Estimating kinetic energy for therapy sessions

Alejandro Romero, Raymundo Cornejo, Fernando Martínez, Claudia Barraza, Vania Álvarez

Published: 31 October 2018

Abstract

Therapists usually base the progress of the patients on a daily observation with a global evaluation every six months. This scenario could create a lack of exact and measurable daily data. Measurable data could be very helpful for monitoring patient's progress and take important decisions regarding the therapy activities. A way to calculate the movement of a human body is through its kinetic energy. The kinetic energy measures the amount of energy spent in a therapy session or activity. The present study calculates the kinetic energy spent by children during movement based learning therapy through a data set captured with a motion sensing input device. Our preliminary results indicate an important impact on kinetic energy during this type of therapy

Keywords: Kinetic energy; therapy; serious games; movement; body segment mass; body gesture analysis.

1 Introduction

The National Joint Committee on Learning Disabilities [9] defines learning disabilities (LD) as a general term that refers to a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning, or mathematical abilities.

Vestibular treatment is a common complementary therapy to help children with their LD. The vestibular rehabilitation treatment is an exercise-based program tailored to address eye-movement control, dynamic visual acuity, balance, developmental reflexes, and body-movement functions [2]. Strengthening the vestibular system of these children might impact positively in their learning abilities.

Prior research [1, 6] have created serious games to support vestibular treatment. The use of serious games offers the opportunity of reinforcing health aspects while engaging children in ludic activities. However, these results are based on the qualitative assessment of therapists and computer scientists.

This work is focused on monitoring hard data of the movement of children with LD while performing therapy with serious games. The aim is to monitor their progress, particularly understanding the kinetic energy employed by patients during game sessions.

We can expect the kinetic energy employed by a child with LD might differ from a child without disabilities. Even between subjects who have the same disability since the heterogeneous group of disorders affecting LD. Therefore, therapists may use this tool to measure the patient progress along the work plan programmed for each patient.

The goal for the current work, is to monitor possible children' changes of movement during the therapy sessions by calculating their kinetic energy. The purpose of monitoring their kinetic energy is to see if through the game sessions exists any improvement by a given exercise or setting.

The current work develops a tool to estimate the most accurate kinetic energy of a human body based on data set from a prior study. The current work first explains the related work on sensing body movement, then it explains the implementation of the algorithm, and finally the results and conclusion of the present work

2 Related work

Similar studies with the Kinect sensor describe how to measure physical distance with an algebraical equation [11]. Establishing such distance allows to calculate velocity needed to get the Kinetic energy of the body [10], where time variable can be obtained by calculating the frames per second (fps) of the Kinect sensor [5,12]. Aside from velocity, the kinetic energy formula needs the mass of the body, this can be calculated depending on the height and weight of the person and body segment [4].

The amount of movement activity is important for differentiating emotions. The highest values of energy are related to emotions of anger, joy and fear. The lowest values correspond to sadness and boredom. It is showed that the movement activity is a relevant feature in recognizing emotion from the full-body movement [10]. Therefore, Kinetic energy can tell more than just the spent energy on an activity. It also allows us to identify emotions of the person during the therapy activity based on the amount of kinetic energy used.

Romero, A., Cornejo, R., Martínez, F., Barraza, C., Álvarez, V.
Universidad Autónoma de Chihuahua
Chihuahua, México.
Email: a310938@uach.mx, rcornejo@uach.mx, fmartine@uach.mx, cbarraza@uach.mx, valvarez@uach.mx

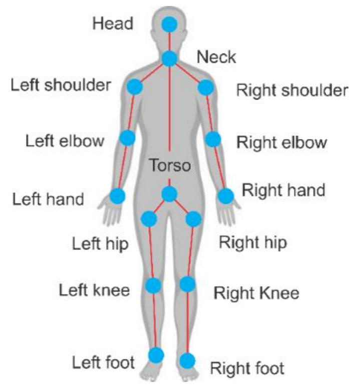

Figure 1 Joints read by Kinect sensor as human body shape

3 Implementation

The current work calculates the kinetic energy of a person (in this case a child between 4 and 12 years of age) based on a dataset from a serious game from previous work. The developed software can process the recorded movements of the person in the dataset given.

The dataset provides information of the movement of the body in a 3D space (X, Y and Z axis). The movement of the body was recorded by frame and captured the spatial information of each of the 15 joints tracked by the Kinect sensor (see Figure 1). Joints are distributed strategically throughout the body, each joint let us know the movement in every single part of the skeleton, allowing us to determine the kinetic energy at the end of the game session.

Once the data or information is collected at the end of the game; every movement is registered by X, Y, and Z coordinates, through this information distance and velocity can be calculated. Mass per joint is required to calculate the kinetic energy, this can be estimated depending on the patient's weight and height [4]. Mass and velocity will determinate the kinetic energy.

The dataset consists of a set of XML files, each xml file stores the data session of one patient in one day. Therefore, all xml files of a patient are processed and calculated respectively with a Python 3.6 script. This generates at the end of the calculation a CSV file with the patient ID, date and time, duration of the game, game ID, the total kinetic energy spent in the game and also the kinetic energy generated per joint of each patient.

3.1 Kinetic energy

The kinetic energy is the energy possessed by a body due to its motion. The kinetic energy k of a body of mass m, moving with a speed v is given by the following formula: [7]

$$K = \frac{1}{2}mv^2$$

We need to calculate the energy in the full body, the kinetic energy equation will help us to determinate separately a body joint. Therefore, we define the sum of kinetic energy of every joint as the total amount of energy spent by frame

$$K = \frac{1}{2}\sum_{i=1}^{n} m_i v_i^2$$

Where $\boldsymbol{m_i}$, is the mass of the joint and $\boldsymbol{v_i}$ the velocity of a single frame.

The System international unit for kinetic energy is $Kg * m^2 * s^{-2}$; this combination units is defined to be a joule and is denoted by J [8].

3.2 Mass

We employed the Zatsiorskji and Selujanov's [4] equation to calculate the mass by body segment m_i.

$$m_i = B_0 + B_1 m + B_2 H$$

Where m (Kg) is the total mass of the person and H (cm) is the height. The value of the parameters B_0, B_1, B_2 were taken based on Zatsiorskji and Selujanov's table (see Table 1).

Table 1. Anthropometric values by human body segment [4].

Segment name	B_0[kg]	B_1	B_2[kg/cm]
Head + neck	1.296	0.0171	0.0143
Hand	-0.1165	0.0036	0.00175
Forearm	0.3185	0.01445	-0.00114
Upper arm	0.25	0.03012	-0.0027
Foot	-0.829	0.0077	0.0073
Shank	-1.592	0.03616	0.0121
Thigh	-2.649	0.1463	0.0137
Upper part of the trunk	8.2144	0.1862	-0.0584
Middle part of the trunk	7.181	0.2234	-0.0663
Lower part of the trunk	-7.498	0.0976	0.04896

3.3 Velocity

In order to calculate the velocity, we have to establish the distance covered by each joint. Therefore, given a 3D point in space, the distance from one point to another is defined as

$$di = \sqrt{(x_i - x_{i+1})^2 + (y_i - y_{i+1})^2 + (z_i - z_{i+1})^2}$$

Where d_i, is the distance between one joint and another by frame, coordinates are measured in meters.

While the Kinect sensor can read a maximum of 30 frames per second (fps) it updates the new information received in an average of 25 fps [5], considering that the data set has some fps drops, the average value of 25 was considered to determine the time: $t_i = \frac{1}{25}s$. Therefore, the velocity is given by:

$$v_i = \frac{d_i}{t_i}$$

Where v_i is the velocity of the i-th joint in m/s.

Based on these calculations, we decided to perform studies where movement and kinetic energy are measured. Below are described the preliminary results

4 Results

The study was conducted with 7 children with different coordination disabilities, the results indicate most of them had a decrease on the level of energy employed throughout the sessions. Game sessions may differ on time even when the same game is applied due to the taken effort of the patient to complete the game, and kinetic energy differs as consequence. For that reason, it was decided to use *Joules per second* to show more accurately the average energy spent in a second during the session (see Table 2).

Height and weight were needed to calculate the mass by joint of the patient, in the current work, we had only the age of the children. In order to implement the proper calculation, we took the average weight and height in México by age [7].

Table 2 Joules per second through the game sessions

Child	Day 1 [j/s]	Day 2 [j/s]	Day 3 [j/s]	Day 4 [j/s]
Child 1	76.29850	58.21191	54.76295	47.12402
Child 2	76.29850	51.42094	37.43536	47.12402
Child 3	117.1885	95.03761	72.87253	53.74035
Child 4	43.00157	24.77868	37.44965	38.12683
Child 5	71.20425	124.2797	100.6830	69.23136
Child 6	118.4369	83.70296	67.18848	76.71323
Child 7	86.83982	126.6238	175.2220	117.9785

4.1 Standard deviation

Standard deviation is calculated by getting the average measurement of all the 4 game sessions per child, this in order to quantify the amount of dispersion between the energy used, from one child to another. The result given in Table 3 shows the standard deviation of the seven children. This dispersion of energy is given because of the variation of age of the patients, age and mass are directly proportional, and mass is required to calculate kinetic energy. Patient´s coordination problems is another element whereby kinetic energy could differ. Despite this, the investigation´s aim is to focus on the improvement of energy, but this can give us an idea of differences for further investigation.

Table 3 Maximum and minimum energy, mean and standard deviation

Minimum energy	Maximum energy	Mean	Std. Deviation
35.83918	126.6660	76.74914	30.02603

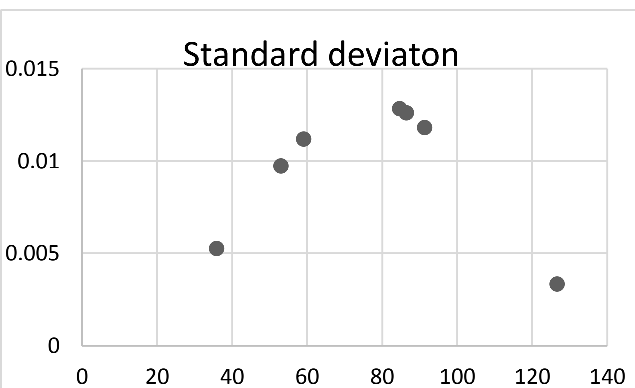

Figure 1 Standard deviation of kinetic energy used by 7 children

5 Conclusion

The kinetic energy is very helpful to serious games, because it can give us exact numbers to determinate some possible patient´s improvement.

The goal of this work was exploring a tool for therapists, computer scientists and even families, to monitoring the kinetic energy employed while playing serious games during therapy. This could have important implications since related research show positive outcomes in therapies for people who suffer coordination and learning disabilities.

As showed in Table 2, all the seven patients presented a relatively "High" kinetic energy in the game, and it might be because they could not use all their movement properly as the game required. By the fourth therapy session the children manifested a remarkable improvement of energy, in comparation with previews days. Children 1 to 6 showed an improvement of energy by the second session, and by the fourth session the child 3 presented more than a half of energy spend on the first game session.

This work was strongly orientated on the improvement of children with learning and coordination problems through the interaction with computers and serious games, making this not only one advantage more for Human Computer Interaction (HCI) but also for the patients who have one more possible tool of HCI for a better recovery.

6 References

[1] Cibrian, F.L. et al. 2016. Hunting Relics: A Persuasive Exergame to Promote Collective Exercise in Young Children. *International Journal of Human-Computer Interaction*. 32, 3 (Mar. 2016), 277–294. DOI= http://10.1080/10447318.2016.1136180

[2] Cronin, G. and Rine, R.M. 2012. Pediatric Vestibular Disorders

[3] Fernandez, V. Q. Tabla de talla y peso del Niño Mexicano.

[4] https://www.scribd.com/doc/134401232/Tabla-de-talla-y-peso-del-Nino-Mexicano

[5] Richard Goossens, Y. Song. 2016. Introduction to Biomechanics.

[6] https://ocw.tudelft.nl/wp-content/uploads/H-L-2_Introduction_to_Biomechanics.pdf

[7] Huus, A., & Bockstege, B. 2011. Measuring the Performance of the Microsoft Kinect across Multiple Platforms. https://pdfs.semanticscholar.org/53a9/b3a42614275908bc94ce746db8309192eaf1.pdf

[8] Caro, K. et al. 2014. Designing Exergames Combining the Use of Fine and Gross Motor Exercises to Support Self-care Activities. (2014), 247–248.

[9] Jain Mahesh C. 2009. *Engineering physics*. PHI Learning Pvt.

[10] Massachusetts institute of technology. 2015. Work and Kinetic Energy. http://web.mit.edu/8.01t/www/materials/modules/ReviewC.pdf

[11] National Joint Committee on Learning Disabilities 1991. Learning disabilities: Issues on definition. *Asha*. 33, Suppl. 5 (1991), 18–20. DOI= http://10.1044/policy.RP1991-00209.

[12] Stefano Piana, Alessandra Staglianò, Antonio Camurri, Francesca Odone. 2013. A set of Full-Body Movement Features for Emotion Recognition to Help Children affected by Autism Spectrum Condition. ftp://ftp.infomus.org/pub/Staff/AntonioCamurri/2013-IDGEI-ASC-INCLUSION-Full-BodyMovementForEmotionRecognitionToHelpAutisticChildren.pdf

[13] Vangos Pterneas. 2016. Measuring distances using Kinect – the right way.

[14] https://pterneas.com/2016/08/11/measuring-distances-kinect/

[15] A. S. Sabale and Y. M. Vaidya. 2016. Accuracy measurement of depth using Kinect sensor. in Conference on Advances in Signal Processing (CASP), Pune, 2016, pp. 155-159. doi: 10.1109/CASP.2016.7746156