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Keynote Lecture

Rehabilitation Assistance Systems Using Motion Capture Devices and Virtual Reality Feedback

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Abstract. Patients with neurodegenerative diseases, e.g., Parkinson's disease and stroke, show symptoms of motor impairments that disturb gait and mobility. The subjective and objective assessment of their rehabilitation to evaluate the degree of improvement is considerably important. The purpose of this study was to investigate the feasibility of medical and healthcare applications of the Kinect v2 motion capture devices and a head-mounted display in response to the abovementioned practical medical needs: (1) 3D gait analysis system and (2) rehabilitation assistance using virtual reality feedback.

1. Introduction

People with Parkinson's disease typically exhibit a postural instability. As the disease progresses, gait is affected, resulting in decreased stride length and walking speed. Currently, in diagnosing these gait disturbances, evaluation is performed through visual observation using qualitative evaluation, such as the scale for the assessment and rating of ataxia (SARA). SARA is used as a clinical scale to assess a range of different impairments in cerebellar ataxia. The scale comprises 8 items related to gait, e.g., "*1. Slight difficulties, 2. Clearly abnormal, 3. Considerable staggering, 4. Marked staggering*" and so on. However, these subjective evaluations are ambiguous, and the judgment results vary according to evaluators. Therefore, in this research, noncontact vital sensing using a motion capture device and its medical welfare application is proposed to perform objective and quantitative evaluation of gait disturbance.

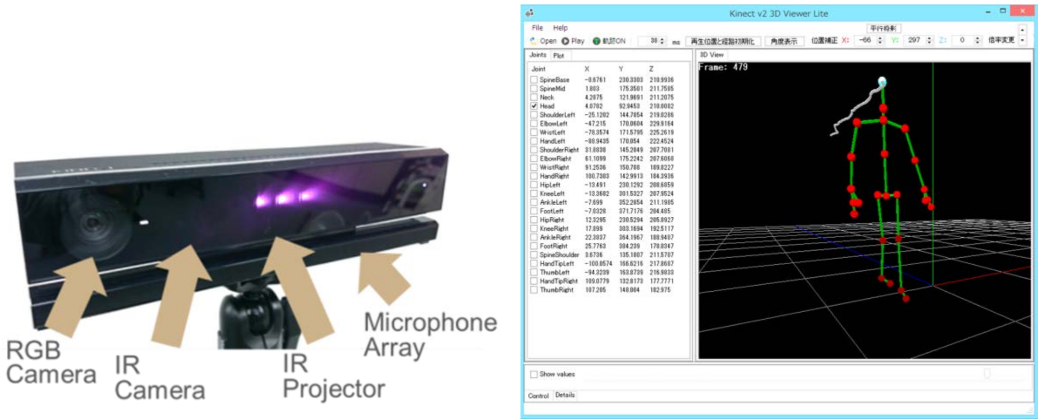
We develop another rehabilitation assistance system for promoting the desired outcome of increased range of motion in rehabilitation exercises by indicating visual feedback using a head-mounted display (HMD). The rehabilitation assistance system can provide effective feedback that assumes movement after improvement. Particularly, in a patient whose movement range of the arm is restricted, by displaying the trajectory of the hand in the virtual space with inertia, it is misidentified that the user's hand is moving more than the actual range of motion. As a result, it is expected that the function of the arm will be improved.

In this study, we propose medical and healthcare application systems using Kinect and/or HMD to assist both therapists and patients in rehabilitation especially for cognitive and motor deficits [1-6]. According to practical medical needs, we developed applications using Kinect v2, 3D gait analysis systems, and rehabilitation assistance using virtual reality (VR) feedback.

2. 3D gait analysis using motion capture devices

Human gait is an important indicator of health, with applications ranging from diagnosis, monitoring, and rehabilitation. As the disease progresses, gait is affected, resulting in decreased stride length and walking speed. Usually, such 3D motion is captured by attaching many markers on the patients and monitored by infrared cameras. The system is expensive and typically set at medical facilities, requiring a large area. In contrast, the Microsoft Kinect v2 motion capture device (Fig. 1(a)) has a time-of-flight (TOF) depth sensor for three-dimensional (3D) motion capturing and tracking of 25 skeletal joints in real time in a noncontact manner, wherein *X*, *Y*, and *Z* coordinates are provided for each joint position [1]. Using the measured 3D data, we have developed a 3D motion analysis system, shown in Fig. 1(b). This viewer can display the body movement from any angles using 3D data of 25 joints.

However, the precious gait analyses are difficult only from the skeletal view. Superimposition of the video and skeletal images seems useful. However, the camera angle is fixed, and a privacy problem occurs.



(a) (b)

Fig. 1. (a) Kinect v2, (b) previously proposed 3D motion analysis system [3]

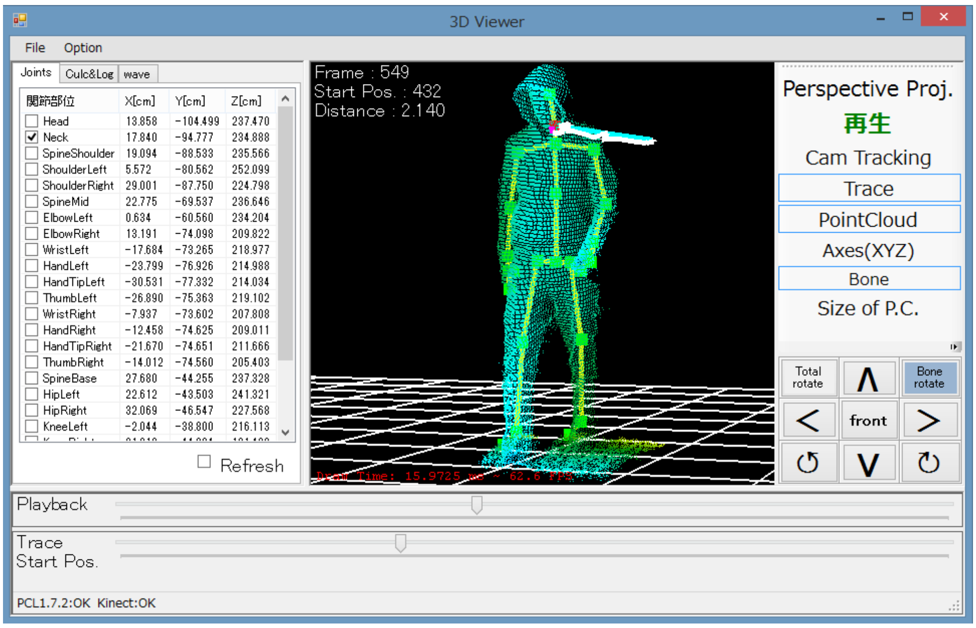


Fig. 2. Proposed 3D motion analysis system using point cloud

To address the abovementioned problems, we propose a point cloud registration method to synthesize the skeleton and surface of the body for gait analysis. A point cloud obtained from depth image of Kinect is a data set defined as a collection of multidimensional points of the sample surface in *X*, *Y*, and *Z* coordinates. As shown in Fig. 2, the gait movement can be observed accurately compared with that in Fig. 1(b). The newly proposed 3D viewer can calculate gait parameters, e.g., walking speed and stride length, to evaluate gait quality quantitatively. Moreover, the point-cloud-based rendering of motion preserves the privacy of the patients, which is essential for healthcare systems.

Using the proposed 3D gait analysis system, we conducted the walk test for 6 patients with actual ataxia and 6 healthy subjects for comparison. Subjects are required to go back and forth between 1 and 4.5 m before Kinect v2. By recording the behavior during walking and comparing the stride width, feet width, and walking distance, correlation was found between the average value of a foot width, walking distance difference, and SARA score. In particular, a significant difference was observed between the patient group and the healthy subject group in the mean value and variation of walking speed and stride length.

2. Rehabilitation Assistance using VR Feedback

A substantial part of the rehabilitation is remediation of cognitive and motor deficits to improve the functional ability of patients. However, rehabilitation interventions that require simple repetitive movements might cause monotony and boredom, which result in lowering the patient’s motivation to continue the rehabilitation. In recent years, clinical and rehabilitation studies demonstrate the effectiveness of VR as an intervention tool for a variety of neurological deficits resulting from hemisphere stroke.

As a rehabilitation intervention tool for recovery from such syndrome caused by cerebral or muscular disorders, VR feedback has attracted attention [7]. Such immersive VR environment can be achieved through an HMD worn over the head, shown in Fig. 3. VR systems allow users to interact in various virtual environments, providing real-time feedback in relation to the therapeutic goals for the patient’s needs.

The patient is required to pick up one block using a virtual hand according to the sensor and move the block to the designated part to create a sort of objects. For the patients with motor impairments, the movable range of the arm is limited. The VR system shows the expected trajectory considering inertia movement, even if the patient is not moving in reality, which increases the patients’ motivation to participate in their rehabilitation as well as confidence in using the paretic arm (Fig. 4). The immersive component of VR can generate greater brain activity in motor-related regions of the brain than simply doing conventional motor task using blocks. This system can facilitate further experiments to clarify the effect of haptics in VR and may be used to recover brain function and behavior associated with stroke-related hand paresis.

Fig. 3. Rehabilitation using HMD

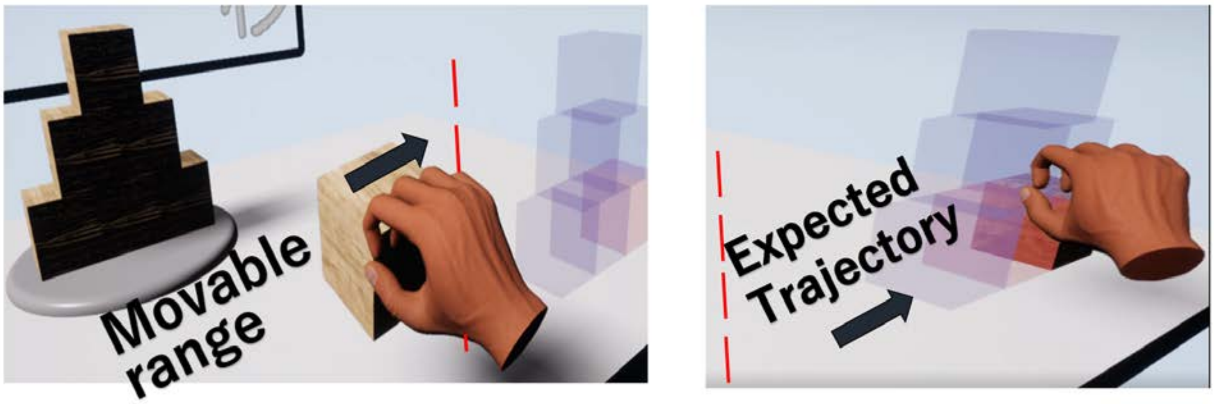


Fig. 4. VR feedback using HMD

3. Conclusion

This study investigated the feasibility of ICT-based medical and healthcare applications in response to practical medical needs. A low-cost noninvasive motion capture device and/or HMD can be used in an objective clinical assessment of patients with stroke and Parkinson's disease who display manifestations of gait and motor deficits. Based on the feedback from patients and therapists, improvements of the interface and measurement accuracy are subjects of our future research.

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