, it was observed that the ranges of speed (0-3834.4) and acceleration (0-32120.44) from the young were nearly half of those (speed: 0-5310.60; acceleration: 0-57245.01) from the old. This information can be interpreted that old people have to gain a big moment with high-speed motion to cross the bathtub. This indicates that aged people have less confidence in their mobility even when you can physically perform a movement. This degeneration was further evidenced by the time interval between starting the

crossing (corresponding to a small wave just before a big wave) and reaching the peak of the crossing. The young man used 87 seconds while the old 105. That is to say, the old people may had psychological barrier to cross the string and needed more time to thinking. Of course, the dynamic information needs to be studied fully to support the design. It is obvious that the 700mm height of a bathtub needs to be reduced.

V. CONCLUSION

A 3D motion capturing system as a tool can be used to simultaneously obtain both static and dynamic anthropometric data of elderly people for ergonomics study and design. The method can capture task-specific dynamic information related to mobility and physiological degenerations. Motion data allows us to extract a great number and variety of measurements long after the subject has moved. It is very useful for ergonomic design applications. The experimental results from the case studies will be reported separately.
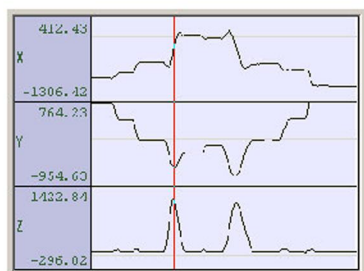

Figure 5a. Performance of a young subject (23yrs old): position graph
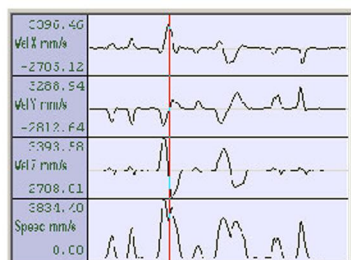

Figure 5b. Performance of a young subject (23yrs old): position graph
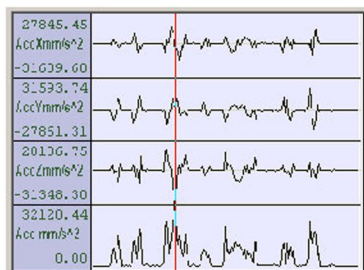

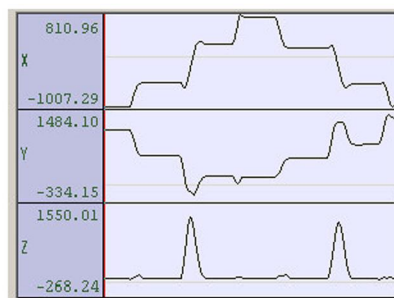Figure 5c. Performance of a young subject (23yrs old): position graph

Figure 6a. Performance of a middle-aged subject (50yrs old): position graph

Figure 6b. Performance of a middle-aged subject (50yrs old): velocity graph

Figure 6c. Performance of a middle-aged subject (50yrs old): acceleration graph.

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