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A Survey on the Use of Microsoft Kinect for Physical Rehabilitation

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Abstract— In recent years, Kinect has gained more popularity as a portable, low cost, markerless human motion capture device with easy software development. As a result of these advantages and the advanced skeletal tracking capabilities, it has become an important tool for clinical assessment, physical therapy and rehabilitation. In this paper, we represent the capabilities of Microsoft Kinect and investigate the studies that uses Kinect technology for rehabilitation purposes. The selected studies about the related work are categorized and outlined with the results.

Keywords— Kinect, physical therapy, rehabilitation, skeletal tracking, computer vision

I. INTRODUCTION

Microsoft Kinect is a device originally designed for sensing human motion and developed as an controller for Xbox game console that is being sold since 2010. It did not take too long for researchers to notice that its applicability goes beyond playing video games, but to be used as a depth sensor that facilitates interaction using gestures and body motion. In 2013, a new Kinect device is introduced with the new game console called as Kinect v2 or Kinect for Xbox One. The new Kinect replaced the older technologies and brought many advancements to the quality and performance of the system. The older Kinect named as Kinect v1 or Kinect for Xbox 360 after new Kinect's arrival.

A. *Kinect Hardware Specifications*

The Kinect for Xbox 360 has a RGB camera as the the color sensor, and a depth sensor comprised of an infrared (IR) light source emitter and an IR depth sensor. The later Kinect brings out new technologies with an IR illuminator and an IR Time-Of-Flight (TOF) depth sensor. Both Kinects and a detailed comparison of their specifications are shown in Fig. 1 [1, 2, 3, 4].

Device	Kinect for Xbox 360	Kinect for Xbox One
Photo		
Color Camera	640 x 480 @30 FPS	1920 x 1080 @30 FPS
Depth Camera	320 x 240	512 x 424
Min / Max Depth Distance	40 cm / 4.5 m	50 cm / 8 m
Horizontal Field Of View	57 degrees	70 degrees
Vertical Field of View	43 degrees	60 degrees
Tilt Motor	Yes	No
Number of Skeleton Joints Identified	20	25
Number of Full Skeletons Tracked	2	6
USB Standard	2.0	3.0
Minimum Latency (Lag)	102 ms	20 ms
Active IR (able to use in dark/low light)	No	Yes

Fig. 1. A comparison of specifications for Kinect versions

B. *Computer Vision Capabilities of Kinect*

Although it is categorized as a depth camera, the Kinect sensor is more than that. It has several advanced sensing hardware containing a color camera, a depth sensor, and a four-microphone array. These sensors ensure different opportunities at 3D motion capture, face and voice recognition areas [5]. While Kinect for Xbox 360 uses a structured light model to get a depth map of a scene, Kinect for Xbox One uses a faster and more accurate TOF sensor.

After the arrival of Kinect, it did not take long that the computer vision community discovered the potential of Kinect that could extend far beyond gaming. Kinect costs much lower than traditional 3-D cameras (such as stereo cameras and time- of-flight (TOF) cameras) [6]. Not only indoor 3-D mapping, Kinect may be used for many other Computer Vision topics including object tracking and recognition, human activity analysis, and hand gesture recognition.

A tree-structured classification in Fig.2 shows what kind of vision problems can be addressed or enhanced by means of the Kinect sensor. Taking account of these topics, we can say that Kinect shows a great potential for academic studies in many areas.

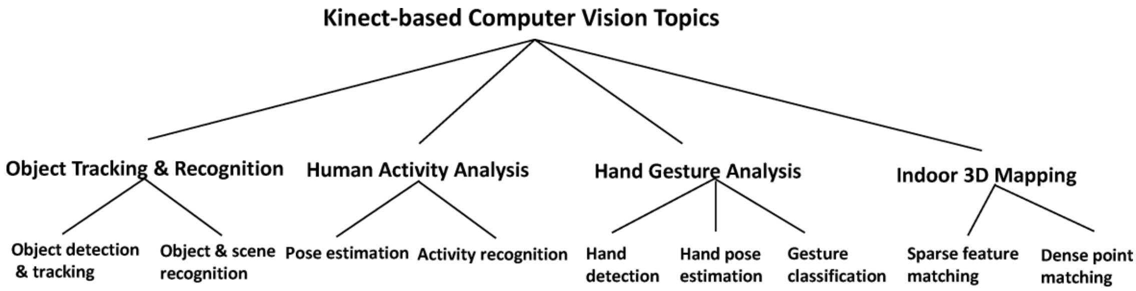


Fig. 2. Kinect-based Computer Vision Topics [6]

C. *Kinect Skeletal Tracking*

The key to the innovation behind Kinect is its advanced skeletal tracking ability. In skeletal tracking, RGB and depth streams are processed by the software to create a visual stick skeleton to represent the human body. Skeleton is constructed by a number of joints representing body parts such as head, neck, shoulders, and arms. After calculating 3D coordinates of all joints, Kinect succeeds at determining all the 3D parameters of these joints in real time to allow fluent interactivity [5]. Fig. 3 shows all the joints and their labels supported by Kinect for Xbox One sensor and the constructed skeleton map [7].

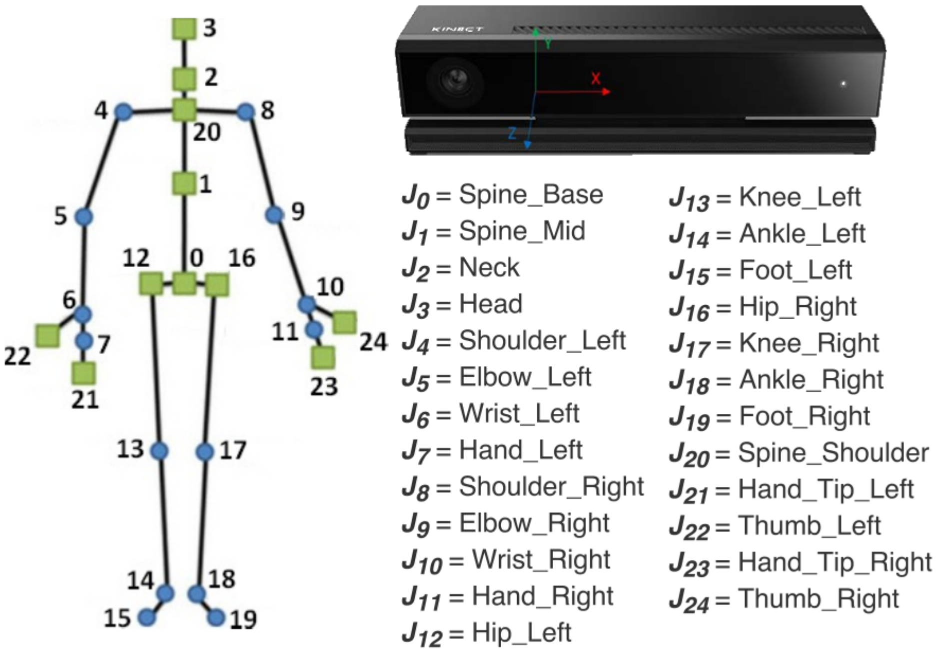


Fig. 3. Skeleton map and all 25 joint labels

Skeleton tracking features of Kinect are used to analyse human body movement for applications related to human computer interaction, motion capture, human activity recognition and more areas. Moreover, it makes a great use for studies especially in physical therapy and rehabilitation.

II. RELATED WORK

This section of paper describes the chosen studies that uses Microsoft Kinect sensor in physical therapy and rehabilitation area. Researchers developed different kinds of applications for monitoring, identifying or supporting patients. Some of these applications are games that aims to make patients more engaged in physical therapy. Studies reviewed shows that Kinect enabled games mostly used for rehabilitation of children to make them participate more willingly. After examining and classifying studies, most studied topics are defined as motor rehabilitation mostly studied for autistic or disabled children, rehabilitation for stroke patients and upper limb rehabilitation. An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

A. Studies Focusing on Motor Rehabilitation

People with motor impairments have general limitations in skills like range of motion, strength and motor control. Daily tasks, such as eating, dressing, and rising from a chair independently can become dramatically a hard mission to achieve. Furthermore, these deficits can cause a lack of social participation in community and spare time activities.

Chang, Yao-Jen et al. studied in a public school on rehabilitating two young adults with motor impairments with the help of developed Kinect system. They aimed at motivating motor disabled people to exercise for o longer time period and improve their motor skills and enhance the quality of life. They indicated that system succeeded at helping the therapists rehabilitate and motivating individuals [8].

Chang, R. K. Y. et al. developed a framework on Kinect technology for motor rehabilitation. The framework has the capability to combine the Kinect with an easy-customizable application to produce a home rehabilitation system that will motivate the patient, provide feedback and track the progress of the rehabilitation [9].

Roglic, Milos, et al. developed a Kinect-based game for fine-tuning of motor skills, and improving success of basic cognitive tasks of autistic children in Serbia. They developed five games on different activities of sorting, math exercises, catching, imitation and seeking. The game is user-friendly and colorful to inspire autistic children. According to children's therapists, game will be very useful for children in long term, make a big contribution to children's cognitive and motor skills. Fig. 4 shows screenshots from two games [10].

(a) (b)

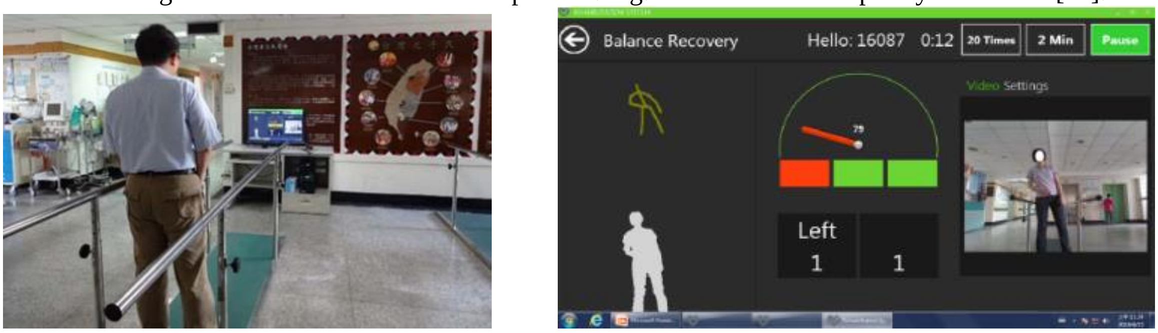
Fig. 4: Screenshots from two game modes (a) Sorting game (b) Catching game

Kouraklı, Maria, et al. presented a pilot research study at two primary schools with 20 children who have special educational needs. They used a suite of games called Kinems that contains movement-based educational games for such children. According to their analysis, game suite have a positive impact on children's academic performance and improves children's cognitive, motor and academic skills [11].

B. Studies Focusing on Rehabilitating Stroke Patients

PARK, Dae-Sung, et al. noticed that applicability of Kinect-based virtual reality (VR) training to improve motor function following a stroke has not been investigated. They investigated the effects of Xbox Kinect-based game system with VR training, on the motor recovery of patients with chronic hemiplegic stroke. Comparing data they gathered from the intervention group and the control group, the use of additional VR training with the Xbox Kinect gaming system effectively improved motor function during stroke rehabilitation [12].

Lai, Chung-Liang, et al. developed training system that includes four rehabilitation-oriented games for patients with movement disorders. Patients can use the system at home while the therapist can access remotely and inspect the training. They called it the Kinect Virtual Rehabilitation System (KVRS) and tested on stroke patients to improve their balance skills. In their paper, they indicated that the system exhibited a significant effect in recovering balance function for the stroke patients. Fig. 5 shows the developed system in use [13].



(a) (b)

Fig. 5: Balance recovering system (a) patient under training (b) screen with balance shifts

Pool, Sean M., et al. used Kinect to develop an interface and a virtual environment to navigate multiple routes through body gestures and voice commands. They tested the system on 12 post-stroke individuals and 15 individuals with cerebral palsy (CP). CP patients hardly managed to complete voice commands with little success. They stated in the paper that Kinect may be useful for people with mobility impairments but effectivity of the various gestures changes depending upon the disability of the person [14].

C. Studies Focusing on Upper Limb Rehabilitation

Chen, Pei-Jam, et al. developed a game to rehabilitate the upper part of the body. In addition to Kinect they have already used wireless Inertial Measurement Units (IMUs) to improve the accuracy of the Kinect system. They indicated in their paper that Kinect has a greater error ratio on extremity angles originating from depth or overlapping extremities, but calculation by IMUs has higher accuracy and stability. They propose that their system improves the validity and reliability of rehabilitation process [15].

SINHA, Sanjana, et al. represent an upper body rehabilitation system in their study. To improve the accuracy of the Kinect-based system against the marker using systems, they proposed an optimization method that utilizes Kinect depth and RGB information. According to experimental study on ten healthy participants, they reported 72% reduction in body segment length variance and advancement in Range of Motion (ROM) angle by 2° [16].

III. CONCLUSIONS

This paper surveys the studies that use Microsoft Kinect technology to develop applications and games in physical rehabilitation field. Kinect shows a great potential with its low-cost and portability and fast application development times against its rivals using markers for human motion sensing. There is an ongoing interest in developing Kinect-based systems for physical rehabilitation purposes, and the new studies improves as in the accuracy and performance, and reveals new usage areas for Kinect in the field of rehabilitation.

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