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(54) **System and method for rehabilitation**

System und Verfahren zur Rehabilitierung

Système et procédé de réhabilitation

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EP 2 067 462 B1

Description

[0001] The invention relates to a system for rehabilitation with a linkage that can be applied to the body of a human being according to the preamble of claim 1.

[0002] Rehabilitation through therapeutic exercises is employed among other things with damages of the brain which can be of traumatic origin, have another cause (bleeding, infections or similar) and can cause a comatose state or sensor-motoric disorders which result in a disability. More preferably in the latter case it can be attempted through training of the brain to heal the disability or alleviate its effects. The present invention however is not restricted to this particularly preferred area of application but can always be employed in a supportive manner with any therapeutic exercises.

[0003] Today, such therapeutic exercises are usually conducted by a trained therapist who sets the sequence of movements for the patient to emulate. Alternatively the therapist himself/herself moves certain parts of the body, for example arms or legs of the patient in order to execute the desired sequence of movements with the patient, provided said patient is not independently capable of doing so.

[0004] In addition, training devices that can be employed for rehabilitation are also known which permit a limited number of certain sequences of movements which the patient has to repeatedly execute against an adjustable resistance if applicable.

[0005] These systems have the disadvantage that they usually permit only one or a few selected sequences of movements and provide no possibilities of detection as to the quality in which the set movements are executed.

[0006] The US 2004/0102723 A1 describes a method for controlling movement using a device including an actuator, joint position sensor, muscle stress sensor and control system. The device provides muscle and joint support and is designed for operation in several modes to provide either assistance or resistance to a muscle for the purpose of enhancing mobility, preventing injury or building muscle strength. The system is designed to operate autonomously or coupled with other like devices to provide simultaneous assistance or resistance to multiple muscles. The actuator is preferably an electrostatic motor. However, also DC motors, servomotors or gear motors are possible. For different operation modes, a muscle detector is provided to detect muscle activation in order to perform an assistance mode of the device.

[0007] In the US 2004/0106881 A1 a similar powered orthotic device is described sensing relatively low signals in the vicinity of the joint generated by a patient having nerve damages. In response to the relatively low level signals the powered orthotic device moves causing the patient's joint to move accordingly.

[0008] The WO 2005/074371 A2 discloses a rehabilitation device comprising a frame, an actuator including a movement mechanism capable of applying a force that interacts with a motion of the patient's limb in at least

three degrees of freedom of motion of the actuator and capable of preventing substantial motion in any point and any direction in a volume of at least 30 cm in diameter. Though the device is typically a stand-alone frame, also a linkage device for an elbow movement is disclosed. Further, it is described to support the motion of the patient's limb by a virtual reality device.

[0009] To provide controlled amounts of resistance to movement in exercise equipment or orthotic devices, a control module according to the US 5,954,621 A has cooperating resistance elements. The force between the elements is varied in accordance with the position of the elements with respect to each other. For example the control module can connect two splints of a knee brace so that the resistance to flexion and extension are programmed in accordance with the position of the leg and with respect to each other.

[0010] The EP 1 442 704 A1 describes a walking condition determining device and method. To this aim, a measuring means measures a parameter indicating a displacement speed or acceleration of a bottom portion of one leg to another leg. In a storage means, patterns of walking conditions are stored such that the different conditions are associated with each other. Using these stored patterns, a determining means determines the walking conditions of the walker.

[0011] In the EP 1 723 941 A1 a similar wearing type behaviour help device is disclosed detecting a joint angle and a myoelectric signal. In difference of these two signals, a physical phenomenon signal and a biosignal, the reaction of the device is determined.

[0012] Finally, the US 2004/0172097 A1 discloses a therapeutic device comprising a mechanical orthotic element constituting a contact surface with the patient's limb and a neuromuscular stimulation element including at least a pair of electrodes. The orthotic element includes motorised articulations each of which is equipped with an angular sensor, a force sensor and a torque sensor to enable a feedback control.

[0013] The object of the present invention therefore is to propose a system for rehabilitation which make possible the setting of a large number of different sequences of movements and which support and monitor the execution of said sequences of movements.

[0014] According to the invention this object is solved with the characteristics of claim 1 and the dependent claims.

[0015] To this end, a linkage with integrated joints can be applied to the body of a human being according to the invention such that the applied linkage is able to re-enact selected movements of the body. An integrated joint has a drive for moving the joint and at least one position detector to sense the position of the drive and/or the joint. In addition, a control for triggering the drives and/or for sensing the sequence of movement by evaluating the position of the drives and/or of the joints is provided in the system. For example the system according to the invention can be a linkage for applying to an arm or a leg

which is able to re-enact typical sequences of movements of the arm or leg. In other words, the linkage assumes the function of an external skeleton which makes possible the re-enacting or initiating of the sequence of movements of the human skeleton. Through the design as linkage with integrated joints the system according to the invention is constructed so light-weight compared with most conventional exercise devices that, once applied for example to the arm or leg of a patient, it is not so heavy as to interfere with a natural and free movement. By providing a position detector and a drive for preferably each joint driven or evaluated in a coordinated manner through a common control, the system according to the invention can be used for both monitoring the execution of a set movement as well as for support with the execution of a set movement or a combination of both of these, where a correct movement through the patient is detected and supported and an incorrect movement counteracted if applicable.

[0016] For implementing such a system the drive is designed as a rotary drive with a motor for rotating a driveshaft, a motor sensor or encoder for detecting the motor position and a joint sensor or encoder for detecting the joint position. Basically the motor also has a gearing so that the motor can be designed as a geared motor. This has the advantage that the same motor with the same electronics and control can be provided for all joints which are employed and different motion speeds of the joint movement can be realised for example through different gear ratios. This simplifies the construction of the system considerably.

[0017] In order to be able to set a controlled sequence of movements on the one hand and on the other hand detect and support or counteract such movement if applicable through triggering the drive the drive of one or each joint is a servo drive where phase-shifting in the drive is possible between a motor movement and a joint movement. Such a servo drive has various advantages. Hence, it makes possible the sequence of movements of the body with an applied linkage relative to the motor position known to a control, This is possible quickly and with only little electronic effort so that the system in an ideal manner can also be operated such that a body movement applied to the linkage from the outside is supported during the sequence of movements through additional following-up of the drives. In addition, the system permits deviations in the sequence of movements in the case of a movement set by the drives which allow drawing conclusions as to whether the patient is capable of following the set sequence of movements or if major resistances occur here. In the latter case such greater resistances can be detected through a comparatively large deviation between the motor position and the joint position so that the sequence of movements can be stopped to avoid injuries.

[0018] A particularly advantageous development of the servo drive provides that the movement of the drive, more preferably the driveshaft, and the movement of the

joint are decoupled through a coupling whose coupling effect increases with rising phase shift for example a spring coupling. Through this it is more preferably achieved that with a set movement the force exerted by a patient has to be increased ever more the further he moves away from the set movement. As a result, an incentive for example to follow the sequence of movements set by a therapist is automatically created.

[0019] In order to implement a set sequence of movements and/or to record a set movement by a body to which the linkage according to the invention is applied, the control is equipped to set a movement of the joints of the linkage through triggering a drive or several drives and to determine a movement of the joints of the linkage (for example through detecting a phase shift between the joint position sensor and the motor position sensor) in deviation from a triggering of the drive and to record said phase shift depending on, the operating mode. Further, a follow-up of the drive is possible. Through this it can more preferably be achieved that the drive follows the movement of a joint set from the outside in order to support the movement set from the outside and for example offset the dead weight of the linkage that serves as external skeleton or counteract the actual movement of the linkage, provided another (set) movement objective is to be attained.

[0020] An embodiment of the system which is preferred more preferably in the treatment of neurological damages provides for a device to create a virtual reality with a display and a computation unit with which, taking into account the coordinates of a movement objective for the linkage and the current position of the joints and/or drives of the linkage, a scene supporting the movement objective is presented. With a linkage for an arm this can for example be an object to be gripped arranged in the position of the movement objective. This serves to train a movement coordinated between stimulation of the brain and executions of the locomotor system, which strongly resembles a real situation. By playing concrete objectives the execution of the desired sequence of movements is therefore supported in a mentally active manner.

[0021] According to a simple realisation the device to create a virtual reality can have a three dimensional display each with a separate display for each eye, which for example is integrated in a helmet having the respective display in front of each eye. By taking into account the perspective situation for each eye in the separate display it can be used to actively create the impression of a three-dimensional scene.

[0022] In order to make possible particularly realistic planning of the for example three-dimensional scene the device for creating a virtual reality can take into account movements of the head and/or the eyes relative to the linkage, more preferably if the device has a helmet equipped with suitable sensors.

[0023] For making use of the prescribed system for the rehabilitation, the control has a synchronous operating mode, an asynchronous operating mode and/or a virtual

operating mode in order to execute a set sequence of movements of the linkage. The operating modes which are described in more detail in the following can also be combined with one another according to the invention.

[0024] With the synchronous operating mode two linkages can be used according to the invention of which one linkage is a master linkage and one linkage is a slave linkage, wherein the master linkage sets a sequence of movements and the slave linkage executes the set sequence of movement, i.e. re-enacts such sequence of movements. The linkages can be identical linkages or linkages corresponding to one another, for example for a left or a right arm. In this way a therapist for example with the healthy arm or a healthy arm of the patient itself can set the sequence of movements for the disabled arm.

[0025] Here, the control can monitor and display on the master linkage the sequence of movement in the slave linkage and more preferably parameterised deviations from the set movements. The display can for example take place through blocking, accelerating and/or retarding the sequence of movement. Since, according to the invention, the way in which the deviation from the set movement occurs is sensed, it can be displayed through appropriate signals on the master linkage where the deviations occur. This allows the therapist to recognise causes for the deviation and take suitable therapeutic measures.

[0026] With an asynchronous operating mode a sequence of movements can be recorded in a first step with the linkage according to the invention and the recorded sequence of movements executed in a second step, wherein the recorded sequence of movements for this purpose can be stored in the control and transmitted to the linkage for execution.

[0027] With the virtual operating mode, which more preferably can be combined with the asynchronous operating mode, the sequence of movements to be executed can be supported through presentation of a virtual reality on a display in that a scene is created which gives the executing person an incentive, starting from the current position of the linkage, to reach the movement target of the linkage. The movement target in this case can more preferably be an end or target position or a defined intermediate position of a pre-definable sequence of movements.

[0028] Stimulation can be further supported in that the virtually presented scene is continually adjusted to the actual sequence of movements of the linkage.

[0029] In order to be able to configure different therapeutic intensities it is particularly preferentially provided according to the invention that the degree of support of the sequence of movements can be parameterised through the drive. To this end, drive moments to be executed by the drives of the linkage can be set for example. The setting can be in a relative graduation between a maximum drive moment which is selected just so that injuries on the guided body are prevented and a minimum drive moment which just compensates for the dead

weight of the linkage, thus not signifying any support in the sequence of movements.

[0030] With the system according to the invention the deviation from the set sequence of movements is preferentially detected by the control. This can be achieved in that a connecting straight line between the movement target (end position or intermediate position) and the end point of the linkage, which is to reach the movement target, is determined and, starting from the end point of the linkage, a cone with a settable opening angle around this connecting straight line is defined. The opening angle can then be selected or set such that upon remaining of the end point of the linkage within the cone, reaching of the movement target remains possible even if the end point of the linkage deviates from the connecting straight line without gradients of a directional change having to occur, i.e. no severe directional changes would have to be performed within the course of the sequence of movements to still reach the target. It is then monitored if the end point of the linkage departs from this cone and in this case the control can counteract the movement to support the correct sequence of movements. This check is continually repeated with the movement of the linkage so that in each case the current position of the linkage relative to the end or intermediate target is being monitored.

[0031] To actively support adherence to a set sequence of movements the control, on determining a deviation in the sequence of movements, can trigger the drives such that the correct sequence of movements is supported. If this can no longer be achieved the control can memorise the last correct end position or the position of departure from the prescribed cone, completely release the movement and, if applicable, start supporting the free movement through active tracking of the drives to avoid injuries. In this way it is possible to resume therapy exactly at the aborted point once the linkage, upon a control command by the control, has been returned to this positions.

[0032] The system according to the invention is described in more detail by means of the example of a linkage that can be applied for a right and a left arm, from which further characteristics, advantages and possible applications of the present invention are obtained. Here, all described and/or depicted characteristics form the object of the present invention, even independent of their combination in the claims or their references.

[0033] It shows:

Fig. 1 a system according to the invention for rehabilitation for the right and left arm of a patient;

Fig. 2 a linkage designed as an external arm skeleton according to Fig. 1 in detail view;

Fig. 3 a drive of the linkage according to the invention according to Fig. 2;

Fig. 4 a schematic diagram of the components of the

system for rehabilitation according to the invention;

- Fig. 5 a signal flow-chart for carrying out a method for the rehabilitation using the system according to the invention in an asynchronous operating mode;
- Fig. 6 a signal flow chart for carrying out a method for rehabilitation using the system according to the invention in a synchronous operating mode and
- Fig. 7 a signal flow-chart for carrying out a method for rehabilitation using the system according to the invention in a virtual operating mode.

[0034] Fig. 1 shows a linkage 1 belonging to a system for rehabilitation which is designed as external skeleton for a right or a left arm 2 of a body. In Fig. 1 the linkage 1 is shown in a state applied to the arm 2 of a human being. The linkage 1 has integrated joints 3 wherein a drive 4 for moving the joint 3 is assigned to each integrated joint 3. The linkage 1 with the joints 3 and the respective assigned drive 4 is described in more detail in the following, making reference to

Fig. 2 and 3. It is emphasised that the linkage 1 designed as external arm skeleton merely constitutes an embodiment of the invention to which the invention however is not restricted. In principle, corresponding linkages 1 are conceivable in the same manner of operation and a suitably adjusted realisation also for application to other body parts, more preferably arms, trunk, head or such like.

[0035] The linkage 1 presented in three-dimensional view in a design drawing in Fig. 2 has a total of six joints 3a to 3f and thus makes possible six degrees of freedom of movements. The different joints 3 are connected with one another via suitably shaped and connected linkage parts 5 so that they make possible applying the linkage 1 to the arm 2 of a human being. In addition, each joint 3 is provided with a drive 4 which is described in more detail later on, making reference to Fig. 3.

[0036] The joint 3a is designed as a hinge joint in order to re-enact bending of the arm in the shoulder. With the joint 3b, likewise designed as hinge joint, rotation of the arm about its longitudinal axis of the upper arm can be simulated. The joint 3c designed as additional hinge joint performs a movement for lifting the arm to the front or to the back wherein the joint designed as a linear sliding joint 3d re-enacts the longitudinal offset up to the elbow. The hinge joint 3e is responsible for re-enacting a bending movement of the elbow, wherein the linear sliding joint 3f in turn re-enacts the longitudinal offset of the linkage 1 up to the wrist.

[0037] To fix the linkage 1 to the arm of the patient a collar 6 enclosing the wrist is arranged in the region of the wrist and, in the region of the elbow, a semicircular collar 6 is arranged, which if applicable can be fixed to the elbow with a band which is not shown.

[0038] Each joint 3a to 3f is assigned a separate drive 4 which, as is evident from Fig. 3, has an electric motor 7 which is connected with a gearing 8 and via the gearing 8 drives a drive shaft 9 to execute the desired movement (rotation or translation). To detect the position of the drive 4 a motor position detector 10 is provided.

[0039] Based on the design of the drive 4 as geared motor, movement of the joint 3 connected with the drive 4 is only possible if the motor 7 is triggered if the drive shaft 9 were directly connected with the joint 3. However, since it is desired that the linkage 1 can also be moved through a movement of the arm without the movement being initiated by the drive 4, a coupling 11 designed as actuator coupling is provided to connect the drive shaft 9 with the joint 3 which, in the drive 4, enables a phase shift of a motor movement and a joint movement. Here it is provided that the coupling effect of the coupling 11 increases with rising phase shift between the position of the drive shaft 9 and the position of the joint 3, for the purpose of which a spring 12 loaded in accordance with the phase shift is provided in the coupling 11. To detect the phase shift between the drive 4 or its drive shaft 9 and the joint 3 a joint position detector 13 is provided in the drive 4 on the joint 3 which determines the joint position. From the difference of the joint φ_V and the motor position φ_M it is then possible to determine the phase shift $\Delta\varphi$, which indicates a self-movement of the joint 3 and thus the linkage 1 relative to the drive 4.

[0040] The positions of the drive 4 and the joint 3 determined through the position detectors 10, 13 are monitored in a control 14 for example as phase shift $\Delta\varphi$, which coordinates all functions of the system 15 for rehabilitation. When the phase shift $\Delta\varphi$ detected in the control 14 exceeds a set more preferably configurable threshold value, the drive 4 assigned to this phase shift $\Delta\varphi$ can be activated in order to follow-up the drive shaft 9 such that the phase shift between the drive 4 and the joint 3 disappears and no additional force against the linkage 1 has to be expended by the person to whose arm the linkage 1 is applied in order to hold the arm position.

[0041] This and additional functions are executed by the central control 14 of the system 15 for rehabilitation shown in Fig. 3 which, for this purpose, is connected to a triggering unit 16 which in each case is connected with the linkage 1 and the drives 4 located therein. The triggering unit 16 itself is preferably constructed in a modular manner from several parallel computers so that adequate computation power is available to make possible a real time activation of all drives 4 in the linkage 1 and to read out the read-out position data of the motor position detector 10 and the joint position detector 13. Here, the triggering unit 16 can preferably already calculate possible phase shifts $\Delta\varphi$, passing these on to the central control. Obviously it is also possible to set up the control 14 to calculate a phase shift $\Delta\varphi$. The system 15 additionally has a unit 7 connected to the control 14 to create a virtual reality which will be described in more detail later on. In addition, the control 14 is connected with a data base

unit 18 known per se in which both data relevant for triggering the linkage 1 as well as patient-related therapy data and such like can be stored, which can be suitably input, processed and retrieved through an administrative program integrated in the control 14. It is also possible to detect the therapy process over several sittings and the sequence of movements of a therapy session by means of the position detectors 10, 13, to evaluate these in the control 14 and to file these as history in the data base or storage unit 18 so that a therapist has access to old therapy data for comparison of therapy progress or such like. Set sequences of movements, which are to be executed by the linkage 1, can also be filed in form of suitable control files. For operation, the control 14 has an operating unit 19. Thus, the system 15 constitutes a comprehensive system for rehabilitation which, in addition to the active execution of therapeutical exercises by means of a linkage 1, also makes possible the administration, archiving and evaluation of the therapies for one or several patients.

[0042] However, the following description is concentrated on the operation of the linkage 1 in different operating modes which are explained in more detail by means of Fig. 5 to 7. Nevertheless, the overall system 15 with all its functions presented before is the object of the present invention.

[0043] A method for rehabilitation with the system 15 described above in an asynchronous operating mode is described with regard to the flow diagram shown in Fig. 5.

[0044] A predefined exercise is executed in the asynchronous operating mode through the linkage 1 applied to the arm 2 of a patient in that the drives 4 of the linkage 1 move the joints 3 in accordance with a set movement schedule to execute a movement of the arm 2 of the patient. To set the sequence of movements the linkage 1 is initially put in a recording mode in order to record a sequence of movements in a first step with the linkage 1. To this end, the linkage 1 can be applied to the patient who performs a sequence of movements in accordance with the settings of the therapist. Alternatively, the therapist can put on the linkage 1 and record the desired sequence of movements. This recorded sequence of movements is processed by the control 14 and stored for example as file in the data base unit 18, from where the file can be loaded back into the control 14 at any time in order to execute the sequence of movements as part of the therapy.

[0045] At the start of recording the linkage 1 is in a reset position in which it is put in recording mode by pressing a recording button (not shown). In order to set the starting position of the sequence of movements the switch is pressed and held in the reset position of the linkage 1 until the linkage 1 is guided to the desired starting position for the sequence of movements. During this movement, each drive 4 passes the recorded joint positions φ_V and motor positions φ_M on to the triggering unit 16 which processes said positions and determines the current linkage position as a function of time. Since the

movement is not initiated by the drives 4 a phase shift $\Delta\varphi$ occurs between the joint positions φ_V and the motor position φ_M which the triggering unit 16 as part of the control 14 uses to send a movement command B ($\Delta\varphi$) dependent on the phase shift $\Delta\varphi$ to the triggering device 20, which then passes a control command S on to the respective drives 4 to actuate the electric motors 7. This means that the linkage 1 through the control 14 or the triggering unit 16 is made to follow the movement set by the arm 2 to achieve a phase shift of $\Delta\varphi = 0$.

[0046] Once the starting position has been reached the switch, which is not shown, is released and recording of the sequence of movements commences wherein the linkage 1 is made to follow the movement of the arm 2 in the manner described above. As soon as the end position of the sequence of movements is reached, the switch is actuated once more to indicate the end of the sequence of movements. Subsequent to this, the triggering unit 16 returns the linkage 1 to the reset position in which the linkage 1 can be removed from the arm 2. The recording function of the linkage 1 is then deactivated and the set sequence of movements is stored.

[0047] When the exercise is to be performed with the recorded sequence of movements a corresponding data file is loaded from the data base 18 into the control unit 14. The set sequence of movements ψ is passed on to the respective triggering unit 16 which then issues a movement command to the triggering device 20 as a function of the stored sequence of movements ψ as B (ψ), which subsequently generates the control command S for the motor 7 of the drive.

[0048] During the execution of the exercise it is possible to change the execution speed via the control 14. The movements are always executed with exactly the speed with which they were recorded. This sequence of movements however can be optionally accelerated or retarded by specifying a percentage deviation.

[0049] It is further possible to set the degree of difficulty of the exercise in the control 14. This is performed by selecting the degree of support of the movement through the motor drive 4. Such a value can be specified in percent, for example in stages relative to the maximum torque with which the linkage 1 is supported at each joint 3, if the patient does not at all contribute to the desired sequence of movements in order to guide the arm of the patient. As a lower limit of adjustability a minimum torque can be selected which does not provide any active movement support but is merely sufficient to support the dead weight of the linkage so as not to render the movement of the patient more difficult through the dead weight of the linkage. Between these two values of a minimum and a maximum torque, support can be selected freely or in set stages.

[0050] Even during the execution of the exercise the joint positions φ_V and the motor positions φ_M are detected by the position detectors 10, 13 in the drives 4 and transmitted to the triggering unit 16 which determines the phase shift $\Delta\varphi$ for each individual drive. These phase

shifts $\Delta\phi$ are then transmitted to the control 14 for each drive 4 which is therefore able to check the quality of the execution of the sequence of movements through the patient in that it monitors and evaluates the phase shifts $\Delta\phi$ of the various drives 4. Because of the servo drives 4 and the parallel signal processing in several triggering units 16 this is almost possible in real time.

[0051] The control 14 detects movements for example spastic movements or an accelerated sequence of movements deviating from the set sequence of movements for example through the exceeding of certain thresholds which can also be individually defined and parameterised. Once these thresholds are exceeded the control then sets that the triggering unit 16 is to follow the movements of the patient by adjusting the phase shift $\Delta\phi$ with the movement command $B(\psi)$ to avoid injuries. At the same time the last regular position of the linkage 1 within the scope of the movement command and the deviating movement is recorded until stoppage of the uncoordinated or incorrect movements occurs. The control 14 then sets reverse operation of the movement of the linkage which more preferably is executed with the maximum support. As soon as the starting point of the uncoordinated movement is reached, the mode that executes the set sequence of movements within the scope of an exercise is switched on again.

[0052] In the synchronous operating mode illustrated in Fig 6 a second linkage 1 is provided instead of a prior recording of the sequence of movements which in the following is named master linkage. The master linkage 1 is either provided identically or in mirror-image to the linkage 1 which is to execute the therapy and is subsequently named slave linkage. The master linkage for example is situated on a healthy arm of the patient or therapist while the slave linkage is located on the arm of the patient to be treated.

[0053] Once the master and slave linkage have been applied, both are in their reset position. By pressing a switch that is not shown on the master linkage, movement synchronisation of the two linkages 1 is started. Upon releasing of this switch and on re-actuating said switch the synchronous actuating process is stopped and both linkages are moved back to their reset position. A switch that might be provided on the slave linkage is deactivated in synchronous operating mode.

[0054] Through the motor position detector 10 and the joint position detector 13, the joint positions ϕ_V and the motor positions ϕ_M of all drives 4 of the master linkage 1 involved are detected in the already described manner and passed on to the triggering units 16 which determine the phase shifts $\Delta\phi$ from these. The phase shifts $\Delta\phi$ of each drive 4 are passed on to the control 14 which generates a sequence of movements ψ from these. Since preferentially a separate triggering unit 16 is provided for each drive, the data of the various drives 4 is transmitted to the control 14 almost at the same time, which is therefore able to create the sequence of movements ψ in real time, passing it on to the triggering units 16 of the slave

linkage 1. These create a movement command $B(\psi)$ as a function of the set sequence of movements ψ which is passed on to the respectively assigned triggering device 20 where it is converted into a control command S to the drives 4 of the slave linkage 1 so that the movements can be re-enacted almost in real time.

[0055] As previously described in connection with the asynchronous operating mode, the degree of support can also be adjusted in this case.

[0056] During the execution of the movement through the slave linkage 1 the joint position ϕ_V and the motor position ϕ_M are detected by the position detectors 10, 13 on each drive 4 of the slave linkage and passed on to the respective triggering unit 16 of the slave linkage 1, which determines a phase shift $\Delta\phi$ from these. This shows how well the patient follows the said movement. This is monitored by the control 14 in the manner described, which in the case of greater deviations can issue a movement command B to the triggering unit 16 of the master linkage 1 which in the known manner is passed on to the master linkage 1 via the triggering device 20 so that for example the therapist notices when the patient fails to optimally follow the movements preset by said therapist. Here, the exact movement deviation of the patient is advantageously re-enacted.

[0057] Making reference to Fig. 7 a particularly preferred embodiment of the invention is described in the following where the method for rehabilitation is executed in a virtual operating mode. To this end, the control 14 which otherwise cooperates with the linkage 1 similar to the embodiments described before, is additionally connected with a unit 17 for creating a virtual reality running a program for creating images as a function of a sequence of movement ψ set by the control 14.

[0058] Here, the unit 17 for creating a virtual reality preferably creates two image commands V which are passed on to monitors arranged in front of the eyes of the patient which are arranged in a helmet 21 for the playing of the virtual reality. The helmet 21 is equipped with sensors 22 which make possible the detection of the position of the helmet 21 and/or the direction of vision of the eyes within the helmet, which are passed back as sensor data D to the unit for creating the virtual reality 17, so that, in creating the virtual reality, it can be used to react to a corresponding movement behaviour of the patient.

[0059] Depending on the set sequence of movements ψ a scene is then played to the patient in the helmet 21 for example in which the patient is to grip an object which is exactly located at the end point of the set sequence of movements ψ . In the already described manner the sequence of movements of the linkage 1 is then monitored and/or supported.

[0060] In order to decide if the movement of the patient is in agreement with the said virtual reality it is possible for example based on the actual position of the end of the linkage 1 to decide if the movement is directed in the direction of the set intermediate or end position of the

sequence of movements ψ or not. To this end, starting from the actual position of the linkage 1, a linear connection to the next target point (intermediate or end position) can be defined and starting from the linkage 1 a cone with a certain opening angle can be set which is dimensioned so that upon continuation of the movement the target point can be reached without abrupt directional change, which can be configured by means of threshold values.

[0061] As soon as the linkage 1 departs from the interior of this cone corrective intervention is possible. This procedure is continually repeated so that in each case, based on the current position of the linkage 1, a topical basis for decision making is available.

[0062] The provision of a virtual reality is more preferably suitable in the treatment of neurological illnesses since in this case the nervous stimulations of a real world are simulated in the brain and the typical movement reactions in this regard can be expertly trained.

[0063] List of reference numbers:

- 1 Linkage as external arm skeleton
- 2 Arm of a human being
- 3 Joint
- 4 Drive
- 5 linkage parts
- 6 Collar
- 7 Electric motor
- 8 Gearing
- 9 Drive shaft
- 10 Motor position detector
- 11 Coupling
- 12 Spring
- 13 Joint position detector
- 14 Control
- 15 System for rehabilitation
- 16 Triggering unit
- 17 Unit for creating a virtual reality
- 18 Data base unit
- 19 Operating unit
- 20 Triggering device
- 21 Helmet

- φ_V Joint position
- φ_M Motor position
- $\Delta\varphi$ Phase shift
- ψ Sequence of movements
- B Movement command
- S Control command
- V Image command
- D Sensor data

Claims

1. A system for rehabilitation with a linkage (1) with integrated joints (3) that can be applied to the body of a human being such that the applied linkage (1) is

able to follow selected movements of the body wherein an integrated joint (3) has a drive (4) for moving the joint (3) and a position detector (10, 13) for detecting the position of the drive (4), and with a control (14) for triggering a drive (4) and for detecting a sequence of movements through evaluating the position of the drive (4), said drive (4) being designed as a rotary servo drive, **characterized in that**

- said drive (4) has a motor (7) for rotating a drive shaft (9), a motor sensor (10) for detecting the motor position and a joint sensor (13) for detecting the joint position, said drive (4) allowing a phase shift in the drive (4) between a motor movement and a joint movement and
- said control (14) is designed to set a movement of the joints (3) of the linkage (1) through triggering a drive (4) or several drives (4) and to determine and to record a movement of the joints (3) of the linkage (1) in deviation from a triggering of the drive (4).

2. The system according to claim 1, **characterized in that** the movement of the drive (4) and the movement of the joint (3) are decoupled through a coupling (11) whose coupling effect increases with rising phase shift.
3. The system according to any one of the preceding claims, **characterized in that** the control (14) follows-up the drive (4).
4. The system according to any one of the preceding claims, **characterized** through a device for creating a virtual reality with a display and a computation unit (17) in which, taking into account the coordinates of a movement target for the linkage (1) and the current position of the linkage (1), a scene supporting the movement target is displayed.
5. The system according to claim 4, **characterized in that** the device for creating a virtual reality has a three-dimensional display with a separate display for each eye.
6. The system according to claim 4 or 5, **characterized in that** the device for creating a virtual reality takes into account movements of the head and/or the eyes relative to the linkage (1).
7. The a system according to any one of the preceding claims, **characterized in that** the control (14) has a synchronous operating mode, an asynchronous operating mode and/or a virtual operating mode in order to execute a set sequence of movements of the linkage (1).
8. The system according to claim 7, **characterized in**

that with the synchronous operating mode two linkages (1) are used of which one linkage (1) is a master linkage and one linkage (1) is a slave linkage, wherein the master linkage (1) sets a sequence of movements and the slave linkage (1) executes the set sequence of movements.

9. The system according to claim 8, **characterized in that** the control (14) monitors the sequence of movements in the slave linkage (1) and, upon deviations from the set movements, indicates set sequence of movements on the master linkage (1).

10. The system according to any one of the claims 7 to 9, **characterized in that** with the asynchronous operating mode in a first step a sequence of movement is recorded with the linkage (1) and the recorded sequence of movement is executed in a second step.

11. The system according to any one of the claims 7 to 10, **characterized in that** with the virtual operating mode the sequence of movements to be executed is supported through presentation of a virtual reality on a display **in that** a scene is created which gives the executing person an incentive, based on the current position of the linkage (1), to reach the movement target of the linkage (1).

12. The system according to claim 11, **characterized in that** the virtually presented scene is adapted to the actual sequence of movements of the linkage (1).

13. The system according to any one of the claims 7 to 11, **characterized in that** the degree of support of the sequence of movements by the drive (4) can be parameterised.

14. The system according to any one of the claims 7 to 13, **characterized in that** the deviation of the sequence of movements from the set sequence of movements is detected.

15. The system according to claim 14, **characterized in that** the control (14) upon detection of a deviation in the sequence of movements triggers the drives (4) such that the correct sequence of movements is supported.

Patentansprüche

1. System zur Rehabilitation mit einem derart an den Körper eines Menschen anlegbaren Gestänge (1) mit integrierten Gelenken (3), dass das angelegte Gestänge (1) ausgewählte Bewegungen des Körpers nachvollziehen kann, wobei ein integriertes Gelenk (3) einen Antrieb (4) zum Bewegen des Gelenkes (3) und einen Positionsdetektor (10, 13) zum Er-

fassen der Stellung des Antriebs (4) aufweist, und mit einer Steuerung (14) zum Ansteuern eines Antriebs (4) und zum Erfassen eines Bewegungsablaufs durch Auswerten der Stellung des Antriebs (4), wobei der Antrieb (4) als Dreh-Servo-Antrieb ausgebildet ist, **dadurch gekennzeichnet, dass**

- der Antrieb (4) einen Motor (7) zum Drehen einer Antriebswelle (9), einem Motorsensor (10) zum Erfassen der Motorposition und einem Gelenksensor (13) zum Erfassen der Gelenkposition aufweist, wobei der Antrieb (4) eine Phasenverschiebung in dem Antrieb (4) zwischen einer Motorbewegung und einer Gelenkbewegung erlaubt und
- die Steuerung (14) dazu eingerichtet ist, eine Bewegung der Gelenke (3) des Gestänges (1) durch Ansteuern eines Antriebs (4) oder mehrerer Antriebe (4) vorzugeben und eine Bewegung der Gelenke (3) des Gestänges (1) in Abweichung von einer Ansteuerung des Antriebs (4) festzustellen und aufzuzeichnen.

2. System nach Anspruch 1, **dadurch gekennzeichnet, dass** die Bewegung des Antriebs (4) und die Bewegung des Gelenks (3) durch eine Kupplung (11) entkoppelt sind, deren Koppelwirkung mit steigender Phasenverschiebung zunimmt.

3. System nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die Steuerung (14) den Antrieb (4) nachführt.

4. System nach einem der vorhergehenden Ansprüche, **gekennzeichnet durch** eine Einrichtung zur Erzeugung einer virtuellen Realität mit einem Display und einer Recheneinheit (17), in welcher unter Berücksichtigung der Koordinaten eines Bewegungsziels für das Gestänge (1) und der aktuellen Position des Gestänges (1) eine das Bewegungsziel unterstützende Szene dargestellt wird.

5. System nach Anspruch 4, **dadurch gekennzeichnet, dass** die Einrichtung zur Erzeugung einer virtuellen Realität ein dreidimensionales Display mit je einer eigenen Anzeige für jedes Auge aufweist.

6. System nach Anspruch 4 oder 5, **dadurch gekennzeichnet, dass** die Einrichtung zur Erzeugung einer virtuellen Realität Bewegungen des Kopfes und/oder der Augen relativ zu dem Gestänge (1) berücksichtigt.

7. System nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die Steuerung (14) einen synchronen Betriebsmodus, einen asynchronen Betriebsmodus und/oder einen virtuellen Betriebsmodus aufweist, um einen vorgegebe-

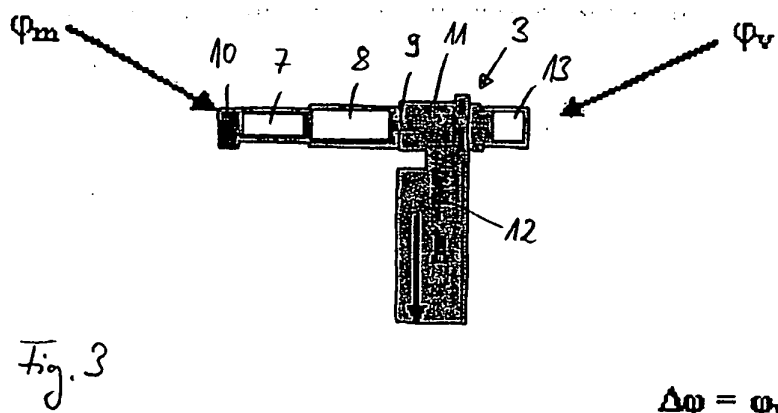
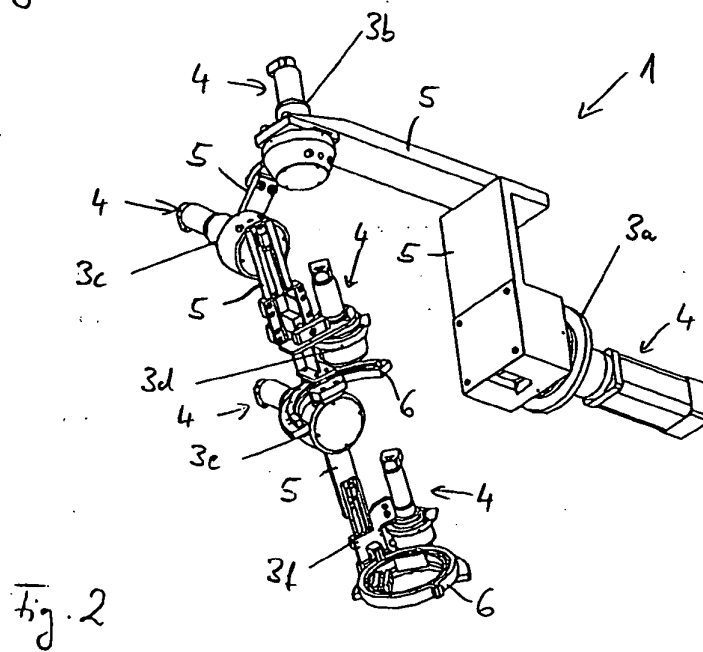
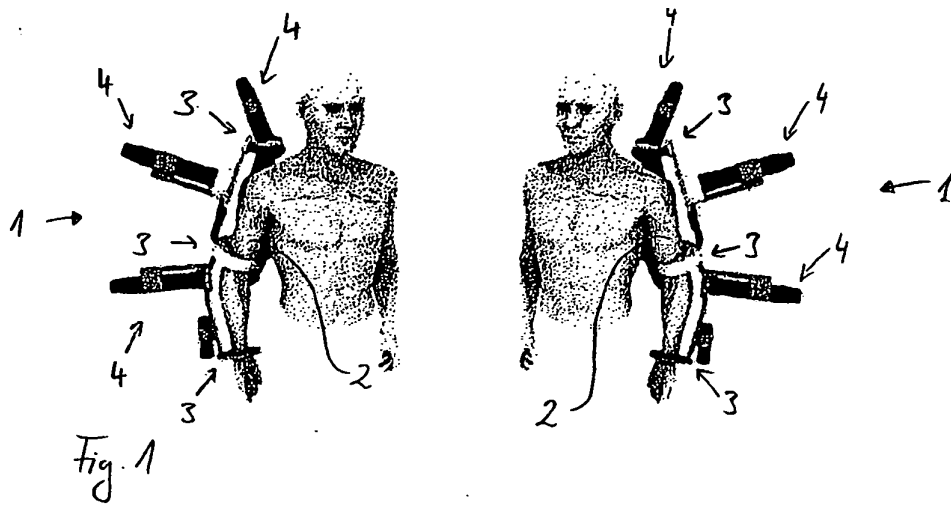
nen Bewegungsablauf des Gestänges (1) auszuführen.

8. System nach Anspruch 7, **dadurch gekennzeichnet, dass** bei dem synchronen Betriebsmodus zwei Gestänge (1) verwendet werden, von denen ein Gestänge (1) ein Master-Gestänge und ein Gestänge (1) ein Slave-Gestänge ist, wobei das Master-Gestänge (1) einen Bewegungsablauf vorgibt und das Slave-Gestänge (1) den vorgegebenen Bewegungsablauf ausführt. 5
9. System nach Anspruch 8, **dadurch gekennzeichnet, dass** die Steuerung (14) den Bewegungsablauf in dem Slave-Gestänge (1) überwacht und bei Abweichungen von der Bewegungsvorgabe an dem Master-Gestänge (1) anzeigt. 10
10. System nach einem der Ansprüche 7 bis 9, **dadurch gekennzeichnet, dass** bei dem asynchronen Betriebsmodus in einem ersten Schritt mit dem Gestänge (1) ein Bewegungsablauf aufgenommen und der aufgenommene Bewegungsablauf in einem zweiten Schritt ausgeführt wird. 15
11. System nach einem der Ansprüche 7 bis 10, **dadurch gekennzeichnet, dass** bei dem virtuellen Betriebsmodus der auszuführende Bewegungsablauf durch Darstellung einer virtuellen Realität auf einem Display unterstützt wird, indem eine Szene erzeugt wird, welche dem Ausführenden einen Anreiz gibt, ausgehend von der aktuellen Position des Gestänges (1) das Bewegungsziel des Gestänges (1) zu erreichen. 20
12. System nach Anspruch 11, **dadurch gekennzeichnet, dass** die virtuell dargestellte Szene an den tatsächlichen Bewegungsablauf des Gestänges (1) angepasst wird. 25
13. System nach einem der Ansprüche 7 bis 11, **dadurch gekennzeichnet, dass** das Maß der Unterstützung des Bewegungsablaufs durch den Antrieb (4) parametrierbar ist. 30
14. Verfahren nach einem der Ansprüche 7 bis 13, **dadurch gekennzeichnet, dass** das Abweichen des Bewegungsablaufs von dem vorgegebenen Bewegungsablauf festgestellt wird. 35
15. Verfahren nach Anspruch 14, **dadurch gekennzeichnet, dass** die Steuerung (14) bei dem Feststellen einer Abweichung in dem Bewegungsablauf die Antriebe (4) derart ansteuert, dass der richtige Bewegungsablauf unterstützt wird. 40

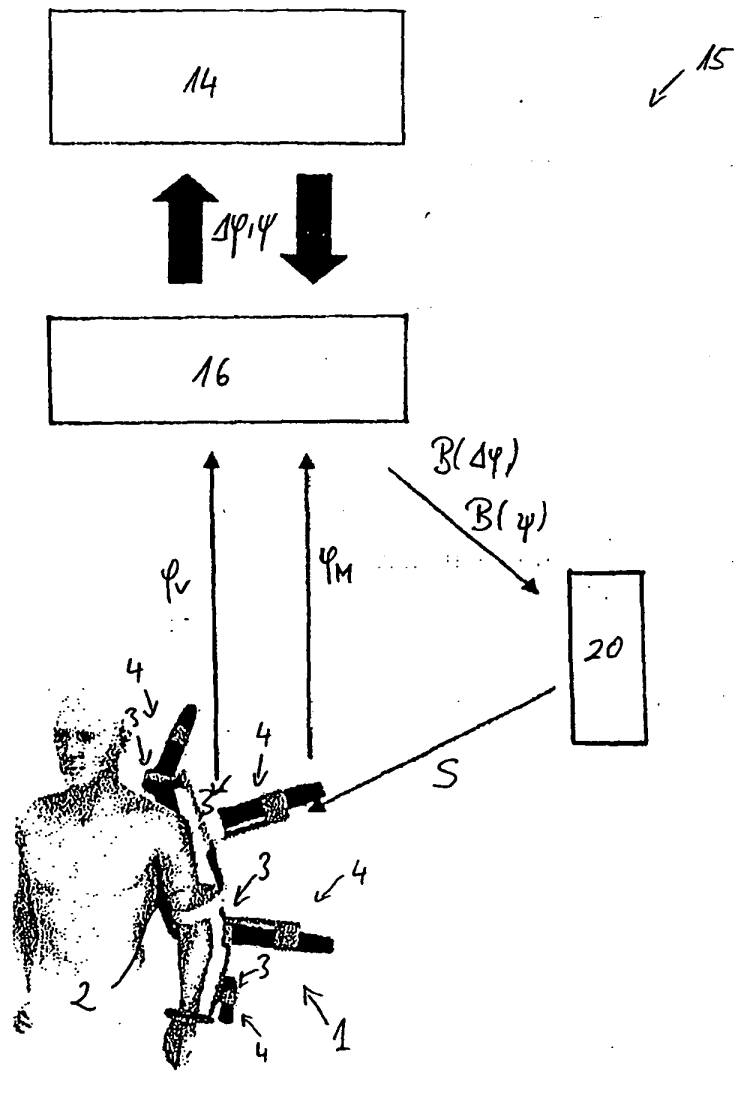
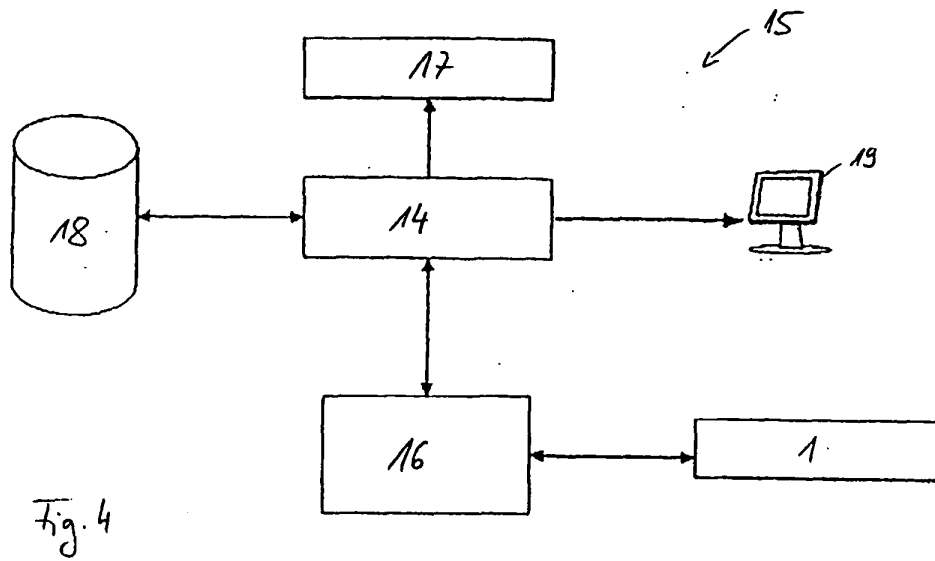
Revendications

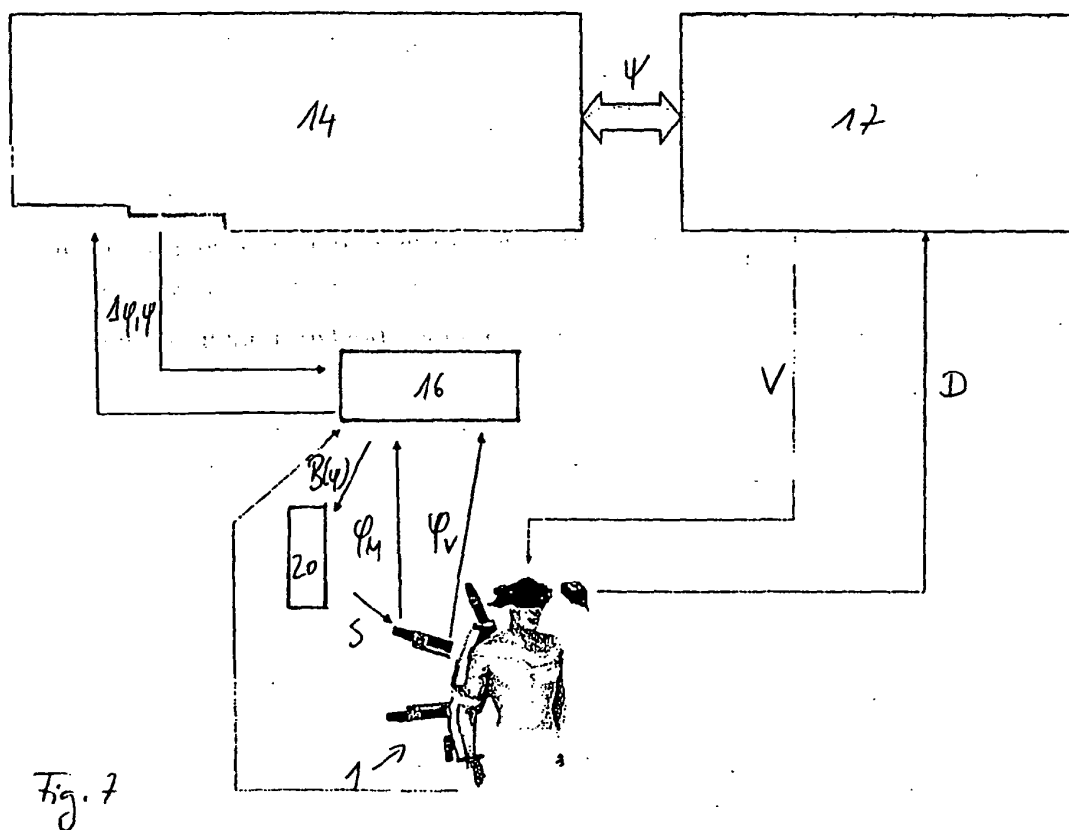
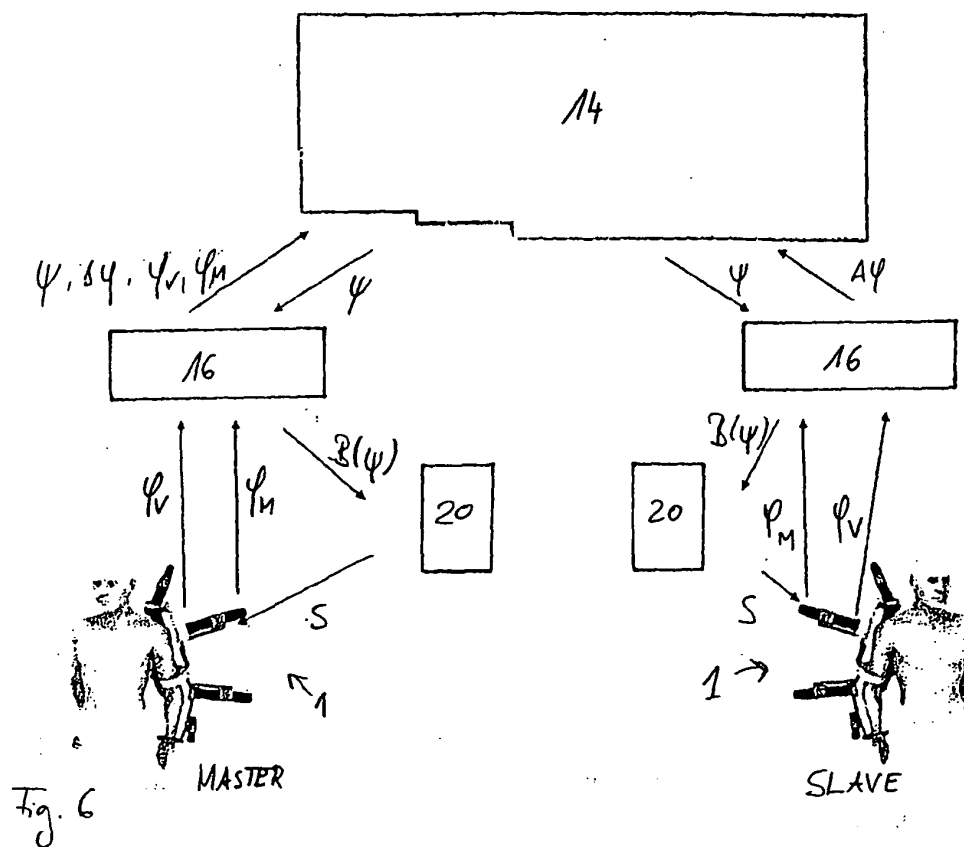
1. Système de rééducation comportant une tringlerie (1) à articulations intégrées (3) qui peut être appliquée sur le corps d'un humain de manière à ce que la tringlerie appliquée (1) soit apte à suivre des mouvements sélectionnés du corps, dans lequel une articulation intégrée (3) comporte une transmission (4) pour faire bouger l'articulation (3) et un détecteur de position (10, 13) pour détecter la position de la transmission (4) et une commande (14) pour déclencher une transmission (4) et pour détecter une séquence de mouvements en évaluant la position de la transmission (4), ladite transmission (4) étant conçue sous forme d'une servocommande rotative, **caractérisé en ce que**
 - ladite transmission (4) a un moteur (7) pour faire tourner un arbre moteur (9), un capteur de moteur (10) pour détecter la position du moteur et un capteur d'articulation (13) pour détecter la position de l'articulation, ladite transmission (4) permettant un changement de phase dans la transmission (4) entre un mouvement du moteur et un mouvement de l'articulation et
 - ladite transmission (4) étant conçue pour régler un mouvement des articulations (3) de la tringlerie (1) en déclenchant une transmission (4) ou plusieurs transmissions (4) et pour déterminer et enregistrer un mouvement des articulations (3) de la tringlerie (1) en déviation par rapport à un déclenchement de la transmission (4).45
2. Système selon la revendication 1, **caractérisé en ce que** le mouvement de la transmission (4) et le mouvement de l'articulation (3) sont découplés par un couplage (11) dont l'effet de couplage augmente au fur et à mesure que le changement de phase augmente. 50
3. Système selon l'une quelconque des revendications précédentes, **caractérisé en ce que** la commande (14) suit la transmission (4). 55
4. Système selon l'une quelconque des revendications précédentes, **caractérisé par** un dispositif de création d'une réalité visuelle à l'aide d'une unité d'affichage et de calcul (17) dans laquelle, en prenant en compte les coordonnées d'une cible de mouvement pour la tringlerie (1) et la position momentanée de la tringlerie (1), une scène supportant la cible de mouvement est affichée.
5. Système selon la revendication 4, **caractérisé en ce que** le dispositif de création d'une réalité virtuelle comporte un afficheur tridimensionnel avec affichage séparé pour chaque oeil.

6. Système selon la revendication 4 ou 5, **caractérisé en ce que** le dispositif de création d'une réalité virtuelle tient compte des mouvements de la tête et/ou des yeux par rapport à la tringlerie (1). 5
7. Système selon l'une quelconque des revendications précédentes, **caractérisé en ce que** la commande (14) a un mode opératoire synchrone, un mode opératoire asynchrone et/ou un mode opératoire virtuel afin d'exécuter une séquence de mouvements établie de la tringlerie (1). 10
8. Système selon la revendication 7, **caractérisé en ce que**, dans le mode opératoire synchrone, on utilise deux tringleries (1) dont une (1) est une tringlerie maîtresse et une (1) est une tringlerie asservie, la tringlerie maîtresse (1) réglant une séquence de mouvements et la tringlerie asservie (1) exécutant la séquence de mouvements établie. 15 20
9. Système selon la revendication 8, **caractérisé en ce que** la commande (14) contrôle la séquence de mouvements dans la tringlerie asservie (1) et, en cas de déviation par rapport aux mouvements établis, indique la séquence de mouvements établie sur la tringlerie maîtresse (1). 25
10. Système selon l'une quelconque des revendications 7 à 9, **caractérisé en ce que**, dans le mode opératoire synchrone, dans une première étape, une séquence de mouvements est enregistrée avec la tringlerie (1) et que la séquence de mouvements enregistrée est exécutée dans une deuxième étape. 30
11. Système selon l'une quelconque des revendications 7 à 10, **caractérisé en ce que**, dans le mode opératoire virtuel, la séquence de mouvements à exécuter est assistée par présentation d'une réalité virtuelle sur un afficheur du fait qu'il est créé une scène qui incite la personne exécutante, en se basant sur la position momentanée de la tringlerie (1), à atteindre la cible de mouvement de la tringlerie (1). 35 40
12. Système selon la revendication 11, **caractérisé en ce que** la scène présentée virtuellement est adaptée à la séquence réelle de mouvements de la tringlerie (1). 45
13. Système selon l'une quelconque des revendications 7 à 11, **caractérisé en ce que** le degré d'assistance de la séquence de mouvements par la transmission (4) peut être paramétré. 50
14. Système selon l'une quelconque des revendications 7 à 13, **caractérisé en ce que** la déviation de la séquence de mouvements par rapport à la séquence de mouvements établie est détectée. 55
15. Système selon la revendication 14, **caractérisé en ce que** la commande (14), en cas de détection d'une déviation dans la séquence de mouvements, déclenche la transmission (4) de manière à assister la séquence de mouvements correcte.



$$\Delta\varphi = \varphi_v - \varphi_m$$





REFERENCES CITED IN THE DESCRIPTION

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