Claims:

1. A compensation-aware rehabilitation system for assisting psychomotor training of an individual with movement disabilities comprising:

a processing unit having a processor and a memory;

a gesture-based camera;

a haptic device;

a display; and

instructions store on said memory executed by said processor to:

provide a calibration procedure;

initiate a game session comprising:

initiate a game task comprising:

capture motion data of said individual via said gesture-based camera, wherein said motion data comprises orientation and position of seven joints of said individual;

determine a compensatory motion of said individual comprising:

determine angle differences between each of said seven joints in motion data with respective joints in said determined best match motion data;

normalise each of said determined differences to a value between 0 and 1 comprising:

assign said value of said difference as 1 in response to said angle difference being more than 60 degrees;

assign said value of said difference as 0 in response to said angle difference being 0; and

determine said value with the following expression in response to said angle difference being between 0 and 60 degrees,

$$V = 1 - (60 - A) / 100$$

where A is the angle difference between two orientations, and V is the value of difference;

determine total differences of all seven joints;

compare said total differences with a predetermined threshold; and

determine a compensatory motion in response to said total difference being more than said predetermined threshold,

determine a compensation strategy based on said determined compensatory motion of said individual,

adjust a next game task according to said determined compensation strategy,

record a performance of said individual in said memory;

determine whether said game session has completed,

repeat said instruction to initiate said game task for next game task in response to said game session has not been completed,

display said performance of said individual on said display in response to said completion of said game session.

2. The system according to claim 1 wherein said instruction to record a performance of said individual comprises instructions to:

record a hand trajectory captured by said gesture-based camera.

~~3. The system according to claim 1 wherein said motion data comprises orientation and position of seven joints of said individual.~~

34. The system according to claim 1 wherein said instruction to provide a calibration procedure comprises instructions to:

display a posture sample stored on said memory of said processing unit;

obtain motion data of individual from said gesture-based camera; and

determine a best match motion data.

45. The system according to claim 34 wherein said instruction to determine said best match comprises instructions to:

retrieve a standard motion data from said memory;

compare each of said motion data of said individual with said standard motion data; and

determine said best match motion data based on one said motion data of said individual being the closest to said standard motion data.

~~6. The system according to claim 5 wherein said motion data comprises orientation and position of seven joints of said individual.~~

~~7. The system according to claim 6 wherein said instruction to determine a compensatory motion of said individual comprises instructions to:~~

~~determine angle differences between each of said seven joints in motion data with respective joints in said determined best match motion data;~~

~~normalise each of said determined differences to a value between 0 and 1;~~

~~determine total differences of all seven joints;~~

~~compare said total differences with a predetermined threshold; and~~

~~determine a compensatory motion in response to said total difference being more than said predetermined threshold.~~

58. The system according to claim 17 wherein said instruction to determine angle differences between each of said seven joints in motion data with respective joints in said determined best match motion data comprises instructions to:

determine each of said angle differences, A, between each of said seven joints in motion data with respective joints in said determined best match motion data with the following expression,

$$A = \text{acos}\ (P_x \times S_x + P_y \times S_y + P_z \times S_z)$$

where P is the individual's joint orientation defined along x, y, z dimensions as Px, Py, Pz, and S is the best-matched joint orientation defined along x, y, z dimensions as Sx, Sy, Sz.

~~9. The system according to claim 7 wherein said instruction to normalise each of said determined differences to said value between 0 and 1 comprises instructions to:~~

~~assign said value of said difference as 1 in response to said angle difference being more than 60 degrees;~~

~~assign said value of said difference as 0 in response to said angle difference being 0; and~~

~~determine said value with the following expression in response to said angle difference being between 0 and 60 degrees,~~

~~$V = 1 - (60 - A) / 100$~~

~~where A is the angle difference between two orientations, and V is the value of difference.~~

6~~10~~. The system according to claim 1~~9~~ wherein said instruction to determine total differences of all seven joints comprises instructions to:

determine total differences, Vt, of all seven joints with the following expression,

$$Vt = V_1 \times 40\% + (V_2 + V_3) \times 30\% + (V_4 + V_5) \times 20\% + (V_6 + V_7) \times 10\%$$

where V1 is the orientation difference value of Shoulder Centre; V2 and V3 are the orientation difference value of left and right shoulder, respectively; V4 and V5 are the orientation difference value of left and right elbow, respectively; and V6 and V7 are the orientation difference value of left and right wrist, respectively.

7~~11~~. The system according to claim 6~~10~~ wherein said instruction to determine a compensation strategy comprises instructions to:

read the difference of shoulder centre;

compare said angle difference of said shoulder centre with a predetermined threshold;

determine a forward orientation, PF, in response to said difference of shoulder centre being above said predetermined threshold;

determine forward orientation, SF, during calibration procedure;

determine and normalise angle difference of PF and SF;

compare said difference of PF and SF with a predetermined threshold;

determine trunk rotation in response to said difference of PF and SF being above said predetermined threshold.

8~~12~~. The system according to claim 7~~11~~ wherein said forward orientation, PF, is determined with the following expression,

$$PF = (L_2\text{-}L_1) \times (L_3 - L_1)$$

where L1 is the position of Shoulder Centre; L2 is the position of Left Shoulder; L3 is the position of Right Shoulder; and × is a cross operation between two vectors.

9~~13~~. The system according to claim 8~~12~~ wherein said forward orientation, SF, is determined with the following expression,

$$SF = (T_2\text{-}T_1) \times (T_3 - T_1)$$

where T1 is the position of Shoulder Centre; T2 is the position of Left Shoulder; T3 is the position of Right Shoulder; and × is a cross operation between two vectors.

10~~14~~. The system according to claim 9~~13~~ wherein said angle difference of PF and SF is determined with the following expression,

$$A = \text{acos}\ (PF_x \times SF_x + PF_y \times SF_y + PF_z \times SF_z)$$

where PF is the individual's forward orientation defined along x, y, z dimensions as PFx, PFy, PFz, respectively, and SF is the best-matched forward orientation defined along x, y, z dimensions as SFx, SFy, SFz, respectively.

11~~15~~. The system according to claim 10~~14~~ wherein said instruction to normalise said angle difference of PF and SF comprises instructions to

assign said value of said angle difference as 1 in response to said angle difference being more than 60 degrees;

assign said value of said angle difference as 0 in response to said angle difference being 0; and

determine said value with the following expression in response to said angle difference being between 0 and 60 degrees,

$$V = 1 - (60 - A) / 100$$

where A is the angle difference between PF and SF, V is the value of difference.

1216. The system according to claim 1115 wherein said instructions to determine a compensation strategy further comprises instructions to:

determine position difference of shoulder centre in response to said difference of shoulder centre being below said predetermined threshold;

compare said position difference of shoulder centre with a predetermined threshold, said predetermined threshold being half of shoulder width; and

determine trunk lean in response to said position difference being more than said predetermined threshold.

1317. The system according to claim 1216 wherein said position difference of shoulder centre is determined with the following expression,

$$SCD = | L_1 - T_1 |$$

where SCD is the distance between two Shoulder Centre positions; L1 is the position of Shoulder Centre captured by said gesture-based camera; T1 is the position of Shoulder Centre collected in calibration procedure; and | | is Absolute operation on one vector.

1418. The system according to claim 1317 wherein said instruction to determine a compensation strategy further comprises instructions to:

determine three distances values between unaffected wrist joint and the affected upper limb in response to said difference of shoulder centre being below said predetermined threshold;

compare said three distances values with a predetermined threshold; and

determine limb support in response to said three distances values being less than said predetermined threshold.

1519. The system according to claim 1418 wherein said instruction to determine three distances values between unaffected (left) wrist joint and the affected (right) upper limb in response to said difference of shoulder centre being below said predetermined threshold comprises instructions to:

determine a first distance between left and right wrist of said individual,

determine a second distance between left wrist and right elbow of said individual; and

determine a third distance between left wrist and right shoulder of said individual.

1620. A method for assisting psychomotor training of an individual with movement disabilities, said method comprising:

providing a calibration procedure;

initiating a game session comprising:

initiating a game task comprising:

capturing motion data of said individual via said gesture-based camera, wherein said motion data comprises orientation and position of seven joints of said individual

determining a compensatory motion of said individual comprising:

determining angle differences between each of said seven joints in motion data with respective joints in said determined best match motion data;

normalising each of said determined differences to a value between 0 and 1 comprising:

assigning said value of said difference as 1 in response to said angle difference being more than 60 degrees;

assigning said value of said difference as 0 in response to said angle difference being 0; and

determining said value with the following expression in response to said angle difference being between 0 and 60 degrees,

$V_i = 1 - (60 - A_i) / 100$

where Ai is the angle difference between two orientations, Vi is the value of difference and i= 1 to 7;

determining total differences of all seven joints;

comparing said total differences with a predetermined threshold; and

determining a compensatory motion in response to said total difference being more than said predetermined threshold,

determining a compensation strategy based on said determined compensatory motion of said individual,

adjusting a next game task according to said determined compensation strategy,

recording a performance of said individual in said memory;

determining whether said game session has completed,

repeating said step to initiate said game task for next game task in response to said game session has not been completed,

displaying said performance of said individual on a display in response to said completion of said game session.

17~~21~~. The method according to claim 16~~20~~ wherein said step of recording a performance of said individual comprises:

recording a hand trajectory captured by said gesture-based camera.

~~22. The method according to claim 20 wherein said motion data comprises orientation and position of seven joints of said individual.~~

1823. The method according to claim 1620 wherein said step of providing a calibration procedure comprises:

displaying a posture sample stored on said memory of said processing unit;

obtaining motion data of said individual from said gesture-based camera; and

determining a best match motion data.

1924. The method according to claim 1823 wherein said step of determining said best match comprises:

retrieving a standard motion data from said memory;

comparing each of said motion data of said individual with said standard motion data; and

determining said best match motion data based on one said motion data of said individual being the closest to said standard motion data.

~~25. The method according to claim 24 wherein said motion data comprises orientation and position of seven joints of said individual.~~

~~26. The method according to claim 25 wherein said step of determining a compensatory motion of said individual comprises:~~

~~determining angle differences between each of said seven joints in motion data with respective joints in said determined best match motion data;~~

~~normalising each of said determined differences to a value between 0 and 1;~~

~~determining total differences of all seven joints;~~

~~comparing said total differences with a predetermined threshold; and~~

~~determining a compensatory motion in response to said total difference being more than said predetermined threshold.~~

2027~~7~~. The method according to claim 1626~~6~~ wherein said step of determining angle differences between each of said seven joints in motion data with respective joints in said determined best match motion data comprises:

determining each of said angle differences, A, between each of said seven joints in motion data with respective joints in said determined best match motion data with the following expression,

$$A = \text{acos}\,(P_x \times S_x + P_y \times S_y + P_z \times S_z)$$

where P is the individual's joint orientation defined along x, y, z dimensions as Px, Py, Pz, and S is the best-matched joint orientation defined along x, y, z dimensions as Sx, Sy, Sz.

~~28. The method according to claim 27 wherein said step of normalising each of said determined differences to said value between 0 and 1 comprises:~~

~~assigning said value of said difference as 1 in response to said angle difference being more than 60 degrees;~~

~~assigning said value of said difference as 0 in response to said angle difference being 0; and~~

~~determining said value with the following expression in response to said angle difference being between 0 and 60 degrees,~~

$$V_i = 1 - (60 - A_i) / 100$$

~~where Ai is the angle difference between two orientations, Vi is the value of difference and i= 1 to 7.~~

2129. The method according to claim 2028 wherein said step of determining total differences of all seven joints comprises:

determining total differences, Vt, of all seven joints with the following expression,

$$Vt = V_1 \times 40\% + (V_2 + V_3) \times 30\% + (V_4 + V_5) \times 20\% + (V_6 + V_7) \times 10\%$$

where V1 is the orientation difference value of Shoulder Centre; V2 and V3 are the orientation difference value of left and right shoulder, respectively; V4 and V5 are the orientation difference value of left and right elbow, respectively; and V6 and V7 are the orientation difference value of left and right wrist, respectively.

2230. The method according to claim 2129 wherein said step of determining a compensation strategy comprises:

reading the difference of shoulder centre;

comparing said angle difference of said shoulder centre with a predetermined threshold;

determining a forward orientation, PF, in response to said difference of shoulder centre being above said predetermined threshold;

determining forward orientation, SF, during calibration procedure;

determining and normalising angle difference of PF and SF;

comparing said difference of PF and SF with a predetermined threshold;

determining trunk rotation in response to said difference of PF and SF being above said predetermined threshold.

2331. The method according to claim 2230 wherein said forward orientation, PF, is determined with the following expression,

$$PF = (L_2\text{-}L_1) \times (L_3 - L_1)$$

where L1 is the position of Shoulder Centre; L2 is the position of Left Shoulder; L3 is the position of Right Shoulder; and × is a cross operation between two vectors.

2432. The method according to claim 2331 wherein said forward orientation, SF, is determined with the following expression,

$$SF = (T_2\text{-}T_1) \times (T_3 - T_1)$$

where T1 is the position of Shoulder Centre; T2 is the position of Left Shoulder; T3 is the position of Right Shoulder; and × is a cross operation between two vectors.

2533. The method according to claim 2413 wherein said angle difference of PF and SF is determined with the following expression,

$$A = \text{acos}\ (PF_x \times SF_x + PF_y \times SF_y + PF_z \times SF_z)$$

where PF is the individual's forward orientation defined along x, y, z dimensions as PFx, PFy, PFz, respectively, and SF is the best-matched forward orientation defined along x, y, z dimensions as SFx, SFy, SFz, respectively.

2634. The method according to claim 2533 wherein said step of normalising said angle difference of PF and SF comprises:

assigning said value of said angle difference as 1 in response to said angle difference being more than 60 degrees;

assigning said value of said angle difference as 0 in response to said angle difference being 0; and

determining said value with the following expression in response to said angle difference being between 0 and 60 degrees,

$$V = 1 - (60 - A) / 100$$

where A is the angle difference between PF and SF, V is the value of difference.

2735. The method according to claim 2634 wherein said step of determining a compensation strategy further comprises:

determining position difference of shoulder centre in response to said difference of shoulder centre being below said predetermined threshold;

comparing said position difference of shoulder centre with a predetermined threshold, said predetermined threshold being half of shoulder width; and

determining trunk lean in response to said position difference being more than said predetermined threshold.

2836. The method according to claim 2735 wherein said position difference of shoulder centre is determined with the following expression,

$$SCD = | L_1 - T_1 |$$

where SCD is the distance between two Shoulder Centre positions; L1 is the position of Shoulder Centre captured by said gesture-based camera; T1 is the position of Shoulder Centre collected in calibration procedure; and | | is Absolute operation on one vector.

2937. The method according to claim 2836 wherein said step of determining a compensation strategy further comprises:

determining three distances values between unaffected wrist joint and the affected upper limb in response to said difference of shoulder centre being below said predetermined threshold;

comparing said three distances values with a predetermined threshold; and

determining limb support in response to said three distances values being less than said predetermined threshold.

3038. The method according to claim 2937 wherein said step of determining three distances values between unaffected (left) wrist joint and the affected upper limb in response to said difference of shoulder centre being below said predetermined threshold comprises:

determining a first distance between left and right wrist of said individual,

determining a second distance between left wrist and right elbow of said individual; and

determining a third distance between left wrist and right shoulder of said individual.