Habilitation Aid for Children with Balance Disorders

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Abstract— **Gézengúz Foundation for Children with Birth Injuries offers a complex habilitation-rehabilitation therapy. The patented hemisphere-like tool, Huple®, can improve the balance ability of affected children. The reported research work focused not only on objectively and quantitatively assessing the balance ability but also increasing the devotion of children to take part actively in the habilitation. Based on a 3D accelerometer sensor children can control simple PC games with the hemisphere. This preoccupies them for quite a long time. Quantitative assessment of balance ability is based on the evaluation of the output signal of two sensors (one on the head and one on the Huple®). Inclination angle of the head to upright position of healthy subjects is close to zero even when tilting their trunk. For children with birth injuries this angle can be as high as 50 degrees.**

Keywords— **habilitation, balance ability, objective assessment, Huple.**

I. INTRODUCTION

Fig. 1 The Gézengúz hemisphere, Huple®.

The Gézengúz Foundation was established in 1990. The purpose of the foundation has been to provide early intervention and complex therapy to children with birth injuries. To aid the complex therapy for these children – and also to help healthy children improve their balance ability –, a special therapeutic tool, the Huple® (Figure 1) was developed and patented [1], [2], [3].

The hemisphere shaped tool helps instructors in playfully assessing and improving the balance ability of children. Sitting in the Huple® is a complex task requiring the coordinated movement of the trunk and muscles around the pelvic grindle. This task in itself has beneficial effect. Nevertheless, this is boring for the children. New games are needed to preoccupy them. If they can control PC games by moving the hemisphere (Figure 2) a new game can always attract them. This helps the habilitation process. Attaching a sensor to the head and one to the petal of the hemisphere makes possible to measure the tilting angle of the head as a function of the tilting angle of the tool.

Fig. 2 Controlling PC game by moving the Gézengúz hemisphere.

II. MATERIALS AND METHODS

A. The sensor hardware

The 3D acceleration sensor (MMA7260QT) was interfaced to the rapid prototyping environment (mitmót, [4]) of the Department of Measurement and Information Systems of Budapest University of Technology and Economics. A simple board (4 x 8cm) was assembled that is plugged into the connector of the mitmót mainboard. This made possible a short development time. The complete sensor together with the local processor and batteries weighs 150g. The full scale value of the sensor is programmable, ±1.5g, ±2g, ±4g or ±6g can be selected. During the research work full scale value was set to ±1.5g. This sensitivity was found to be sufficient both for using the sensor as an input device for PC games and for measuring the tilting angles. The resolution is 12 bit, the sampling frequency was set to 100Hz.

B. The model for using the sensor for control

For the habilitation very simple PC games are needed as most children concerned are below 6 years and have movement disorders. The 3D acceleration sensor was attached to the Huple® (see Figure 2), the movement of the object on the screen can be controlled by moving the hemisphere. There are three possibilities for control. The tilting angle can determine the ***position*** of the object. In this case measurement noise – even after low-pass filtering – causes annoying vibration of the object on the screen. The second possibility is to move the object on the screen ***as if a steel ball was moving on a tilted tray***. The third model is when the tilting angle determines the ***velocity*** of the object. All three possibilities were tested at the Gézengúz Foundation, and the third was found to fit best to the application.

C. Simple PC games for habilitation

The children participate in habilitation with pleasure if they have success experience. Therefore the operator can set the difficulty level of the games, even while the child is playing. The variable parameters are: the velocity of the moving object, the dependence of its speed on tilting angle, the size of the objects. The simplest game requires moving an object (a hedgehog) in one dimension, along a straight line. Apples are falling from trees along a line and the apples must be gathered by the hedgehog by moving it either to the left or to the right. The tilting angle of the sphere in the frontal plane determines the direction and the velocity of the hedgehog. The next game requires the movement of a hand in two dimensions, along the whole screen, see Fig. 3. Ladybirds are crawling along the screen and they should be caught by the hand. The tilting angle in the frontal as well as in the sagittal plane determines the position of the hand. Figure 2 shows a child playing with this game. There are eight ladybirds on the screen, the hand is actually in the middle.

Children can also control the PC games by moving their head when the sensor is attached to a helmet they are wearing.

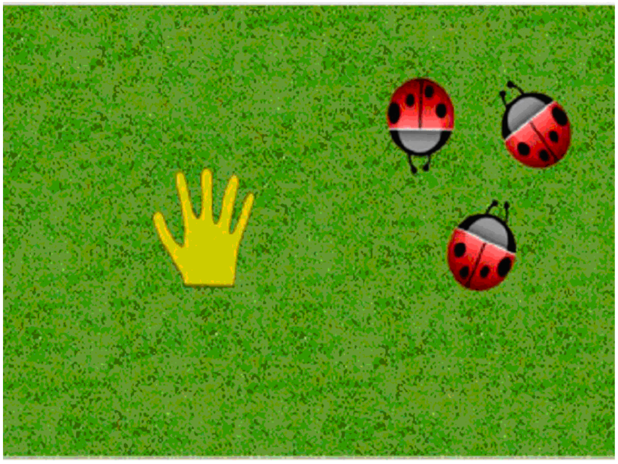

Fig. 3 Ladybirds are gathered by the hand. Objects are big enough not requiring too fine control.

III. MEASURING THE BALANCING ABILITY

A second sensor was embedded into a helmet. The helmet was covered with a textile mouse so that children do not object to wearing it. The output signals of the two sensors are collected while the Huple is tilted several times in both directions by the therapist. Subjects with healthy balancing ability hold their head in the upright position independent of the tilting angle of the hemisphere.

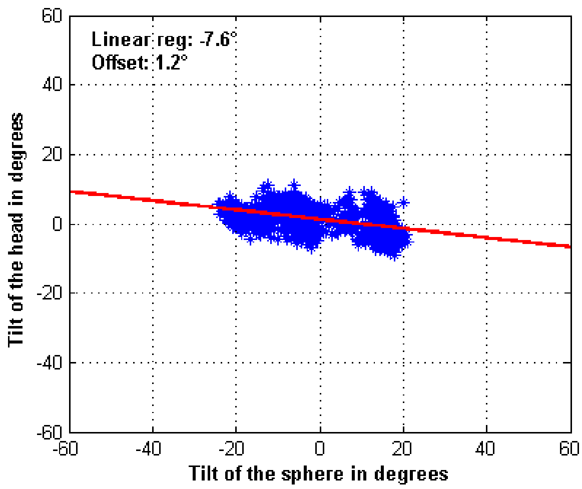

Fig. 4 Angle of the head and of the hemisphere, healthy subject.

Figure 4 shows the head angle versus tilting angle of the hemisphere for a young healthy adult (43 year old female). Less than 10 degrees is the maximum angle, when the hemisphere is tilted by 20 degrees. A slight overcompensation can be observed as well.

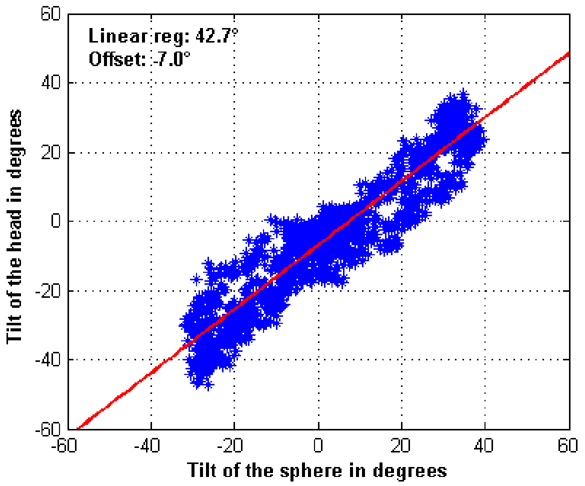

Fig. 5 Angle of the head and the hemisphere; child with balance disorders.

This is not the case for children with balance disorders. Figure 5 (10 year old male) shows that the head is practically moving together with the trunk, showing no activity of the vestibular compensation mechanism. The minimum recording time was 20s. The time function of the tilting angle during sitting in the Huple (healthy control subject, the sensor kept in hand) and the frequency spectrum corresponding to the marked part of the time function are given in Figure 6.

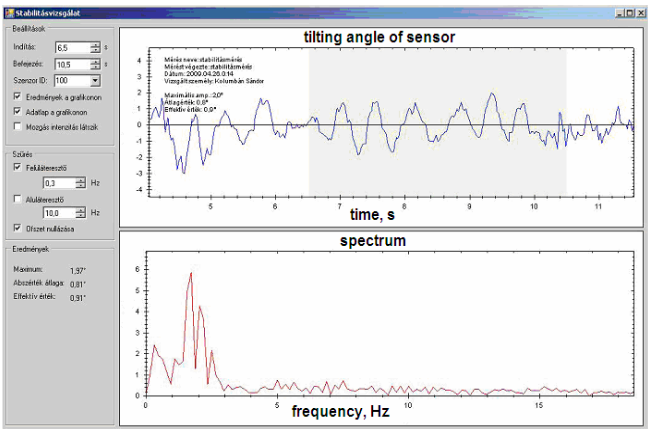

Fig. 6 The angle-time function (top) and its frequency spectrum (bottom) during balance measurement, the sensor is held by tested subject.

Balancing ability is characterized by three parameters. The simplest parameter is the maximum value of the tilting angle (after bandpass filtering), Θ_{max}, see Fig. 6. Usually, the smaller is the swaying of the subject sitting in the Huple, the smaller is the maximum tilting angle. Nevertheless, the maximum can derive from a single unskillful movement. Thus the mean value (I_{abs}) of the absolute value of the tilting angle - time function, $\Theta(t)$, over a given time interval (from T_0 to T_1) is a better estimate.

$$I_{abs} = \frac{1}{T_1 - T_0} \int_{T_0}^{T_1} \left| \Theta(t) \right| dt$$

The third possible parameter is the effective value (P) of the tilting angle – time function for the same (from T_0 to T_1) time interval.

$$P = \sqrt{\frac{1}{T_1 - T_0} \int_{T_0}^{T_1} \Theta^2(t) dt}$$

Θ_{max}, I_{abs}, and P are calculated after each test and displayed on the screen.

Balancing ability was tested under different circumstances. The simplest test is when the subject is sitting still in the Huple. Another test is when the subject is asked to stretch upwards for different objects (most frequently a plastic fruit) handed over by the physiotherapist. All these parameters have been found to be helpful during the habilitation process resulting in an objective assessment of the subjects' actual state.

Further testing situations can be easily realized using the above described measurement set-up. Neither the testing procedure nor the parameters to determine the subject's actual state are to be standardized before gathering measurement data from enough subjects at different habilitation centres.

IV. Conclusions

A simple sensor has been developed that greatly helps not only the quantitative assessment of the balancing ability but also the habilitation process. Children with birth injuries were found to be motivated and they played with pleasure when the level of the game was set to their ability. Further PC games can be offered that are controlled by the Huple®. Although the connection wire did not bother the children sensors using wireless transmission are under development. The wireless sensor together with the local processor and battery weighs only 24g. This will make the very effective everyday use, even at home, much simpler.

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