FYP12013
Kinect in Physiotherapy

Project Plan

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Section 1 – Introduction

1.1 Overview

Many hospitals and homes for elderly use ceiling hoist for assisted gait training of patients with mobility difficulties. Physiotherapists assess and prescribe training sessions to individual patients with very simple record such as whether the training has been carried out and how long the training lasted.

To enhance the monitor of these training sessions, accurate measurement of user performance and recording is needed to facilitate daily training and monitor progress of each individual. In some hospitals, sophisticated equipments were installed for this purpose. However, many other organizations might not have the budget for such large-scale system and hence a more inexpensive tool is needed to serve the same purpose.

With the aid of motion sensing system, we hope to build a system which can identify users, measure and record distance walked, time spent, cadence of steps, length of steps and other relevant data for better quality care and control. With the collection of these data, further analysis can be carried out by the system to assist physiotherapists in examining the performance of each individual or each session.

1.2 Related Work

In the real world, there are numerous of medical organizations making use of the powerful functionalities of Kinect to assist their daily duties, like the Royal Berkshire Hospital[1] used the skeletal tracking function

Fig. 1.1 – Kinect in Royal Berkshire Hospital

[1] Stroke Patients at Royal Berkshire Benefit from Playing Kinect (http://www.xbox.com/en-US/Kinect/Kinect-Effect)

of Kinect to provide rehabilitation practice for stroke and other brain injury patients. Likewise the Tokyo Women's Medical University in Japan[2], or Tedesys, a Spanish I.T. company, designed numerous of software to make use of Kinect in hospitals to assist the surgeons during surgery by Kinect's motion sensing function.[3] All of these examples show the potential of Kinect in medical use is tremendous and feasible, and the value is considerable.

Fig. 1.2 – Use of Kinect in surgery

Fig. 1.3 – IT company Tedesys uses Kinect

1.3 Role of Kinect in this Project

In physiotherapy world, there are many standard tests to determine ones' mobility. For example, Berg Balance Scale[4], Elderly Mobility Scale[5], Six-Minute Walk Test[6] etc. All of these provide an objective scale and conclusion to the performance of the participants. With the help of Kinect, the testing process can be recorded accurately and automatically, and it will be stored in database and be processed later.

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[2] Opect (http://www.nichiiweb.jp/medical/category/hospital/opect.html)
[3] Tedesys Uses Kinect in Hospitals (http://www.xbox.com/en-US/Kinect/Kinect-Effect)
[4] American Academy of Health and Fitness (http://www.aahf.info/pdf/Berg_Balance_Scale.pdf)
[5] Chartered Society of Physiotherapy, UK (http://www.csp.org.uk/sites/files/csp/secure/agile_outcome_measures_ems_v2.pdf)
[6] American Thoracic Society (http://www.thoracic.org/statements/resources/pfet/sixminute.pdf)

Section 2 – Objective

The objective for this project is to:

1) Automate the collection of raw data from walking, e.g. coordinates of joints, time spent etc.;
2) Compute and analyze the collected data to produce relevant results, e.g. distance walked, step length etc.; and
3) Provide a user interface for accessing analyzed data.

A motion-sensing tool (Kinect for Windows) is used to gather data for further analysis. Actions of targets are captured and measure, which will then undergo the system's computation and analysis to produce useful information.

It is hoped that through this project, a low-cost system can be set up to provide instant feedback for both patients and therapists.

Section 3 – Problem Setting

3.1 Project Description

To achieve the objectives, our team will setup Kinect to trace the movement of the target, store useful information into database and display desired data through a user interface.

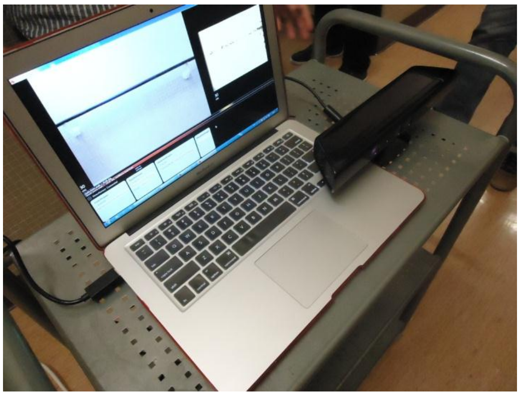

Fig. 3.1 – Tests on Kinect

In order to suit our project to real life environment, our team visited The Hong Kong Chinese Women's Club Madam Wong Chan Sook Ying Memorial Care & Attention Home for the Aged (hereafter refers as "Home for the Aged") for case study. Tests on Kinect concerning about sensitivity, stability and sensibility during movement were conducted.

Fig. 3.2 – Walkway with ceiling hoist

According to Mr. Ken Cheung, physiotherapist who works at Home for the Aged, walking is a common practice they used to monitor alderfly's body function. Therefore, we tested the Kinect on tracing walking motion. The elderly walks along a walkway with a length of 30m and they may turn around to walk back at any moment. There is a ceiling hoist that provides support to the elderly and a helper will be accompanying the elderly during the process for safety reasons.

Under this setting, the performance of Kinect is encouraging. Since the depth sensor range of Kinect is from 800mm to 4000mm[7] and the effective sensible depth ranged only from about 1.5m to 4m by our measurement, it has to move with the user for recording. Ideally we would like to install the Kinect onto the track so that it moves with the ceiling hoist as the target moves. For simulation, it is placed on a trolley. Despite of the short range of detection, the sensibility and stability of Kinect sensing during movement is great.

3.2 Modeling

The Kinect can track skeleton data which consists of 20 joints as shown in Fig. 3.3 and the coordinate system for these data is a full 3D system[8]. With these coordinates, we are going to compute useful information such as step length or uprightness of body posture and report them through a user interface. Fig 3.4 below shows the muscle and joint movements of a body during a walk cycle. This inspires us on what are the raw data needed.

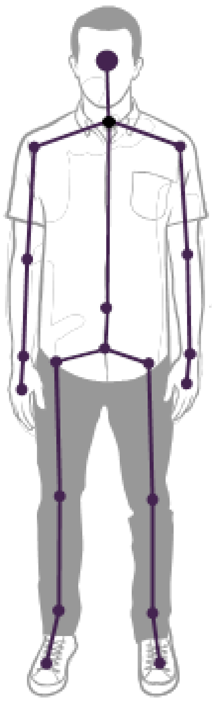

Fig. 3.3 – 20 Joints Kinect can identify

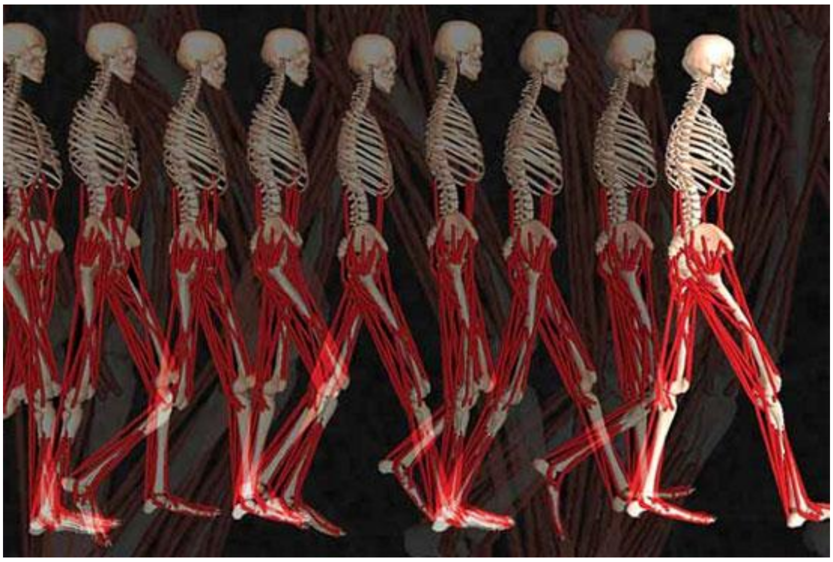

Fig. 3.4 – Walk cycle muscle and joint movements

[4] Microsoft Developer Network – Kinect Sensor (http://msdn.microsoft.com/en-us/library/hh438998.aspx)
[8] Microsoft Developer Network – Kinect Sensor (http://msdn.microsoft.com/en-us/library/hh438998.aspx)

Data extraction tests were conducted to clarify the data collection rate of the Kinect working with Microsoft Kinect SDK v1.6. With different sets of parameters in testing, we defined 3 modes of testing and recorded the time (in millisecond) needed to get 100 sets of joint data. In order to enhance the accuracy and reliability of the testing, the maximum and minimum values are ignored in computation. By applying formula,

$$Average = \frac{\text{sum of all data} - \text{minimum} - \text{maximum}}{(\text{count of data} - 2)}$$

the 6 sets (in 3 modes) of results in Table 3.1 demonstrate that it takes around 1700-1800 milliseconds to record 100 datasets.

	Raw1	Raw2	Default1	Default2	Smooth1	Smooth2
1	1764	1756	1728	1860	1693	1773
2	1671	1717	1697	1816	1832	1783
3	1647	1676	1792	1741	1835	1885
4	1738	1711	1780	1806	1674	1835
5	1717	1815	1697	1896	1778	1725
6	1757	1722	1721	1714	1796	1746
7	1781	1765	1715	1755	1678	1874
8	1743	1750	1799	1850	1711	1755
9	1663	1740	1724	1876	1715	1827
10	1786	1667	1749	1724	1786	1715
11	1716	1758	1823	1795	1736	1832
12	1726	1791	1715	1859	1681	1843
13	1673	1835	1677	1761	1770	1809
14	1731	1791	1760	1773	1799	1740
15	1810	1753	1780	1816	1695	1764
16	1744	1732	1718	1844	1725	1777
17		1721		1778		1731
18		1663		1766		1779
19		1708		1815		1756
20		1748		1730		1725
21		1686		1695		1677
22		1683		1680		1762
23		1717		1734		1752
AVERAGE	**1729.29**	**1733.67**	**1741.07**	**1786.1**	**1742.5**	**1776.33**

Table 3.1 – Data Extraction Test Result Table

3.2.1 Problem Formulation

Let $\mathrm{P} = \{\mathrm{p}_0, \mathrm{p}_1, \dots, \mathrm{p}_{19}\}$ be the set of joints. We denote any single joint by p. For each $p \in P$, it contains the 3D coordinates (See Table 3.2) recorded by the Kinect, so that $p_n = (x_n, y_n, z_n)$ where $0 \leq n \leq 19$.

Joint ID	Joint Name
0	HipCenter
1	Spine
2	ShoulderCenter
3	Head
4	ShoulderLeft
5	ElbowLeft
6	WristLeft
7	HandLeft
8	ShoulderRight
9	ElbowRight
10	WristRight
11	HandRight
12	HipLeft
13	HipRight
14	AnkleLeft
15	FootLeft
16	HipRight
17	KneeRight
18	AnkleRight
19	FootRight

Table 3.2 – Coordinates recorded by the Kinect

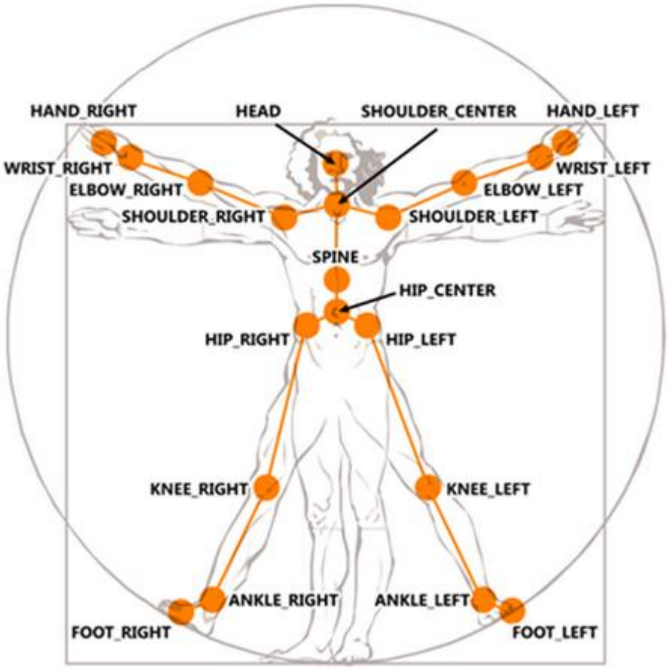

Fig. 3.5 – Set of joints detected by the Kinect

Let $S = \langle P_0, P_1, \dots, P_{|S|-1} \rangle$ be the set of joint set recorded in one activity, where $|S|$ is the total number of joint sets recorded. We denote any single joint set by s, so that $s_n = P_n$ where $0 \leq n \leq |S| - 1$. We denote the record time of joint set P by $\mathrm{P.t}$.

3.3 Application

Apart from walking motion, the project also addresses other physiotherapy exercise where the Kinect can be used to detect the target's movement and record data for analysis, such as the magnitude or degree of movement. For instance, the Hawkin's

Test (Fig. 3.6), Standing Hip Flexion Test (Fig. 3.7), Standing Trunk Sidebend Test (Fig. 3.8) and Supine Straight Leg Raise Test (Fig. 3.9) are all applicable in this project.

Fig. 3.6 – Hawkin's Test

Fig. 3.7 – Standing Hip Flexion Test

Fig. 3.8 – Standing Trunk Sidebend Test

Fig. 3.9 – Supine Straight Leg Raise Test

Section 4 – Project Schedule

The project schedule is as follow: