EVALUATION OF RECORDS OF CLICKABLE GAME FOR STRABISM RETRIEVAL

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Abstract

In this paper we would like to present our work in evaluation of simple clickable game used in retrieval and treatment of patients suffering from strabism. We processed raw records of games and extracted 12 features describing the game. We found 4 interesting relationships that prove that repeated playing of game in one day improves patient accuracy in aiming at points, but also decreases patient concentration measured by standard deviation of acceleration. We also found that patient improves his accuracy and concentration over longer periods of playing game which proves that the simple clicking game is beneficial for patients suffering from strabism.

Keywords

Signal processing, retrieval game, strabism.

Introduction

At present time the estimated ratio of people suffering from some type of strabism is 16%. The treatment of this disease is started by special examination and making a diagnosis. The diagnosis is followed by regular appointments at specialized medical doctor to control the treatment. During the treatment patients undergo a series of orthoptical and pleoptical exercises at specialized doctor. In between appointments the patient is fully responsible for doing of exercises but the doctor has no feedback of patient's treatment in his domestic environment. For that purpose was created a set of specialized exercises offered as web application. First benefit of this web application is the creation of a set of rehabilitation games which are reachable from patient's home and allow him to exercise in between regular appointments at specialized doctor. Second benefit lies in the adaptive nature of games which takes patient's skill into account and sets up difficulty of the exercise according to it. All the results of games played by patient are logged and provided to the doctor to have a feedback of patient treatment. Records of games played at home can be compared to objective measurements at an appointment. [1]

The use of simple clickable games is very successful in the rehabilitation of patients suffering from strabism especially children. These simple games provide powerful training of eye moving muscles. Regular training helps to compensate eye moving muscles' defects and weaknesses. The main benefit of this way of retrieval lies in the nature of the training which is based on the game principle. That is why patients are better motivated and thus the retrieval is quicker and more efficient. In addition the game principle is attractive for children patients and facilitates the compensation of eye moving muscles in early age. In our work we analyzed records of game developed in our department and successfully used in a 15 of retrieval clinics. We chose the most popular game according to patients suffering from strabism preferences and analyzed it. The process of game is following: playing the game a set of points is sequentially shown to patient who has to move the mouse cursor to the location of the point shown and click as close to the point shown as he can. The points are visualized on the screen in the way to maximize the moves of eye moving muscles to practice them. During the game all the mouse moves are recorded and stored for further analysis.

Objectives

In our paper we would like to propose a simple methodology for extracting features describing the current state of patient's rehabilitation from records of games played for a long period. We would like to show a trend in extracted features that show the game is beneficial to patients suffering from strabism and that there exist some relationship between the number games that had been played and the success rate in game, so that the more patient plays a certain game the more accurate he is and consequently his eye moving muscles are better trained and the retrieval is better also.

Methods

Data preparation

We had got records from games of 11 patients over various time periods. The original data contained coordinates of all the points shown to patient, the coordinates of all patient responses (mouse clicks), recorded trajectory of patient's mouse move between points and identification of patient and time specification. As the original data format was not appropriate for following analyses we decided to transform data. We projected the record of patient mouse move on the shortest path defined by the points sequentially introduced to patient. The projection served to decrease the complexity of recorded mouse moves data and as a transformation of mouse moves records that allowed us to use standard time series methods on the data. From projected mouse moves we extracted twelve features, namely the mean of projected moves, the median of projected moves, the standard deviation of projected moves, maximum and minimum of projected moves, the standard deviation of acceleration of projected moves, the maximum and minimum of acceleration of projected moves, the accuracy in aiming to introduced points, the distance between points shown to patient during the game, the distance of patient's trajectory between points and the ratio of patient's trajectory length to the ideal trajectory between points. All the features were computed using standard statistical procedures. The acceleration of mouse move was approximated using discrete difference and the feature accuracy was obtained as mean value of distances between points shown to the patient and his response.

Data exploration

From extracted features we formed standard data table. We had got 890 observations of 15 variables. Extracted features were described in previous paragraph and these 12 do not need any further description. We added variables *id* which is the identification of patient, variable *day* which refers to a day from the beginning of playing rehabilitation game and variable *ind* which identifies the game in one day. According to observed data we found out that 11 patients in our analysis played 4 instances of game in a day. Most of the patients did not play retrieval game every day, but played on the weekly basis. We did not observe any missing value in the data table, but there were a few outlying values. We decided to remove 5% of data according to distribution of accuracy variable, which seemed to us as the best measure to detect outlying value. We removed 45 instances of data where the value of accuracy variable was greater than 16.6. These instances of data correspond to games where the patient did not any response or clicked chaotically with no effort to aim at points shown. A sample of outlier game is shown in Figure 1 and 2.

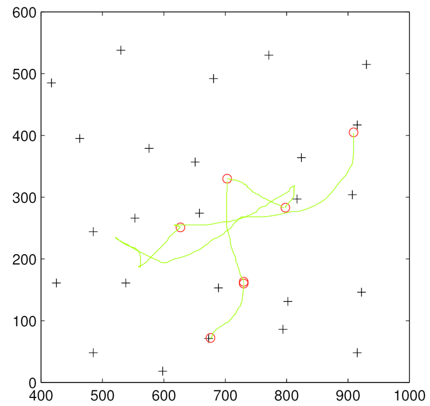

Figure 1: A game where patient did not any response to points shown to him. Such a game produces outlying values in processed data.

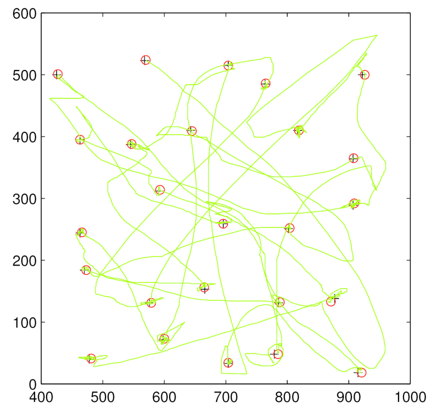

Figure 2: A successful game. Compare to outlier game in Figure 1.

Data modeling

Following preceding study about this simple clickable game we tried to find periodical changes in patient’s performance. Due to nonregular playing these analyses are not trustworthy and we can only report that this behavior was observed in a few of patients who played at the daily basis.

During the exploratory analysis we observed all the extracted features except variables like patient identification, day and number of game in a day, need to be logarithmically transformed before modeling. We also found that most of the variables are highly correlated (values of Pearson correlation coefficient greater that 0.5) and that is why we decided to use only variables accuracy, average of mouse move, standard deviation of mouse move and standard deviation of acceleration. We chose these variables because of they are prospective in future evaluation of retrieval games or can easily explained and interpreted. Based on the exploratory analysis we found a few relationships that we modeled using linear regression. The parameters of linear models were estimated using ordinary least squares. [3] Two interesting relationships are visualized in Figure 3 and 4.

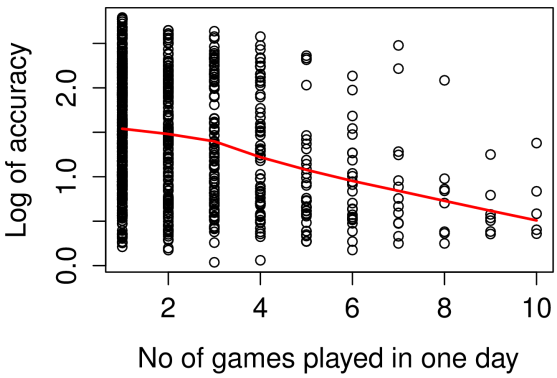

Figure 3: The dependency of accuracy on number of games played in one day with lowess estimate of dependency [4].

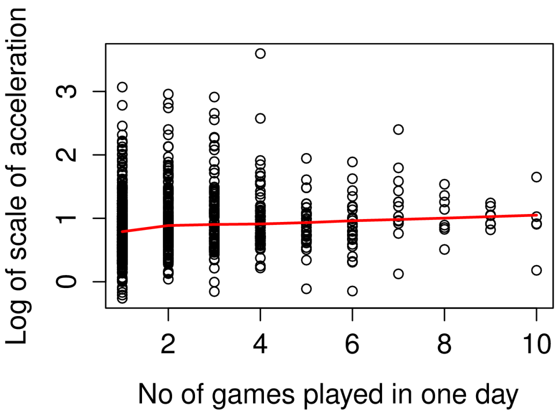

Figure 4: The relationship between standard deviation of acceleration and number of games played in one day with lowess estimate of dependency [4].

Results

Trying to describe relationships observed during the exploratory analysis we fitted 4 models. First two of models show the effect of repeated playing game. We created model, which can be described by following equation:

Log(accuracy) = $\boldsymbol{\beta_0}$
+ $\boldsymbol{\beta_1}$***·no of game played in one day +*** $\boldsymbol{\varepsilon}$

We estimated the values of β_0 to be 1.67 and β_1 to be equal to – 0.1, the p values of both coefficients is approximately 0. This relation can be interpreted as if patient plays a few games sequentially his logarithm of accuracy will be reduced by 0.1 with every new game. Please note that the accuracy measure is in negative relation with actual skill. The lower the value of accuracy is the better is patient in playing the game. And according to this model the patient is better in playing the game with every new try.

Opposite to the first relation, we found by means of linear regression:

Log(standard deviation of acceleration) = $\boldsymbol{\beta_0}$
+ $\boldsymbol{\beta_1}$***·no of game played in one day +*** $\boldsymbol{\varepsilon}$

We estimated the values of β_0 to be 0.85 and β_1 to be equal to 0.02, the p values of intercept is approximately 0, the p value of β_1 coefficient is $3.64 \cdot 10^{-3}$. This relationship means that the patient will have the value of standard deviation of acceleration increased by 0.02 with every new game played. This relation can be interpreted as increase in mouse moves. With every new game the patient plays probably more sure and thus quickly. The moves of mouse cursor are bigger and the standard deviation rises.

Second two models we fitted follow up the effect of playing the game in longer period. First we found that the playing of the game in longer period increases patient skill in playing game. This relationship in form of equation is following:

Log(accuracy) = $\boldsymbol{\beta_0}$ ***+*** $\boldsymbol{\beta_1}$***·no of day played + patient skill +*** $\boldsymbol{\varepsilon}$

The estimated value of the coefficient β_1 is – 0.004 with p value $8.4 \cdot 10_{-7}$, the estimates of β_0 and patient skill will not be reported. The coefficient β_0 is a level of skill of patient 1 at the beginning of playing the game, the *patient skill* term refers to set of levels of patients' skills at the beginning of playing the game. The role of these parameters in the model is just a correction of patient ability to play and is not in our interest. The interpretation of the model is that with every day played the game the accuracy of patient will be decreased by 0,004. This means that the longer patient plays the game the better he is in playing the game.

And finally the model:

Log(standard deviation of acceleration) = $\boldsymbol{\beta_0}$ ***+*** $\boldsymbol{\beta_1}$***·no of day played + patient skill +*** $\boldsymbol{\varepsilon}$

In the same fashion as at the previous model the estimated value of coefficient β_1 is – 0.006 with p value $1.22 \cdot 10^{-10}$ and other values will not be reported. Similarly to the previous model the standard deviation of acceleration is subtracted by - 0.006 with every day played the game. It means that patient is during the playing of the game more sure and accurate the longer he plays.

As the values of slopes in last two models may seem to be very small, imagine that a day of playing game patient decrease his accuracy by 0.004 in logarithm of accuracy, that is a decrease of 0.028 in a week and 0.124 in a month of playing. Comparing this to the distribution of logarithm of accuracy values which first quartile is 0.77, the median is 1.3 and the third quartile is 1.99, the decrease is maybe slow, but the effects over long period of time are big. The gain in standard deviation of acceleration is even bigger, it is 0.006 in one day, 0.042 in one week and 0.186 in one month compared to first quartile 0.6, median 0.88 and third quartile 1.1690 in observed standard deviation of acceleration.

Conclusion

In our work we showed that the simple clickable game helps to patients suffering from strabism. We proposed methodology to preprocess a raw game record and extract useful features. Our results show that patients improved their abilities playing the game and effectively did their retrieval. We found out that the change in training rate measured in accuracy is the same for all the patients, patients improve their accuracy with every game played. The improvement in repeated playing in one day is 0.1 in accuracy with every game played, but the measure of patient's concentration the standard deviation of acceleration decreases by 0.02 with every game played in one day. In longer time period patients improve their abilities by 0.004 with every day played in accuracy and also the concentration measured using standard deviation of acceleration improves by 0.006 with every game played.

Our results show that our methodology is very powerful in evaluation of simple mouse (finger) tracking games used in patient rehabilitation. Because the methodology is portable and could be used in various problem statements we hope that our approach could serve to join the evaluation of various retrieval tasks and facilitate framework for complete evaluation of current state of patient rehabilitation using simple games.

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