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Motion Capture as a User Research Tool in "Dynamic Ergonomics"

Xiangyang Xin[1], Craig Vogel[2] and Henry Ma[1]

[1]School of Design, Core A, The Hong Kong Polytechnic University, Hung Hom, Hong Kong, sdxin, mchenry@polyu.edu.hk

[2]College of DAAP, University of Cincinnati, Cincinnati, OHIO, USA, craig.vogel@uc.edu

ABSTRACT:

This paper documented an experiment of using motion capture as a quantitative tool to study "dynamic ergonomics," physical ability both in two dimensions and in motion, to provide insights for understanding the physical limitations of users and products' usability. In the experiment, a predefined set of tasks were performed by the research subjects. The motions of the research subjects were captured by an advanced 3D motion capture system as well as a regular video camera. The data collected through the motion capture system were compared with the findings from qualitative video observation. Conclusions were drawn on the potential values of motion capture as a user research tool in the early stage of a product development process rather than the later usability testing stage.

KEY WORDS: Motion Capture, Dynamic Ergonomics, User Research, Qualitative/Quantitative Research, iNPD

1. INTRODUCTION

Usually observation in addition to two dimensional human factor studies is used to understand and evaluate ergonomic aspects of product concepts. On the other hand, motion capture is often used as a production tool in computer games, animations and films for its ability to capture realistic, accurate and precise movements. However, it has seldom been asked whether and how motion capture might help user research and ergonomic study in the early product development process. Perhaps, motion capture as an advanced technology has enough applications that keep most motion capture labs too busy. Maybe the more scientific and quantitative methods are not seen as necessary in the early stage of a product development process.

In a recent experiment at The Hong Kong Polytechnic University, a motion capture exercise was designed to compare the physical limitations between an elderly and a healthy young male. The goal of this research was to explore the possibilities of using motion capture as a complementary user research method to traditional observation techniques and static human factor studies. Furthermore, it explored motion capture as a user-centered decision making tool with users absent through the comparative data collected in the earlier process.

2. A MOTION CAPTURE EXPERIMENT

The motion capture exercise discussed here was part of a one-week intensive workshop on Innovative Product/Service Development for students of Master of Design of the Hong Kong Polytechnic University. The students were asked to identify and develop a product opportunity for Hong Kong elderly by using the iNPD process, integrated New Product Development, developed by Professors Cagan and Vogel at Carnegie Mellon University (Cagan and Vogel, 2002). For the first time, motion capture was introduced as a quantitative tool to complement traditional qualitative user research methods such as observations and field studies. The teaching team, Prof. Craig Vogel and Xiangyang Xin with support from Prof. Henry Ma and Newman Lau from Multimedia Innovation Center (MIC) at The Hong Kong Polytechnic University planned this as an experiment to identify future research opportunities.

As elderly are often physically challenged, the motion capture exercise was set up to study their physical limitations, especially dynamic movement limitation. To better understand the age-related physical limitations, a healthy young male was arranged to perform the same predefined actions to provide a comparative study.

Dynamic Ergonomics is used as a term in this experiment to describe range and speed of movements in a three dimensional space, differentiated from traditional two dimensional ergonomic measurements. The motion capture took place at the MIC, School of Design, The Hong Kong Polytechnic University with an advanced optical motion capture system with twelve hi-speed (up 2k Hz) and high resolution (1280 x 1024) cameras.

Six sets of tasks were designed to simulate daily house hold activities in a controlled environment.

- ☐ Picking up coins from the floor: to simulate a typical house activity of picking up small objects from the floor, which is often challenging for elderly for both reaching low and grabbing small objects from an uncomfortable position.
- ☐ Picking up coins at different heights: to understand how different height positions affect the effectiveness of performing similar tasks (Fig.1).
- ☐ Reaching a high shelf: to understand the difficulty of reaching remote storage in Hong Kong's normally crowded living environment.
- ☐ Preparing pets' food: as feeding pets is part of many people's daily life, the team also designed predefined movements for pets' food.
- ☐ Sitting: while chairs are typically designed based on human factors studies, a complete sequence of movements was captured to better understand the difficulties of sitting and getting up from a chair.
- ☐ Stretching: a set of stretching movements with no specific tasks involved was added to test the limitation of movements, and to compare motion range between an elderly and a healthy young male side by side (Fig. 2).

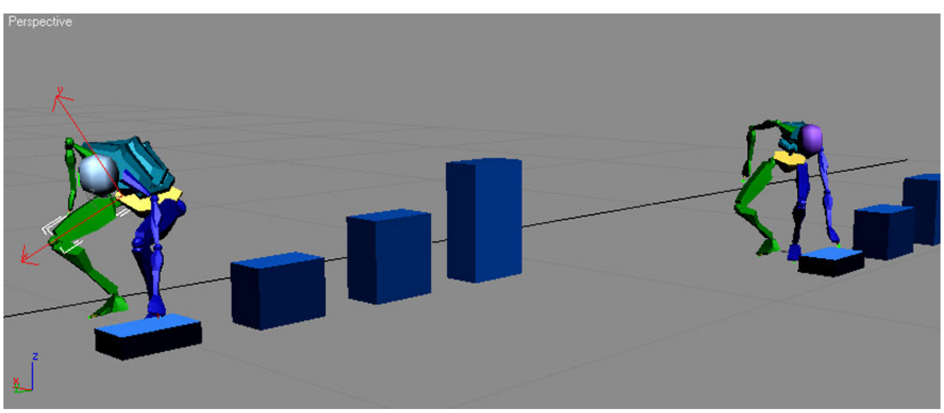


Figure 1: Picking up coins from different levels.

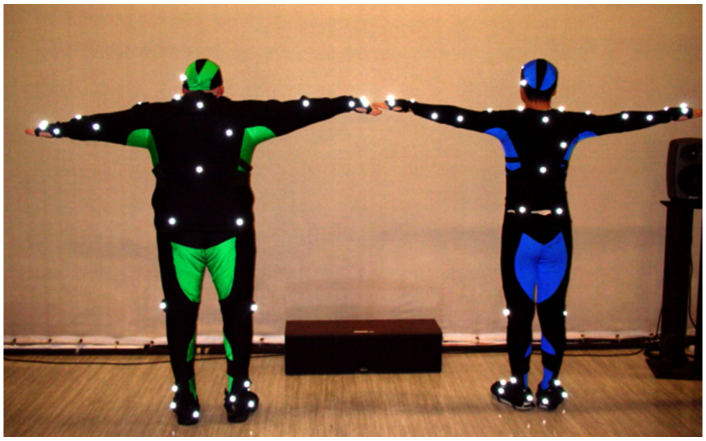


Figure 2: Motion capture exercise of comparative stretching.

Watching the difficulties faced by the elderly when performing those predefined tasks, a team identified “facilitating morning exercise” as a product opportunity for Hong Kong elderly along with other social and economic factors. They developed a concept of “Posture Correction Monitor” for the elderly by using motion capture equipment to obtain and optimize average posture/movement data of the elderly, and to monitor gestures and movements during their morning exercises.

Although, the motion capture exercise did not have much direct influence on identifying product opportunity for the Hong Kong elderly in the workshop, it provided students with clear evidence and insight into the physical challenges that the elderly face. Importantly this complemented the limited observations conducted during the short duration of the exercise. Students were also able to identify potential opportunities for using motion capture as a tool to help conceptualize and realize the product opportunities identified during this one-week workshop. For instance, one student, who identified handbags as the product direction for elderly women, proposed using motion capture to examine specific body movement and its adjustment to different handbag designs. Other students proposed redesigning the motion capture studio to simulate the actual living environment of the elderly, developing portable motion capture devices, or possibly setting up a motion capture system in the street. Although most of the ideas were premature, they were interesting concepts from students who were experiencing motion capture for the first time.

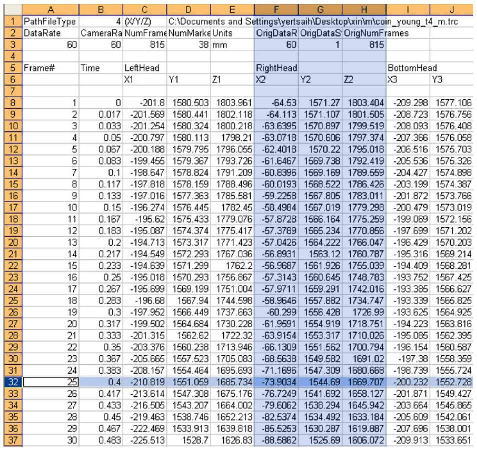
3. MOTION CAPTURE AS A USER RESEARCH TOOL

Accuracy and ability to capture real time data are important factors that make motion capture a useful and valuable tool in animation and the video game industry to create fast and natural movement, or in biomechanics and sports training to diagnose problems or improve performance. However, these advantages are not all relevant to a typical user research process, where emotional, social and other environmental factors may affect how people perform tasks or use products. The following section discusses advantages and disadvantages of using motion capture as a user research tool in "Dynamic Ergonomics."

Compared to most traditionally qualitative user research approaches, clear advantages and disadvantages were quickly noticed when using motion capture as a research method for understanding users and their task performance. For instance, the accurately captured and presented data allows scientific and credible data analysis. Comparing movements side by side between an elderly and a healthy young participant gives a much clearer picture of how age effects task performance, as if amplifies the research findings. As one of the participants was left handed, from the side-by-side comparison during the "reaching high shelf" task performance, we found that most right handed people are actually left hand challenged. It was an interesting finding that challenged the notion of right handed as normal and healthy; it raised interesting questions and product opportunities regarding how to help left hand challenged right handed people.

In contrast, performing predefined tasks and movements within a controlled environment, captured by equipment that are often beyond participant's understanding does not provide them with the necessary psychological confidence or freedom to focus on performing their tasks. While wearing a special "high tech" motion capture outfit is probably an enjoyable experience for an actor for shooting a movie scene, such a tight, colorful outfit with camera sensitive pins all over the body makes a participant feels very uncomfortable, especially when their actions are observed by others.

A major challenge of using motion capture as a user research tool is to make sense of scientifically captured data. Outputs of motion capture exercises including marker data (an x/y/z axis marker position data) (Fig. 3, a) and skeleton data (Fig. 3, b) can be used directly for its specific applications, such as 3D visualization in animation or gait analysis in biomechanics. Such output formats provide a very scientific foundation for dynamic ergonomic analysis. However, unlike computer generated 3D visualization in animation, the goal of introducing motion capture as a user research method in the workshop was to help identify potential product opportunities through better understanding about physical limitation and mobility of the elderly. This requires students to have specific knowledge to understand the captured data, yet there is no specific computer program available to help generate useful user friendly information for product design and inspiration.



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14	7	0.1	-198.647	1578.824	1791.209	-60.8396	1569.169	1789.559	-204.427	1574.898
15	8	0.117	-197.818	1578.159	1788.496	-60.0193	1568.522	1786.426	-203.199	1574.387
16	9	0.133	-197.016	1577.363	1785.581	-59.2258	1567.805	1783.011	-201.872	1573.766
17	10	0.15	-196.274	1576.445	1782.45	-58.4984	1567.019	1779.298	-200.479	1573.019
18	11	0.167	-195.62	1575.433	1779.076	-57.8728	1566.164	1775.259	-199.069	1572.156
19	12	0.183	-195.087	1574.374	1775.417	-57.3789	1565.234	1770.856	-197.699	1571.202
20	13	0.2	-194.713	1573.317	1771.423	-57.0426	1564.222	1766.047	-196.429	1570.203
21	14	0.217	-194.549	1572.293	1767.036	-56.8931	1563.12	1760.787	-195.316	1569.214
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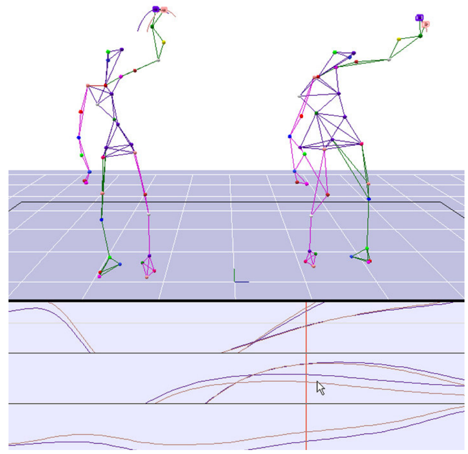
24	17	0.267	-195.699	1569.199	1751.004	-57.9711	1559.291	1742.016	-193.385	1566.627
25	18	0.283	-196.68	1567.94	1744.598	-58.9646	1557.882	1734.747	-193.339	1565.825
26	19	0.3	-197.952	1566.449	1737.663	-60.299	1556.428	1726.99	-193.625	1564.925
27	20	0.317	-199.502	1564.684	1730.228	-61.9591	1554.919	1718.751	-194.223	1563.816
28	21	0.333	-201.315	1562.62	1722.32	-63.9154	1553.317	1710.026	-195.085	1562.395
29	22	0.35	-203.376	1560.238	1713.946	-66.1309	1551.562	1700.794	-196.154	1560.587
30	23	0.367	-205.665	1557.523	1705.083	-68.5638	1549.582	1691.02	-197.38	1558.359
31	24	0.383	-208.157	1554.464	1695.693	-71.1696	1547.309	1680.668	-198.739	1555.724
32	25	0.4	-210.819	1551.059	1685.734	-73.9034	1544.69	1669.707	-200.232	1552.728
33	26	0.417	-213.614	1547.308	1675.176	-76.7249	1541.692	1658.127	-201.871	1549.427
34	27	0.433	-216.505	1543.207	1664.002	-79.6062	1538.294	1645.942	-203.664	1545.865
35	28	0.45	-219.463	1538.746	1652.213	-82.5374	1534.492	1633.184	-205.609	1542.061
36	29	0.467	-222.469	1533.913	1639.818	-85.5253	1530.287	1619.887	-207.696	1538.001
37	30	0.483	-225.513	1528.7	1626.83	-88.5862	1525.69	1606.072	-209.913	1533.651



(a) (b)

Figure 3 a: Marker data (with right head marker high-lighted).
b: Skeleton data (with joint position of left Thumb and Pinky).

To make motion capture a more useful and usable tool in dynamic ergonomic user research, new output information may be needed to make data reading more intuitive; new software is probably necessary to translate captured data in certain ways that can help easily interpret data directly related to dynamic ergonomics (Fig. 4). For instance, it may directly reveal motion range and speed, or automatically identify problems based on predefined criteria or database comparison.

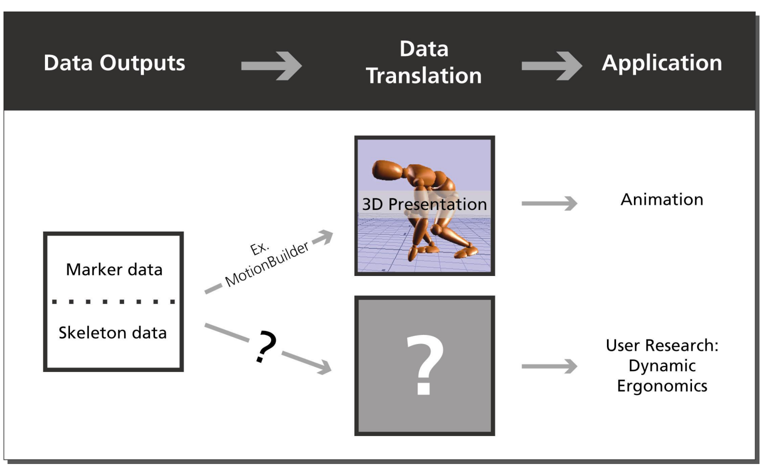


Figure 4: Motion capture exercise.

As problems of design are usually “ill-formulated, where the information is not clear, where there are many clients and decision makers with conflicting values,”[1] another challenge of using motion capture in a design process is to understand how motion capture helps define problems of design and propose meaningful solutions. Figure 5 uses iNPD as an example to apply motion capture as a user research method. In each phase of iNPD, motion capture generates different kinds of insight. For instance, while in Phase One a general database of dynamic ergonomics might be used as a reference tool to help identify potential product opportunities (the database is yet to be built), later motion capture can provide a scientific tool for concept testing.[2]

	iNPD Four Phase	Potential Use of Motion Capture
Phase I	**Identifying Opportunities** To identify one product opportunity through scanning and analyzing emerging social, economical and technological trends	• Referencing a general database of dynamic ergonomics to provide quantitative decision making support to qualitative SET Factors analysis, and thus to help identify relevant product opportunities; • Developing digital models of targeted users for later evaluation and concept testing
Phase II	**Understanding Opportunities** To obtain a holistic product definition through primarily qualitative research and by using tools such as Value Opportunity Analysis	• Developing a preliminary motion capture test that is relevant to the product opportunity identified in the previous phase; • Helping define ergonomic values in the Value Opportunity Analysis chart
Phase III	**Conceptualizing Opportunities** To develop one product concept through an iterative process of generation, evaluation and selection	• Providing a quantitative approach to compare and test different concept models
Phase iV	**Realizing Opportunities** To refine the selected product concept and related program details	• Testing and evaluating the final product concept; • Avoiding potential difficult or dangerous task performance during product testing by using the digital user model built in Phase One; • Demonstrating product ideas digitally with precision and multiple view points

Figure 5: Using motion capture in iNPD (integrated New Product Development).

Motion capture, as a quantitative tool for user research, has great potential; however, its advantages can not be fully utilized unless we overcome the challenges in data interpretation and presentation. Even though transportable and wireless motion capture technologies are well

[1] Horst Rittel, “Wicked Problem,” Management Science, vol. 4, no. 14 (December, 1967)
[2] The iNPD process is introduced in Chapter 5 in “Creating Breakthrough Products” by Cagan, Jonathan and Craig Vogel, Prentice Hall, 2002

developed, such as Gypsy by MetaMotion, they are still expensive, especially when software costs are added. An immediate challenge is the limited access to motion capture equipment or the cost to set up a new motion capture lab. At the same time, additional knowledge, time and effort are required to run motion capture experiments, as well as to analyze the captured data. As discussed earlier, new software is needed to allow easy interpretation of capture data (Fig. 4), and there is no database available for dynamic ergonomics. The database will require much time and effort.

4. CONCLUSION

Motion capture certainly has great potential to expand user research approaches by adding precise quantitative information, which complements the often qualitative approaches of user observations and interviews. However, it is still in a premature stage as a user research tool. Affordable and portable motion capture systems are needed to increase accessibility for everyday designers. The hardware setup and testing environment needs to be more user friendly in order to make test subjects physically and psychologically more comfortable. Above all, new computer programs are needed to make it a more useful and usable tool for its new applications beyond animation and gait analysis.

Following this brief class experiment, we identified possible research topics to be pursued in the near future. For example, we might try to build a database of dynamic ergonomics starting from physically challenged right handed people, or to explore ideas for developing new computer programs for potential application in dynamic ergonomics, thus making this a promising tool for product design.

REFERENCE:

Horst Rittel, “Wicked Problem,” Management Science, vol. 4, no. 14 (December, 1967)

Cagan, Jonathan and Craig Vogel, “Creating Breakthrough Products,” Prentice Hall, 2002