Chapter 1
Description of and Applications for a Motion Analysis Method for Upper Limbs

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ABSTRACT

In daily life, we often perform activities with the upper limbs. Various motions of the upper limbs are required when performing activities of daily living (ADL), such as eating, dressing, grooming, or operating a home appliance. When problems first occur with human upper limb motions, a detailed analysis should be performed to determine where the difficulty with motion exists and to identify conditions under which we can perform these activities more easily and efficiently. Next, adjustments should be made to the activity or to the interface design of appliances to reduce the difficulty posed by the problematic motion. In this chapter, the methods of motion analysis for human upper limbs are explained and the effective method of utilization is shown. A case study is also provided to demonstrate the analysis of the pointer operation for cerebral palsy patients using a laptop PC which operates by a graphical user interface operating system (GUI OS) to provide a barrier-free approach. Additionally, an applied case study of the motion analysis methods for human upper limbs is shown, and the countermeasure to develop an effective pointer operation for cerebral palsy patients is discussed.

INTRODUCTION

Over the course of a day, it is necessary for humans to use their body parts, such as the upper or lower limbs, when performing basic human functions. In daily life, the activities performed with the upper limbs often include ADL such as eating, dressing, grooming, and operating a home appliance. To maximize the productivity of factory workers' manual labor, useless motion should be eliminated and work processes and machine interfaces should be improved to enable workers to perform their tasks easily and quickly.

One well-known method of motion analysis of the human upper limbs is Therblig analysis, which was reported in Gilbreth, F.B. (1911). In this analy-

DOI: 10.4018/978-1-4666-2196-1.ch001

sis, the upper limb motions are classified into two categories: movement activities and termination activities (which end movement activities). This analysis further subdivides termination activities into two categories: activities that involve obtaining an object and activities that involve placing an object. In Fitts, P.M. (1954), Fitts's law was defined as a means of grading the difficulty of upper limb motions. According to this law, the difficulty of upper limb movements increases with movement distance and decrease with object size. Therefore, to create a work environment in which we can work with our upper limbs easily and quickly, the movement distance should be reduced or the target object size enlarged.

To analyze upper limb motions kinetically, markers were put on various areas of the upper limbs and photographed with a high-speed video camera. Coordinates were then assigned to the marker locations in the photographs, allowing upper limb motion traces to be produced. The different upper limb motions can be assigned to the movement activity or termination activity category based on the speed wave pattern.

Notably, PCs that run a GUI OS have recently become commonplace, and various operations can be performed with pointing devices such as a mouse. When we start an application, choose a menu, or input a letter using a software keyboard, we use a mouse to move the pointer and click it on an icon or a key (Raskin, J. 2005). Fitts's law can be applied to upper limb motions such as pointer operations performed with a pointing device. Therefore, the difficulty index of the pointer operation can be reduced by adjustment of the movement distance and icon/key size. The motion duration for a pointer operation can be reduced by controlling the D/C ratio, which is calculated by dividing the pointer movement distance by the movement distance of the pointing device. This aids people with upper limb impairments as it reduces the barriers to movement.

CHARACTERISTICS OF THE UPPER LIMB MOTIONS

In this paragraph, some technical terms are explained to clarify the process by which the characteristics of human upper limb motions were analyzed.

Fitts's Law

The difficulty of upper limb work is usually evaluated using the index of difficulty (ID), which was developed by Fitts. Fitts's law states that the difficulty index is influenced by both the distance of the upper limb movement and the target size, and it is calculated by *formula (1)*, where A is the movement distance and W is target size.

$$ID = \log_2(2A/W) \quad (1)$$

In addition, motion time (MT) is calculated using *formula (2)*, where a worker's work performance is given as the index of performance (IP).

$$IP = ID/MT \quad (2)$$

The ID was originally derived from the result of an experiment analyzing upper limb movement, in which the measurement was based on the placement of a stylus pen point on a target plate. There are several studies reporting that ID calculation can be applied to pointer operation on a GUI screen (Card, S. K. et al., 1978, Epps, B.W. et al., 1986).

Movement and Positioning Activity in Regards to Pointer Operation

Upper limb motion comprises two activities, movement and termination, which correspond to activities such as grasping an object or putting an object on a target, respectively. When we operate a pointer on a GUI screen, we use a pointing device such as a mouse. We move the pointer onto a target