CLAIMS

1. A rehabilitation human-machine interaction apparatus for upper body movement, the apparatus comprising:

a H-shaped cable-driven mechanism comprising only one cable;

two motors for driving the H-shaped cable-driven mechanism, a driving pulley coupled to each motor;

a plurality of guides arranged along the x and y axes; and

a manipulandum coupled to the H-shaped cable-driven mechanism for independent movement along x and y axes, wherein the manipulandum includes:

a horizontal carriage;

a solid base mounted to the horizontal carriage;

a six degree of freedom force/torque sensor mounted to the solid base;

a plurality of idler pulleys; and

a plurality of vertical carriages;

characterized in that

four force channels are available, horizontal and vertical channels being passively obtained by providing mechanical stops on the vertical and horizontal carriages respectively to mechanically block the vertical and horizontal carriages respectively, and 45° channels being passively obtained by providing mechanical stops on one of the driving pulleys to block the driving pulley.

2. The apparatus of claim 1, wherein the H-shaped mechanism is configured in a form of a differential mechanism such that a user holding the manipulandum experiences low inertia.

3. The apparatus of claim 1, wherein the manipulandum further includes a handle.

4. The apparatus of claim 3, wherein the handle is a separate part of the manipulandum.

5. The apparatus of claim 1, wherein the cable is wound at least four turns around the driving pulley coupled to each motor.

6. The apparatus of claim 1, wherein the two motors are controlled by a motor driver.

7. The apparatus of claim 1, wherein a driving force of the two DC motors is determined by a position of the manipulandum.

8. The apparatus of claim 7, wherein the driving force of the two DC motors is determined using the following equations:

$$\begin{bmatrix} i_L \\ i_R \end{bmatrix} = K_i A^{-1} \left(\alpha B_c + \beta B_d\right) \left(A^{-1}\right)^T \begin{bmatrix} \omega_L \\ \omega_R \end{bmatrix}$$ and

$$\begin{bmatrix} V_L \\ V_R \end{bmatrix} = \begin{bmatrix} R_L & 0 \\ 0 & R_R \end{bmatrix} \begin{bmatrix} i_L \\ i_R \end{bmatrix} + \begin{bmatrix} K_{e,L} & 0 \\ 0 & K_{e,R} \end{bmatrix} \begin{bmatrix} \omega_L \\ \omega_R \end{bmatrix}.$$

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9. The apparatus of claim 1, wherein the motor is of a type selected from a group consisting of: DC motor, AC motor, magnetic linear actuator, and pneumatic linear actuator.