Short Proposal: exploring pattern recognition techniques for quantifying balance ability during exergaming

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1 Introduction/Background

Fall incidents are a major cause of disability and loss of independence in the elderly population. Impaired postural control, generally defined as the ability to maintain, achieve, or restore a state of balance during any posture or activity, is one of the main predictors for falls[1]. Postural control however can be improved through training programs, thereby indeed reducing fall incidence. The therapy adherence of these training programs however is low. In the project ‘Exergaming for balance training in elderly’ it is aimed to develop an exergame (exercise + game) that enables elderly to train balance at home. To optimally adapt the game to the individual user, it is aimed to measure balance ability during gameplay and use this information to influence gameplay and provide adequate feedback to the user. In a previous stage in the project several parameters were defined for quantifying balance ability based on movements made during gameplay (of which the objective was to control an ice-skater by shifting body weight in the frontal plane) including sway amplitude, sway frequency, sample entropy and index of harmonicity[2, 3].

Now as a next step more parameters for balance assessment are to be found using data-driven methods. An experiment where young and older adults played an exergame requiring them to perform task-embedded balance exercises while movements were captured using a 3D motion capture camera system, Kinect, force plates and an accelerometer was conducted. It is hypothesized that age-related deterioration of balance ability is reflected in movements performed during gameplay.

Goal

The aim of the current proposal is to identify parameters/features/algorithms that enable quantification of balance ability based on movement data that is acquired during exergaming. It is proposed to adopt pattern recognition techniques to analyze multivariate movement data from young and older adults and find parameters that can differentiate between young and older adults. The analysis should result in new parameters/features that identify balance ability.

The current document serves as a start of a discussion resulting in an approach for reaching the goals described above. It is still a concept and hold ideas and proposed approaches, open for discussion.

2 The available data

Subjects and methods

20 young adults (37.0 ± 16 yrs) and 20 older adults (71.8 ± 4 yrs) played an ice-skating exergame challenging them to shift body weight in the frontal plane. The avatar in the game was controlled by making sway movements with shoulders and hips in both lateral directions while keeping the feet at the same place at self-selected sway speed and sway amplitude. De ice skating track consisted of a straight track which took about 1 minute to complete. Increasing sway amplitude and/or sway frequency increased the speed of the avatar.

Measurements were conducted in the UMCG Computer Assisted Rehabilitation ENvironment (CAREN) lab. Before the elderly participants played the game the Narrow Ridge Balance Test was performed; a clinically valid balance test resulting in a score consisting of 2 numbers[4]. Furthermore all participants were asked to stand as still as possible for 30 seconds with eyes open and with eyes closed. From this test sway parameters can be calculated that have shown to correlate with fall risk[5].
During the experiments 10 trials of approximately one minute were played. Trials were played under different conditions (exergame settings challenging a participant to adopt certain behavior). Five conditions were applied and each condition was tested twice (hence 10 trials per participant). Thus in total 400 time series of 60 seconds are available for analysis.

Data and equipment

- During Gameplay
  - Position data of 15 anatomical landmarks acquired at ~30Hz using the Microsoft Kinect
  - 3D position data of 15 reflective markers positioned on the torso and extremities (fig1) acquired at irregular sample frequency of ~170 Hz (synchronized with force plates) using a 12-camera Vicon V8 system.
  - Force plate data: ground reaction forces and moments measured for each foot individually using 2 Bertec forceplates at irregular sample frequentie of ~170Hz. Center of Pressure data can be computed from this data.
  - Acceleration data (x/y/z) and orientation @100Hz using a Dynaport minimod inertia sensor

- Narrow Ridge Balance Test (only elderly)
  - Score consisting of two numbers.

- 30 seconds standstill
  - Force plate data: as described above
  - 3D position data of 15 reflective markers: as described above

Figure 1: Left: A young adult playing the exergame. Right: stick figure representing Kinect data. Marker trajectories captured during exergaming are represented by colored lines.
3 Approach

Data selection and grouping

The total data set is large and for defining a strategy for data analysis several fundamental choices need to be made: which sensor data exactly is used for defining the parameters/developing the algorithms and what ‘kind’ of data analysis approach is used. It is proposed to start the analysis using only Kinect data, find parameters and use the other instruments for validation. This approach holds the advantage that the parameters found will be rather robust, because limitations posed by Kinect are already included. Secondly Kinect will be used further on up the project and is aimed to be used in the second round of experiments performed in the home environment of elderly. Therefore, to directly develop algorithms for Kinect is a more efficient approach compared to starting with Vicon data and try to make the algorithms suitable for Kinect in a later stage.

The proposed approach therefore is to only use Kinect data in the current analysis and when parameters are found, the data captured by other instruments (Vicon, Force plate and accelerometer) can be used later for validation.

Quantifying balance ability

Parameters able to differentiate between young and older adults should provide insight in balance ability over the course of different timescales; days and weeks (to monitor progression) but also ‘online’ (=during gameplay), to adapt the game difficulty during gameplay. This last time scale is obviously the more challenging; it would require a measure for ‘balancedness’ and changes therein over Δt.

It is proposed to start at a basic level: provide all Kinect data (400 time series*15 anatomical landmarks) with a label ‘old’ or ‘young’ and adopt (unsupervised?) pattern recognition methods for identifying differences. The labels ‘old’ and ‘young’ were chosen because it is assumed that young adults have better postural control than old adults. No knowledge about movement coordination is included in the analysis at this point to keep the analysis as ‘open’ as possible. This stage should yield parameters able to differentiate between young and old. In the previous study (comparing Kinect with Vicon data) Principal component analysis was used, but other unsupervised methods needs to be explored. The unsupervised pattern recognition methods to be used exactly are to be defined.

In a second stage the parameters found can be compared with the parameters defined based on knowledge about movement coordination or parameters described in literature already using for instance a cluster analysis. In a third stage a new series of experiments where elderly use the game for 6 weeks will be conducted to test the sensitivity of the parameters defined for change within individuals.

4 Plan of action

Techniques/knowledge available

- Octave/Matlab
- Dimensionality reduction (Principal Component Analysis)
- Statistics
- Interpretation Postural control/balance ability/anatomy/balancing strategies

Techniques/knowledge required

- Machine learning
  - Unsupervised learning (only clustering or is there more?)
Supervised learning (labels ‘old’ and ‘young’)
- Anomaly detection
- Visualization techniques

Concluding
In the current document a general approach for analyzing the dataset presented was proposed and information about the dataset and the goals that are to be achieved in the analysis was provided. The document serves as input for a discussion about what techniques exactly can be used to differentiate between young and older adults during exergaming and ultimately find parameters/develop algorithms for quantifying balance ability.


3. Lamoth CJC, van Heuvelen MJG: Sports activities are reflected in the local stability and regularity of body sway: Older ice-skaters have better postural control than inactive elderly. Gait Posture 2011, 35:489–93.
