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(54) HANDHELD-REHABILITATION-DEVICE

(57) The invention relates to a handheld rehabilitation device comprising a housing (h), an actuator, a battery, a microcontroller and an opening mechanism including at least one opening plate (1) rotatably connected to the housing (h) by means of radial bearings (14) from a closed position to an open position around at least one axis of rotation (1') up to a maximum angle of rotation (α), wherein the actuator, the battery and the microcontroller are included inside the housing (h), wherein the microcontroller controls the speed and the maximum angle of rotation (α) of the opening mechanism, wherein the at least one opening plate (1) rotates between the closed position and the open position by means of the actuator. Furthermore, the invention also relates to methods for performing hand opening/closing, wrist orientation and tactile localization exercises with an inventive handheld rehabilitation device.

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Description

[0001] The invention relates to a handheld rehabilitation device comprising a housing, an actuator, a battery, a microcontroller and an opening mechanism including at least one opening plate. Furthermore, the invention relates to methods for performing hand opening/closing, wrist orientation and tactile localization exercises with the handheld rehabilitation device.

BACKGROUND OF THE INVENTION

[0002] For quality of human life it is crucial to be able to perform activities of daily living autonomously. In this respect the functioning of the upper limb is of enormous importance. It functions principally for reaching, grasping and manipulation. The arm transports the hand according to the task, context, and goal, placing the hand in the appropriate position and orientation in space to enable interaction with the environment and to achieve a specific goal.

[0003] It is known that the intention as well as the object itself, its physical characteristics and what is to be done with it affect the approach and the grasp as well as manipulation. Grip is typically categorized as either precision (pads of digits, index finger, and/or thumb) or power (whole hand). The anatomical structure of the hand and the cortical motor drive of the hand muscles allow a large number of combinations of joint rotations and of movement possibilities, (for the most fundamental actions as a prerequisite for hand function are opening and closing the fingers and the thumb).

[0004] Various types of central and peripheral diseases of the central nervous system, such as stroke, TBI, spinal cord injury, or multiple sclerosis may affect this ability significantly. Particularly stroke, which is a common medical condition with around 15 million victims worldwide every year, is one of the world wide leading causes of long-term disabilities. Even six months after the attack 55-75 % of the stroke survivors suffer from arm or hand disabilities. These deficits are related to a limited range of movement and a delayed initiation of motion. The movements of the hand, especially hand opening and closing, are crucial operations to perform daily life activities such as drinking and knob manipulation.

[0005] The state of the art considers robotic rehabilitation as a valuable adjunct to conventional stroke rehabilitation, which should be performed on a daily basis. Clinical studies already showed the effectiveness of robot assisted therapy in improving the motor deficits in stroke survivors. In some cases mechanical stimulation is considered even more effective than electrical stimulation. However, currently available mechanical devices are usually more expensive and difficult to prepare for daily usage.

[0006] Robotic devices have a strong potential to increase the frequency of training exercises and lower the costs as the patient can train without the presence of a therapist. However, currently available robotic rehabilitation devices like those disclosed in WO 2010/140984 A1 are large, heavy, cumbersome and expensive and therefore around 75 % of the developed devices are not well established in the daily routine of patients. Most of the available hand rehabilitation devices are based on an exoskeleton, which are bulky and difficult to adjust and to fix on the individual fingers. A device for daily use should be compact and light enough to be transported in the pocket of a coat or a backpack to have the device easily available. This is also highlighted in the article "Robotics for rehabilitation of hand movement in stroke survivors", F. Aggogeri et. al., Advances in Mechanical Engineering 11.4 (2019): 1687814019841921.

[0007] Handheld devices are for example disclosed in US 2013/0072829 A1 and US 7,740,561 B2. Even though these devices support portability, for the device in US 2013/0072829 A1 donning the device requires additional assistance and it is not easy to carry them along. The device in US 7,740,561 B2 is easy to carry but it just allows for passive training, as it does not comprise an actuator.

[0008] If a robotic device is used to perform rehabilitation exercises, the therapist's expertise focuses more on coaching, supervising and guiding the patient than during the straining physical activity of manual treatment. Therefore, it is important that the rehabilitation device monitors and records physical characteristics, which allow the therapist to assess the condition and rehabilitation of the patient. Such characteristics could be among others, the velocity dependent force that is required to open a spastic hand and the hand's range of movement.

SHORT DESCRITPTION OF THE INVENTION

[0009] The object of the present invention is to provide a device for improving the hand function without assistance from a caregiver or therapist. In particular, the device should be portable and easy to use.

[0010] The solution to the above stated problem is given by a handheld rehabilitation device comprising a housing, an actuator, a battery, a microcontroller and an opening mechanism including at least one opening plate. The opening mechanism comprises at least one axis of rotation, around which the at least one opening plate rotates from a closed position to an open position. The at least one opening plate is rotatably connected to the housing by means of radial bearings and rotates up to a maximum angle of rotation. The actuator, the battery and the microcontroller are preferably included into the housing. Hence, the complete housing fits into the palm of a hand. The microcontroller controls the speed and the maximum angle of rotation of the opening mechanism. Hence, the microcontroller also controls the actuator. The at least one opening plate rotates between the closed position and the open position by means of the actuator.

[0011] Thus, the design of the inventive rehabilitation device allows holding it with one hand. Due to its small size, the handheld device can be carried easily, for example in pockets, and it is possible to train and assess hand functions anytime and anywhere with the device. The at least one opening plate as well as the housing of the device may be connected to the hand via straps or similar means. This allows better guidance and fixations for certain exercises.

[0012] In a preferred embodiment the actuator is designed to fit into the small housing of the device. This allows to grab and hold the device with the palm of the hand. This compact design reduces outer dimensions to a minimum and maintains the device's center of gravity close to its centroid of volume. That allows to hold the device in the hand without further fixation during usage. For example, fixation may not be required on a table.

[0013] The rotational movement of the opening mechanism allows hand opening/closing exercises. To keep the device small the at least one opening plate may perform one rotational movement with a cleverly chosen center of rotation. More precisely, the center of rotation may be close to the metacarpophalangeal (MCP) joints of the human hand. If the handheld device shall imitate the hand opening/closing of a grasping movement for the four fingers, at least one opening plate may have its axis of rotation close to the MCP joint of the four fingers. If the device shall imitate the opening/closing movement of the thumb, the opening plate may have its axis of rotation close to the MCP joint of the thumb.

[0014] As the human hand can only open a certain angle, the actuator stops the rotation of the at least one opening plate from the closed to the opened position at a maximum angle of rotation. For a device with a single opening plate this maximum angle of rotation may be up to 180°. Preferably, the maximum angle of rotation is between 90 and 130°, wherein the angle may be larger for a device with a single opening plate compared to a device with two opening plates. Moreover, this angle can be adapted according to the muscle tone of the person using the device. It may also be adapted while using the device by measuring the torque that is needed to open the hand. If the torque exceeds a certain threshold, the opening mechanism will stop the rotation and the at least one opening plate will start to rotate from the opened position to the closed position. The angle of rotation may be increased during a training period, as soon as the person/patient starts to recover her/his impairment.

[0015] In another preferred embodiment the actuator of the handheld device comprises a motor. The motor drives the opening mechanism of the device. Preferably, a servo motor enables the rotational movement of the at least one opening plate. To keep the device small, only one motor may be integrated in the actuator. Moreover, the motor provides the required torque to open a hand with increased muscle contraction.

[0016] The actuator may also comprise a driving mechanism selected from the group consisting of gear drives, capstan drives, cam drives and any combination thereof. The driving mechanism allows transferring the motor torque to the opening mechanism.

[0017] The housing of the handheld device also comprises a battery as a power source. The battery ensures the function of the motor. By using a battery as the power source it is possible to make the inventive device portable and handheld. The portability of the device is especially important for the rehabilitation of hand movement in stroke survivors.

[0018] Furthermore, the handheld rehabilitation device may include at least one force sensor. Preferably, this at least one force sensor is implemented in the at least one opening plate. The force sensor changes its resistance indirectly proportional to a force applied to it. Hence, it may detect resistance forces applied to the surface of the at least one opening plate.

[0019] In this context the at least one force sensor allows to measure the required torque to open a hand. For this purpose also a distance sensor may be implemented in the device. Preferably, the distance sensor measures the distance between the at least one force sensor and the axis of rotation of the at least one opening plate. The measurement of force and distance allows then to compute the torque at the opening plate.

[0020] In another embodiment, the handheld device comprises an angle sensor. The angle sensor may be attached on the motor shaft or the opening mechanism. It allows measuring the angle of rotation and hence, the opening angle of the hand. With the help of this measurement also the opening velocity of the hand may be controlled via the angle sensor. As the opening of impaired hands with too high torques might be painful for the user, the maximum torque may be limited by a reduction of the controlled speed. This maximum torque can be adapted according to the muscle tone of the person using the device. The opening speed may be reduced or increased while using the device by means of the measured data and the microcontroller in connection with the actuator.

[0021] During a hand opening exercise the torque measurement gives a direct information about the resistance against the performing movement and can be used to compare the degrees of muscle contraction. Furthermore, the torque measurement at a given angular velocity can be used to measure spasticity in the hand.

[0022] In a very preferred embodiment the handheld rehabilitation device comprises a current sensor. The current sensor can measure the current of the actuator. With the help of the current also the torque of the actuator can be calculated. Thus, also the current sensor allows measuring the required torque for opening a hand which in turn allows an assessment of the stiffness of the hand. Thus, it is possible to estimate the stiffness of a patient's hand based on the current measurement. Summarizing, for the measurement of the torque via the current of the actuator only a single sensor - the current sensor - is needed, whereas for the measurement via force and distance at least two sensors are needed. The advantage of the current sensor is thus, that the inventive device would be less bulky and complex and the measurement would be simplified. Furthermore, in contrast to the current sensor, the measurement with the force sensor is always influenced by the placement of the fingers, hence, the measurement with the current sensor is more precise when measuring stiffness of the hand and torque.

[0023] In an alternative embodiment the handheld rehabilitation device comprises a finger opening plate and a thumb opening plate. The finger opening plate may be rotatably connected to one side of the housing and the thumb opening plate may be rotatably connected to the opposite side of the housing. The finger and thumb opening plates rotate preferably around different axes of rotation.

[0024] Including two opening plates - one for the thumb and one for the four fingers - in the device, enables an as natural as possible sequence of movements. The natural hand opening/closing movement can be approximated accurately with the help of the finger and thumb opening plate. Moreover, also for an intended grasping action two separate main movements are required, one for the four fingers and one for the thumb.

[0025] The thumb and the finger opening plate may have the same features apart from the axis of rotation and the direction of the rotation. To allow for a small device, the thumb opening plate may be smaller than the finger opening plate. The direction of rotation has to be different, as for the hand opening/closing movement the four fingers and the thumb move in opposite directions. To approximate a natural movement with the opening mechanism, the axes of rotation for the two opening plates differ. As stated above they may be close to the MCP joints of the fingers and the thumb, respectively.

[0026] A particularly preferred embodiment of the inventive device includes a linear sliding mechanism in the opening mechanism, which allows the opening plate to move radially away from the axis of rotation. When the at least one opening plate rotates between the closed and opened position without a linear sliding mechanism the fingers have to slide over the plate. This is because the MCP and the axis of rotation cannot be aligned, while at the same time maintaining a compact design. Further, the sliding mechanism supports an additional extension movement about the proximal interphalangeal and the distal interphalangeal joints. Including this linear sliding mechanism on top of the rotational mechanism in the opening mechanism ensures a natural sequence of motion during training or exercising with the help of the rehabilitation device. Moreover, with the help of this sliding mechanism also an involuntary bending of the fingers is prevented.

[0027] A possible implementation of the opening mechanism with the rotational as well as the linear movement includes at least one U-shaped rod. Preferably, this at least one U-shaped rod comprises one L-shape rod and one additional straight rod, which are connected to form a U-shape. The advantage of this embodiment of the rods in comparison to a single rod that is formed to a U-shape is that any bearing attached to the rod may still be removed after manufacturing the rods. The middle part of the at least one U-shaped rod, which corresponds to the at least one axis of rotation of the opening mechanism, may be connected to the housing with radial bearings and the at least one opening plate may be attached to the side parts of the U-shaped rod with linear bearings. The rod is preferably made from stainless steel and may have a diameter between 4 and 5 mm. The exterior part of the U-shape rod structure allows attaching the opening plate to the rod at each end with linear bearings. The linear bearings may be linear ball bearings. At least one U-shaped rod may also be connected to the actuator and is thus responsible for the rotational movement of the opening mechanism due to the radial bearings, preferably radial ball bearings, connecting the rod with the housing of the device. Hence, the linear bearings enable a smooth sliding movement during the rotational movement of the device. In the case of a device with two opening plates, one for the four fingers and one for the thumb, the device comprises two U-shaped rods for each of the plates, which may have different lengths. For the four fingers the linear displacement should be larger than for the tip of the thumb while the angle of rotation is increasing. Preferably, the U-shaped rod for the finger opening plate allows for a displacement between 25 and 60 mm and the U-shaped rod for the thumb opening plate allows for a displacement between 10 and 30 mm. Furthermore, both ends of the at least one U-shaped rod may be locked with a circlip or locking ring or threaded and locked with a nut.

[0028] In another embodiment the at least one opening plate comprises up to four vibration touch pads. Preferably, each vibration touch pad comprises a vibration motor and a force sensor. The force sensor may be a force-sensing resistor. These vibration touch pads allow measuring the reaction time of patients as well as assessing the maximum fingertip force applied to the vibration touch pads. For measuring the reaction time the vibration motors mechanically stimulate the fingertips of the user. With the help of the force sensors it may be evaluated how fast a user can correctly identify which of the fingers is stimulated. When the user presses the corresponding finger onto the vibration touch pad the force sensor measures the applied force. The vibration may stop as soon as the touch pad is pressed by the user with a force higher than a certain threshold. The threshold may be adjusted according to the capability of the individual user.

[0029] In another embodiment the housing comprises at least three LEDs, which are preferably mounted on the top, left and right surface of the housing. The color of the LEDs may change from red to green, when turning the device. The LEDs may indicate certain instruction for the user. For example, with the guidance of the LEDs an exercise for the tilt movements of the wrist may be performed with the handheld rehabilitation device. Furthermore, one of the LEDs may also indicate a low battery status.

[0030] The device may also comprise an inertial measurement unit and an SD-card inside the housing. The inertial measurement unit may measure accelerations and the angular velocity especially during exercises which aim to improve the range of motion of the wrist. The SD-card allows storing measurement results. Moreover, data may also be send to a computer via a serial port or wireless communication. These measurements allow calculating the orientation of the hand over time.

[0031] The device may also interface with virtual reality/augmented reality (VR/AR) applications via a PC, tablet or smart phone. Moreover, a graphic user interface may allow monitoring any performance in real time.

[0032] In order to transfer the torque provided by the actuator to the opening mechanism of the inventive device several force transmission systems can be considered.

[0033] One example of a force transmission system is given by an actuator comprising a gear wheel system, which may involve at least two gear wheels. The gear wheel system may couple the motor to the opening mechanism, such that the torque is transmitted to the at least one opening plate. Another possibility for a force transmission system is an actuator comprising a cam system with a plate, wherein the plate comprises at least one cam profile. The plate may be rotated by the motor and at least one handle may be connected at one end to the at least one cam profile and at the other end to a fixed point. In an alternative embodiment the actuator comprises a parallelogram mechanism which could involve a gear drive.

[0034] A particularly preferred embodiment of the force transmission system is given by an actuator comprising a capstan drive, wherein the capstan drive involves one input drum and at least one output drum. The cable of the capstan drive may be fixed on the at least one output drum and wrapped around the input drum. To increase the friction of the cable it may be wrapped around the input drum several times. The at least one output drum may be attached to the at least one opening plate. Preferably, one end of the cable of the capstan drive is adjustably attached to the at least one output drum by an adjusting screw to increase preload force. Hence, this mechanical force transmission first transmits the torque from the motor to the input drum, which in turn transmits the force via the cable to the output drum that is mechanically connected to the opening mechanism. Preferably, the diameter of the input drum is smaller than the diameter of the at least one output drum. This allows increasing the torque of the motor.

[0035] For the embodiment with two opening plates the force transmission system comprises also two output drums, wherein the cable is attached to the first output drum, wrapped around the input drum (preferably several times), crossed over and attached to the second output drum. Hence, different rotation directions for the first and second output drum may be achieved. Moreover, the diameters of the two output drums may be different, to set the ratio of the angle of rotation of the finger opening plate to the angle of rotation of the thumb opening plate. Preferably, this ratio may be chosen in a way that the angle of rotation for the fingers is much greater than the angle of rotation of the thumb at each step during a hand opening/closing movement, which is close to the natural opening movement of a hand.

[0036] The present invention also relates to a method for performing a hand opening/closing exercise with the inventive handheld rehabilitation device. This method comprises the steps

- rotating the at least one opening plate from the closed position to the open position, wherein the opening speed of the opening mechanism is constantly adjusted by measuring the torque required to move the at least one opening plate,
- stopping the at least one opening plate at a certain angle of rotation as soon as a torque threshold or the adjusted maximum range of motion is reached,
- rotating the at least one opening plate from the open position to the closed position,
- starting again with step one,

wherein the measured torque is preferably saved and used to compute the stiffness and estimate the spasticity level.

[0037] This hand opening/closing exercise enables patients suffering from increased muscle tone to autonomously train their hand motor functions everywhere and at any time. Moreover, the device allows adjusting the opening speed and the angle of rotation depending on the training level of the person. As the actuator stops rotating the at least one opening plate as soon as a certain torque threshold is reached, no injuries can occur during the training. By measuring the resistance finger force as well as the motor current needed to overcome the torque of the hand, the spasticity of the hand may be assessed.

[0038] Furthermore, the present invention also relates to a method for performing a wrist orientation exercise and an assessment of the range of motions in the wrist with the handheld rehabilitation device with LEDs mounted on the housing of the device. The LEDs indicate the desired wrist orientation. The method comprises the steps

- randomly switching on one of the at least three LEDs on the housing, which lights up in red,
- changing the light of the randomly selected LED from red to green as soon as the LED is essentially facing skywards,
- starting again with step one,

wherein accelerations, and the angular velocity are measured with the inertial measurement unit, wherein the corresponding data is saved.

[0039] Flexion/extension and pronation/supination of the wrist are key movements when performing activities of daily living. The wrist orientation exercise allows to train these movements. For this purpose the LEDs mounted on the top, left, and right surface of the device indicate desired wrist orientation. One of the LEDs will be lit in red, requiring a patient to then rotate the device such that the surface indicated by this LED will be on top (i.e. facing skywards). As soon as the device is within a desired angle range, the colour of the light changes from red to green. The green light thus confirms the completion of a single task. The angle range may be adjusted according to the impairment of the patient. Thereafter, another LED is randomly selected to continue the exercise. Accelerations and the angular velocity during the procedure may be measured with the inertial measurement unit and data may be saved to the SD-card or plotted in a graphic user interface. With the help of this data the range of motion of the hand may be estimated.

[0040] The invention also relates to a method for performing tactile localization and grip strength enhancing exercises with a handheld rehabilitation device including vibration touch pads on the at least one opening plate. These vibration plates mechanically stimulate the fingertips. The method comprises the steps

- randomly turning on one of the vibration motors,
- turning off the vibration motor as soon as the corresponding vibration touch pad is pressed with a force higher than a certain threshold,
- starting again with step one,

wherein the applied fingertip force is measured with the force sensor, wherein the time until force is applied to the vibration touch pad after the vibration started is preferably measured, wherein the corresponding data is saved.

[0041] During this exercise, a patient is asked to correctly localize a randomly generated vibration stimulus. To respond the patient can press the corresponding touch pad, as soon as the stimulus is perceived. The vibration is turned off when pressing the touch pad with a force higher than a threshold. The latter can be adjusted according to the capability of individual patients. The task permits to measure the reaction time of patients as well as to assess the maximum fingertip force applied to the vibration touch pad. With the help of this exercise also the finger localization is trained. In a similar exercise the vibration intensity of a randomly selected touch pad may be slowly increased until the correct touch pad is pressed. This allows assessing the patients' absolute threshold for the vibration stimulus.

[0042] With the help of these exercises also the recovery process of the patients can be monitored by saving the data obtained during the exercise either on an integrated SD-card or send it directly to a PC or smart phone via wireless communication or a USB connection. Furthermore, the device can also be connected via a VR/AR application to a PC, tablet or smart phone. Besides, the performance may be monitored in real time via a graphic user interface (GUI). These means allow for an assisted training with the inventive device and also help to motivate the patients for the training by using the VR/AR application and obtaining real time feedback.

DETAILED DESCRIPTION OF THE INVENTION

[0043] The foregoing and other objects, features and advantages of the invention will become more apparent from the following detailed description, which proceeds with reference to the accompanying figures.

Fig. 1a	shows the two separate main movements - one for the four fingers and one for the thumb - needed for an intended hand grasping action.
Fig. 1b	shows schematically a perspective view (left and middle figure) and a top view (right figure) of the inventive handheld rehabilitation device with one opening plate.
Fig. 1c	shows schematically a bottom view (left figure) and a perspective view (right figure) of the inventive handheld rehabilitation device with two opening plates.
Fig. 2a, 2b	show a schematic drawing of a torque transmission of the inventive handheld rehabilitation device including a combination of a capstan drive and gear wheels.
Fig. 3	shows a schematic drawing of an actuator including a cam system with two profiles.
Fig. 4	shows a schematic drawing of an actuator including a parallelogram mechanism.
Fig. 5a, 5b	depict the actuator of an inventive handheld rehabilitation device including a capstan drive with an input drum and one output drum (Fig. 5a) or two output drums (Fig. 5b).
Fig. 6a, 6b	show schematic drawings of the opening mechanism of the finger plate side including a sliding mechanism (Fig. 6a) and of the opening mechanism of the finger and thumb plate implemented into the housing of the inventive handheld rehabilitation device in a perspective view (left figure in Fig. 6b) and a top view (right figure in Fig. 6b).
Fig. 7a, 7b	show the opening motion of a hand holding a finger and thumb plate (Fig. 7a) of the inventive device with an exemplary axis of rotation of for each of the two plates and the opening motion of a single opening plate (Fig. 7b) with sliding mechanism.
Fig. 8	shows the integration of a force sensing resistor into the finger plate of the inventive handheld rehabilitation device.
Fig. 9	shows a vibration finger pad.

[0044] For the design and construction of the inventive handheld rehabilitation device with one or two opening plates the principle of action for the force transmission as well as the position of the axes of rotation for the opening mechanism with the opening plates is essential.

[0045] As can be seen in Fig. 1a for the grasp movement of a hand two separate main rotations about two axes of rotation are required. The four fingers and the thumb move always in opposite directions. For the device, which includes only a single opening plate 1 for the four fingers, this finger opening plate 1 will simply rotate in the same or opposite direction as the motor shaft respectively, in the housing h of the device. A schematic depiction of a handheld rehabilitation device with one opening plate 1 is shown in Fig. 1b. When the inventive rehabilitation device includes an additional opening plate 2 for the thumb, as shown in Fig. 1a and Fig. 1c, for this thumb opening plate 2 the rotational direction has to be changed. In particular, the axis of rotation of the finger opening plate 1 should be different from the axis of rotation of the thumb plate 2, to allow for natural grasp movements. As the inventive device shall be kept small, only a single actuator or motor respectively, is used for performing both rotation movements around the two axes of rotation. Thus, one of the opening plates 1, 2 may rotate in the same direction as the motor shaft and the other opening plate 1, 2 may rotate in the opposite direction. In Fig. 1a and Fig. 1c (left side) also the center of rotation for the finger opening plate 1' and the center of rotation for the thumb opening plate 2' are shown.

[0046] The schematic illustration in Fig. 1b shows the housing h of the inventive device, which fits preferably into the palm of a hand. To ensure the fixation, a finger strap can be preferably attached outside of the opening plate 1 to place the four fingers under the strap. One additional Velcro strap fixed on the outside of the housing h may be used to hold the device more comfortably. The single opening plate 1 is depicted in three different positions in Fig. 1b. On the left hand side, the opening plate 1 is half opened, in the middle the opening plate 1 is in the closed position and in the top view on the right hand side the opening plate 1 is in the opened position. In the opened position the maximum angle of rotation α is reached. The maximum angle of rotation α may be up to 180°, preferably it is between 90 and 130°.

[0047] In Fig. 1c the opening mechanism comprises two opening plates 1, 2. In the bottom view on the left hand side the two opening plates 1, 2 are in the open position and in the perspective view on the right hand side the two opening plates 1, 2 are in the closed position. The shape of the housing h is not limited to any of the exemplary embodiments (for example in Fig. 1b and 1c) and may be adapted to any other practical design. In Fig. 1c one of the opening plates is the thumb opening plate 2, which is smaller than the finger opening plate 1. This allows to still hold the rehabilitation device nicely in the palm while the opening plates 1, 2 rotate from the closed to the opened position. A silicon strap is preferably placed on the each opening plates 1, 2 in order to avoid dropping the device from the hand and support the hand opening/closing exercise. One additional strap around the palmar and dorsal surface of hand can be placed to provide comfortable opening/closing movements and enhance the wearability. In the open position the maximum angle of rotation α is reached, which is given by the sum of the angle of rotation of the finger opening plate af and the angle of rotation of the thumb opening plate α_t.

[0048] Fig. 2 - 5b show several examples of possible torque transmission mechanisms that allow obtaining the above described movement of the opening plates 1, 2.

[0049] In Fig. 2a an exemplary mechanism consisting of a capstan drive and a pair of gear wheels 6, 6' is shown. This mechanism may be used for a device with two opening plates 1, 2. The capstan drive is transmitting the rotation of the motor shaft to one turning rod and a pair of gear wheels 6, 6' to transmit the rotation and change its direction to another rod. The capstan drive may include an input drum 3, on which an external torque is applied via the actuator, and an output drum 4, which are connected via a cable 5. The cable 5, which is wrapped around the input drum 3 and fixed with both ends on the output drum 4, transfers the rotation of the input drum 3 to the output drum 4. The output drum 4 may be fixed to a first gear wheel 6, which is connected to a turning rod. In Fig. 2a the first gear wheel 6 is geared with a second gear wheel 6', which is thus rotating in the opposite direction. By varying the ratio between the diameter of the input drum 3 and the output drum 4 the torque may be increased. Moreover, the ratio between the diameters of the gear wheels 6, 6' can define the ratio between the angle of rotation of the thumb opening plate α_t and the angle of rotation of the finger opening plate α_f (see also Fig. 1c). Fig. 2b shows another possible combination of the gear wheels and the capstan drive. There, the first gear wheel 6 is connected to the input drum 3 and is geared again with the second gear wheel 6', which is driving the thumb opening plate 2. Thus, the difference to the arrangement in Fig. 2a is that both followers, the output drum 4 and the second gear wheel 6', are directly connected to the driver, the input drum 3. In Fig. 2a the follower which is driving the finger opening plate, i.e. the second gear wheel 6', is driven by the other follower, i.e. the output drum 4 with the first gear wheel 6.

[0050] Fig. 3 shows an alternative mechanism for the force transmission system comprising a cam mechanism. In this embodiment a plate 8' is connected to the motor shaft 7 and at least one cam profile 8 is attached to this plate 8'. In the exemplary model in Fig. 3 two cam profiles 8 are fixed on the plate 8' of the cam mechanism. Thus, the mechanism in Fig. 3 may be used for an inventive device with an opening mechanism comprising two opening plates 1, 2. The at least one cam profile 8 is connected to a handle 10 via a joint 9. The other end of the handle 10 may be connected to a fixed point. Thus, when the actuator initiates a rotation of the cam plate 8' this causes a movement of the handle 10. More precisely, the rotational movement of the cam plate 8' is converted into a hand opening movement of the handle 10. In the example in Fig. 3 the rotation of the plate 8' causes an increase and decrease of the angle between the two handles 10.

[0051] Another embodiment of a mechanical force transmission is shown in Fig. 4. This mechanism consists of a parallelogram mechanism and preferably a gear drive. The mechanism in Fig. 4 allows a force transmission to two opening plates 1, 2. One parallelogram mechanism is driven by the motor shaft 7 and the other parallelogram mechanism is following via the gear drive 11. In Fig. 4 the parallelogram mechanism is shown on the left hand side in closed position and on the right hand side in open position.

[0052] The preferred embodiment for a force transmission system is shown in Fig. 5a-5b. In this embodiment the actuator comprises a capstan drive. This cable based mechanism allows for a small and lightweight device and enhances the design flexibility. Moreover, the capstan drive offers low inertia, no backlash, high stiffness and the possibility to have a spacing between the gear wheels. In Fig. 5a a capstan drive for a handheld device with one opening plate 1 is shown. The input drum 3 (also called motor drum) is connected via a cable 5 to the output drum 4. The cable 5 is wrapped around the input drum 3 and attached to the output drum 4 with both ends via fixations 12. The fixations 12 may correspond to wrapping the cable 5 around screws, which allows to preload the cable 5. As can be seen in Fig. 5a the cable 5 is crossed over when going from the input drum 3 to the output drum 4. Hence, the output drum 4 has the reverse rotation than the motor shaft. It is also possible not to cross the cable 5 to change the direction of rotation, however, in this case the contact area between the motor shaft and the cable 5 would be lower. Thus, also the friction would be reduced.

[0053] The cable 5 of the capstan drive allows to transmit the torque between the input and output drum 3, 4. Force equilibrium may be established between the cable 5 and the drums 3, 4 via friction. The required friction force is established by preloading the cable 5 with a preload force. This friction force can be increased by wrapping the cable 5 several times around the input drum 3.

[0054] As can be seen in Fig. 5a the diameter of the input and output drum 3, 4 differ, as the transmission rate depends on the ratio of the drum diameters. The transmission ratio is equal to the ratio of the radius of the output drum 4 to the radius of the input drum 3. For example, a capstan drive with a transmission ratio of 2, that is, an output drum 4 that is twice as large as the input drum 3. A certain torque is needed to open a spastic hand, such that the torque of the opening mechanism may overcome the forces, which are present due to the constant contraction of the muscles. Using a transmission ratio higher than 1, at a constant opening torque a smaller motor can be used. The capstan drive is an efficient coupling of the actuator to the opening mechanism.

[0055] The capstan drive in Fig. 5b is designed for an opening mechanism with two opening plates 1, 2. Again the finger opening plate 1 allows for an opening movement of the four fingers, whereas the thumb opening plate 2 allows an opening of the thumb. Hence, the capstan drive in Fig. 5b must have two output drums 4, 4'. One of them is the finger output drum 4 transferring the torque to the finger opening plate 1 and the other one is the thumb output drum 4' transferring the torque to the thumb opening plate 2. In this embodiment the cable 5 of the capstan drive is firstly attached at one end to the thumb output drum 4' via a fixation 12. Then the cable 5 may be wrapped around the input drum 3, preferably several times. Afterwards, the cable 5 may be crossed over to achieve the different rotation directions of the two output drums 4, 4' and attached to the finger output drum 4 again via fixation 12. From there the cable 5 goes back to the input drum 3 and finally back to the thumb output drum 4', where it may be fixed via a fixation 12. Preferably, the cable 5 is attached to the thumb output drum 4' on one side by an adjustable fixation 12' like an adjusting screw. This allows to increase the preload force on the cable 5 after assembling it.

[0056] Similar to the embodiment in Fig. 5a the ratios of the drum diameters in Fig. 5b allow on the one hand to increase the torque and on the other hand to set the ratio of the angle of rotation of the finger opening plate α_f to the angle of rotation of the thumb opening plate α_t. Firstly, for the desired transmission rate the diameter of both output drums 4, 4' should be bigger than the diameter of the input drum 3 to increase the provided torque as described above. Secondly, the diameter of the thumb output drum 4' should be preferably two times bigger than the diameter of the finger output drum 4. Then, a natural hand opening process can be imitated with the inventive handheld device. This is because the four fingers move about 60° and the thumb about 30° when the hand reaches an angle of rotation α of 90°.

[0057] In an exemplary embodiment the diameter of the input drum 3 is preferably between 12 and 20 mm, the diameter of the finger output drum 4 is preferably between 20 and 28 mm and the diameter of the thumb output drum is preferably between 44 and 52 mm. The diameter of the input drum 3 allows to reach a high wrap angle, that is, the cable 5 may be wrapped around the input drum 3 several times to increase the friction force. To increase the contact area between the cable 5 and the input drum 3, an outer thread may be cut on the input drum 3.

[0058] In contrast to the opening mechanism with one opening plate 1 in Fig. 5a the opening mechanism with two opening plates 1, 2 in Fig. 5b enables a rotation of thumb and fingers, respectively, around two different axes of rotation. This allows for a more natural grasping movement.

[0059] Fig. 6a shows the opening mechanism for the at least one opening plate 1 (it works analogous for any other opening plate) in more detail. In the embodiment in Fig. 6a the opening mechanism involves a rotational as well as a linear movement. In order to open the hand, the opening plate 1, which is performing the rotational and linear movement, is attached to the corresponding output drum 4 of the force transmission system.

[0060] While most of the parts for the device are preferably manufactured by injecting molding using for example non-allergenic acrylic or polyetheretherketone (PEEK), the parts for the force transmission and the opening mechanism are preferably mainly manufactured out of aluminum and steel. The main part of the opening mechanism in the example in Fig. 6a is a rod 15, preferably between 4 and 5 mm in diameter and preferably made out of stainless steel, which may be bended to a U-shape. The U-shaped rod may consist of a L-shaped rod and a straight rod which are connected together to from a U-shape. This U-shaped rod may be rotatably connected to the handheld device by the use of two radial bearings 14, preferably radial ball bearings, with an outer diameter preferably between 5 and 9 mm. Furthermore, the rod 15 may be attached to an output drum 4 of the force transmission system. The middle part of the U-shaped rod corresponds to the axis of rotation of the opening mechanism and is hence driven by the actuator. The at least one opening plate 1 may be glidingly connected to the rod 15 with two linear bearings 13, preferably linear ball bearings, to ensure a smooth sliding movement during the rotational movement of the device. Both ends of the rod 15 may be locked with a circlip or locking ring or threaded and locked with a nut.

[0061] This exemplary mechanism in Fig. 6a enables a linear displacement of maximum 33 mm for the fingertips (see Fig. 6a on the right) and 18 mm for the tip of the thumb (see also Fig. 6b) while the angle of rotation α is increasing. More precisely, the opening mechanism in Fig. 6a enables the opening plates 1, 2 and the fingers and thumb to slide radially away from the axis of rotation during the opening/closing of the hand. On the one hand the rotating movement of the opening plates 1, 2 opens/closes the hand and on the other hand the linear movement of the opening plates 1, 2 leads a natural opening movement of the fingers and the thumb. This ergonomics of the opening mechanism enables any person to use the inventive handheld device without the support of a caregiver or therapist. Moreover, the opening mechanism prevents any improper strain of the finger joints.

[0062] In Fig. 6b this opening mechanism is connected to the housing h of the device, which is comprising a capstan drive. On the left hand side in Fig. 6b a device with a single opening plate 1 is shown. In this case the capstan drive comprises one output drum 4, which is coupled to the input drum 3 and drives the U-shaped rod 15. On the right hand side in Fig. 6b a device with two opening plates, one finger opening plate 1 and one thumb opening plate 2, is shown. The capstan drive comprises two output drums in this embodiment, a finger output drum 4 driving the finger opening plate 1 around its axis of rotation 1' and a thumb output drum 4' driving the thumb opening plate 2 around its axis of rotation 2'. As explained above two U-shaped rods 15 allow for the rotational and linear movement of the finger and thumb opening plate 1, 2.

[0063] In order to achieve the best possible sequence of motion for the hand during the opening and closing action it is essential to determine the center of rotation (COR) for the opening plates 1, 2. Clearly, the best option would be to put the COR of the opening mechanism of the handheld rehabilitation device exactly at the position of the COR of the fingers. However, as already mentioned above, the human hand and especially the thumb are highly complex and a grasping movement cannot be described by only two rotations. Therefore, a reasonable compromise between a small and handheld device, which is easy to use and a highly natural movement of the hand, has to be found. A preferred model for such a compromise is shown in Fig. 7a and Fig. 7b.

[0064] In the embodiment in Fig. 7a two opening plates 1, 2 are considered. The axis of rotation of the thumb opening plate 2' may be close to the thumb's metacarpophalangeal (MCP) joint 16, whereas the axis of rotation of the finger opening plate 1' may be between the finger's proximal interphalangeal (PIP) joints 17 and the finger's metacarpophalangeal (MCP) joint 16' (see Fig. 7). For this design of the axes of rotation 1', 2' the closed position (left hand side of Fig. 7) is very similar to the resting posture of a human hand. Furthermore, the motion sequence of the hand starts around the finger's PIP joints 17 (middle of Fig. 7) and ongoing rotation of the finger opening plate 1 towards the opening position results in an opening of the finger's MCP joints 16' (right hand side of Fig. 7). The additional involvement of the finger's PIP joints 17 leads to a more natural sequence of motion as well as the possibility to perform therapy by stages. More precisely, in case of a high contraction, the inventive device could be set up to only open the finger's PIP joints 17 in a first step and continue with the full movement after an improvement in mobility is reached. Again, any improper strain of the finger joints is prevented in this case.

[0065] Fig. 7b shows in more detail the opening motion of an opening mechanism with a single opening plate 1. The opening sequence opens the four fingers from the index finger to the little finger using one rotational mechanism as depicted. The additional sliding mechanism provides a guidance of the finger tips while the angle of rotation α is increasing. In Fig. 7b the axis of rotation of the opening plate 1' is also not corresponding to the finger's MCP joints 16'. The finger's PIP joints 17 as well as the finger's distal interphalangeal (DIP) joints 17' perform a guided motion with the help of the opening plate 1 as can be seen in Fig. 7b from left to right. The sliding movement guides the fingertips naturally while opening the hand. In the embodiment in Fig. 7b the finger's DIP joints 17' are fixed to the opening plate 1 via straps 20, in order to fix the DIP joints 17' in a predefined extension. Moreover, in this exemplary embodiment also the wrist is fixed via straps 19 to keep the wrist in an extended position during the hand opening exercise. Thus, a flexed position of the wrist is avoided, which is especially helpful for patients with spastic hands.

[0066] Another possibility for the design of the axes of rotation 1', 2' which is not depicted in the figures would be to put both the axis of rotation for the thumb opening plate 2' and the axis of rotation for the finger opening plate 1' as close as possible to the MCP joints of the fingers and the thumb 16',16. In this case, the focus is on the movement around the MCP joints. However, the sequence of motion of the hand is not as natural as in the embodiment in Fig. 7a.

[0067] In order to compare impairments of affected people or to monitor and evaluate a recovery some data may be measured while using the inventive handheld rehabilitation device. This data may be either stored on an SD-card, which may be included in the device's housing h or directly send to a computer or mobile phone e.g. via wireless connections like Bluetooth or Wi-Fi or via a USB-connection. The most expressive measurable parameter is the required torque to open the hand. It gives a direct information about the resistance against the performing movement and can be used to compare the degrees of muscle contraction. In a further step, it could also be used to measure spasticity in the hand.

[0068] One possibility to determine the torque is to measure the forces applied to the opening plates 1, 2 by fingers and thumb. For the force measurement force sensors like a force sensing resistor (FSR) 18 may be used. Such force sensors 18 are for example developed by Interlink Electronics. These sensors 18 are basically resistors which decrease their resistance with increasing force applied to them.

[0069] Such a force sensor 18 can be implemented in the opening plates 1, 2. At least one force sensor 18 is preferably mounted in each opening plate 1, 2 in a way that the finger and/or thumb force is measured tangentially to the opening path of the fingertips or the thumb. This allows monitoring the maximum torque of the device.

[0070] In a certain embodiment the force sensor 18 is mounted in the finger opening plate 1, which is connected to the U-shaped rod 15, as shown in Fig. 8. The force sensor 18 may be integrated into the finger opening plate 1 by using foam material 23 and screws 22 and springs 22'. The foam material 23 allows preventing a preload and hence, no force is measured without any additional load. In order to recognize small loads, screws 22 and springs 22' are attached, as the foam 23 alone would not recognize small loads.

[0071] To determine the finger and thumb torque, furthermore, the distances between the rotational axes and the force sensors 18 have to be measured continuously due to the sliding mechanism of the opening plates 1, 2. For the device with two opening plates, the finger opening plate 1 and the thumb opening plate 2, for each opening plate a different way to determine the position may be implemented, as the shape as well as the sliding distances may be different for the finger and thumb opening plate 1, 2.

[0072] In a preferred embodiment a time of flight sensor is chosen for the determination of the location of the finger opening plate 1. This sensor may be mounted to the end of the finger opening plate 1. As the time of flight sensor needs a minimum distance to work, a different method has to be used for the smaller thumb opening plate 2. For example, a linear potentiometer could be used in case of the thumb opening plate 2.

[0073] Another possibility to measure the required torque to open the hand is given by measuring the motor current during the opening process via a current sensor. Hence, by measuring the current the torque may be estimated. In this preferred embodiment the handheld rehabilitation device would be less bulky and complex, as the distance and force sensors would not be necessary. Moreover, this would also result in a more stable and smooth sliding mechanism.

[0074] In a certain embodiment the opening plates 1, 2 correspond to vibration plates. An example for such a vibration finger plate is shown in Fig. 9. It can be replaced by a stationary plate or it can be fixed to the housing h. The vibration finger plate comprises a vibration touch pad 25 which is located on the finger opening plate 1 or on the thumb opening plate 2. Preferably, for each finger one vibration touch pad 25 is provided. Moreover, each vibration finger plate comprises also a vibration motor 24 and a force sensor 18. In the embodiment in Fig. 9 also a damper 21 and memory foam 23 are provided.

[0075] The vibration motor 24 allows to mechanically stimulate the fingertip. When the touch pad 25 is pressed a pressure is applied to the force sensor 18 via the touch pad housing 25 onto the damper 21. The damper 21 ensures that the pressure is distributed evenly over the entire surface of the force sensor 18. The additional memory foam 23 helps preventing cross stimulation to adjacent touch pads 25. In addition, the memory foam 23 maintains a uniform distance between the touch pad housing 25 and the force sensor 18, thus preventing incorrect detection of vibrations as finger pressing forces.

[0076] These vibration plates can be employed for sensory assessment and sensory training applications with the help of the inventive rehabilitation device. For example, tactile localization and grip strength enhancing exercises for individual fingers can be carried out autonomously with the help of the vibration plate. During an exercise, a patient is asked to correctly localize a randomly generated vibration stimulus. To respond the patient can press the corresponding touch pad 25, as soon as the stimulus is perceived. The vibration is turned off when pressing the touch pad with a force higher than a threshold. The latter can be adjusted according to the capability of individual patients. The task permits to measure the reaction time of patients as well as to assess the maximum fingertip force applied to the vibration touch pad.

[0077] Summarizing, the device is suitable for a larger range of hand motor impairments. Specifically, the handheld rehabilitation device allows improvement of hand functionality in stroke survivors. It enables passive hand movement to preserve hand functionality and avoid contraction of muscles, which could be used for patients with mid-severe hand function impairments. The device can also provide active-assistive training with the device itself or with VR/AR applications via a mobile phone application or a computer. Furthermore, object assessment of patients' hand function can be carried out in terms of measurements of the range of motion of wrist orientation, hand opening, sensory stimulation and perception via a vibrotactile feedback, and stiffness of a hand.

Claims

1. Handheld rehabilitation device comprising

- a housing (h),
- an actuator,
- a battery,
- a microcontroller and
- an opening mechanism including at least one opening plate (1) rotatably connected to the housing (h) by means of radial bearings (14) from a closed position to an open position around at least one axis of rotation (1') up to a maximum angle of rotation (α), wherein the actuator, the battery and the microcontroller are included inside the housing (h),

wherein the microcontroller controls the speed and the maximum angle of rotation (α) of the opening mechanism,
wherein the at least one opening plate (1) rotates between the closed position and the open position by means of the actuator.

2. Handheld rehabilitation device according to claim 1, wherein the actuator comprises a motor and a driving mechanism selected from the group consisting of gear drives, capstan drives, cam drives and any combination thereof, wherein the motor is preferably a servo motor.

3. Handheld rehabilitation device according to one of the claims 1 or 2, **characterized by** at least one force sensor (18), wherein the at least one force sensor (18) is implemented in the at least one opening plate (1).

4. Handheld rehabilitation device according to one of the claims 1 to 3, **characterized by** a distance sensor, wherein the distance sensor measures the distance between the at least one force sensor (18) and the at least one axis of rotation (1') of the opening mechanism.

5. Handheld rehabilitation device according to one of the claims 1 to 4, **characterized by** a current sensor, wherein the current sensor measures the current of the actuator.

6. Handheld rehabilitation device according to one of the claims 1 to 5, **characterized by** an angle sensor, wherein the angle sensor measures the angle of rotation (a).

7. Handheld rehabilitation device according to one of the claims 1 to 6, wherein the opening mechanism comprises a finger opening plate (1) and a thumb opening plate (2), wherein the finger opening plate (1) is rotatably connected to one side of the housing (h) and the thumb opening plate (2) is rotatably connected to the opposite side of the housing (h), wherein the finger and thumb opening plate (1, 2) rotate around different axes of rotation (1', 2').

8. Handheld rehabilitation device according to one of the claims 1 to 7, wherein the opening mechanism comprises a linear sliding mechanism.

9. Handheld rehabilitation device according to claim 8, wherein the opening mechanism comprises at least one U-shaped rod (15) or at least one L-shape rod and at least one straight rod connected to form the at least one U-shaped rod (15), wherein the middle part of the at least one U-shaped rod (15) corresponds to the at least one axis of rotation (1') and is rotatably connected to the housing (h) with radial bearings (14), wherein the side parts of the at least one U-shaped rod (15) are glidingly connected to the at least one opening plate (1) with linear bearings (13).

10. Handheld rehabilitation device according to one of the claims 1 to 9, wherein the at least one opening plate (1) comprises up to four vibration touch pads (25), wherein each vibration touch pad (25) comprises a vibration motor (24) and a force sensor (18).

11. Handheld rehabilitation device according to one of the claims 1 to 10, wherein the housing (h) comprises at least three LEDs on its surface, wherein the at least three LEDs are mounted on the top, left and right surface of the housing (h), wherein the microcontroller controls the at least three LEDs.

12. Handheld rehabilitation device according to one of the claims 1 to 11, wherein an inertial measurement unit and an SD-card are arranged inside the housing (h).

13. Handheld rehabilitation device according to one of the claims 1 to 12, wherein the actuator comprises a capstan drive, wherein the capstan drive involves one input drum (3) and at least one output drum (4), wherein the cable (5) of the capstan drive is fixed on the at least one output drum (4) and wrapped around the input drum (3), wherein the at least one output drum (4) is attached to the at least one opening plate (1), wherein the diameter of the input drum (3) is smaller than the diameter of the at least one output drum (4).

14. Method for performing a hand opening/closing exercise with a handheld rehabilitation device according to any of the claims 1 to 13 comprising the steps

- rotating the at least one opening plate (1) from the closed position to the open position, wherein the opening speed of the opening mechanism is constantly adjusted by measuring the torque required to move the at least one opening plate (1),
- stopping the at least one opening plate (1) at a certain angle of rotation (a) as soon as a torque threshold is reached,
- rotating the at least one opening plate (1) from the open position to the closed position,
- starting again with step one,

wherein the measured torque is preferably saved and used to compute the stiffness and determine the spasticity.

15. Method for performing a wrist orientation exercise and an assessment of the range of motions with a handheld rehabilitation device according to claim 11 and any of the claims 1 to 10 and 12 to 13, wherein the LEDs mounted on the housing (h) of the device indicate the desired wrist orientation, wherein the method comprises the steps

- randomly switching on one of the at least three LEDs on the housing (h), which lights up preferably in red,
- changing the light of the randomly selected LED preferably from red to green as soon as the LED is essentially facing skywards,
- starting again with step one,

wherein accelerations and the angular velocity are measured with the inertial measurement unit, wherein the corresponding data is saved.

16. Method for performing tactile localization and grip strength enhancing exercises with a handheld rehabilitation device according to claim 10 and any of the claims 1 to 9 and 11 to 13, wherein the vibration touch pads (25) mechanically stimulate the fingertips, wherein the method comprises the steps

- randomly turning on one of the vibration motors with variable intensities (24),
- turning of the vibration motor (24) as soon as the corresponding vibration touch pad (25) is pressed with a force higher than a certain threshold,
- starting again with step one,

wherein the applied fingertip force is measured with the force sensor (21), wherein the time until force is applied to the vibration touch pad (25) after the vibration started is preferably measured, wherein the corresponding data is saved.

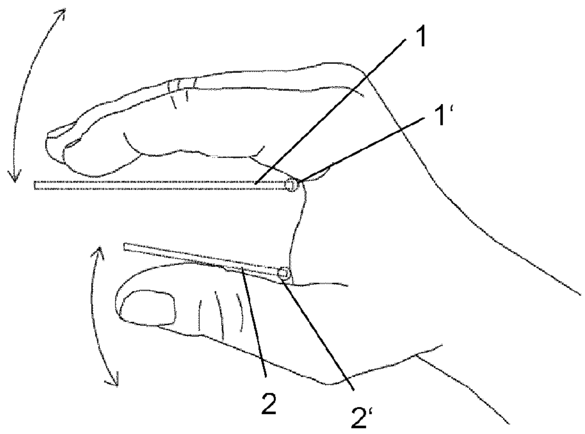

Fig. 1a

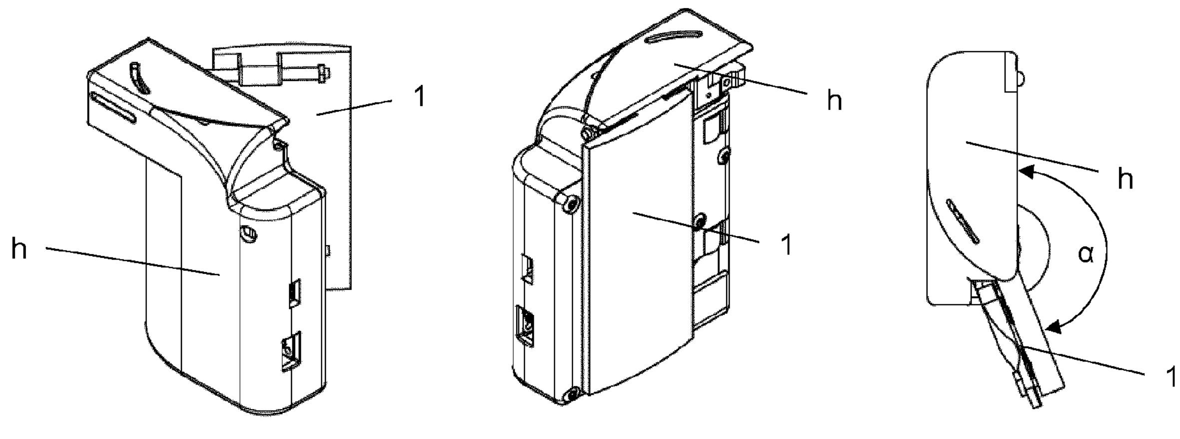

Fig. 1b

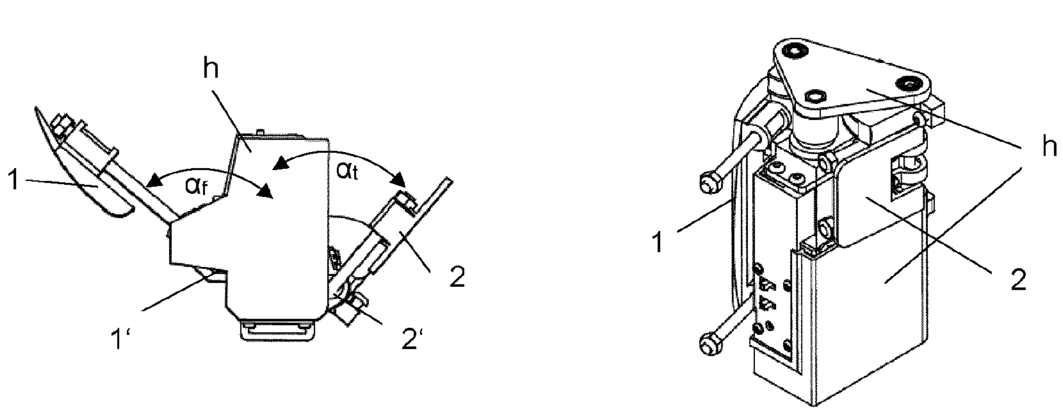

Fig. 1c

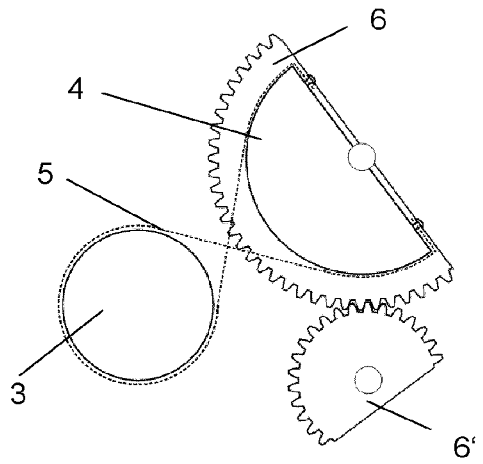

Fig. 2a

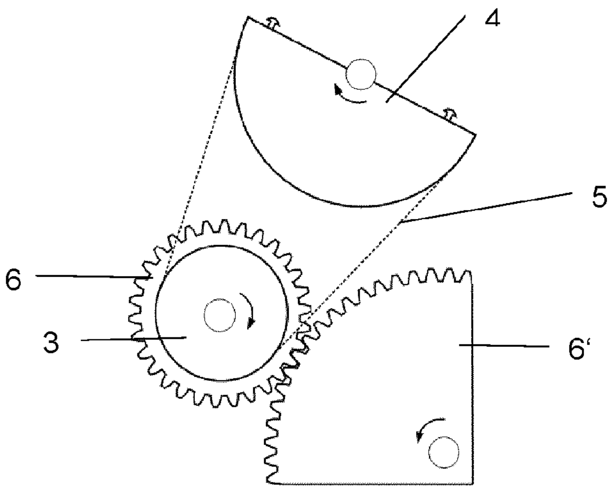

Fig. 2b

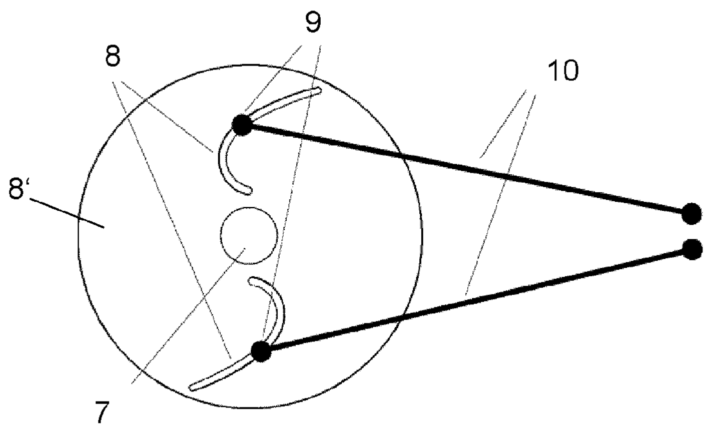

Fig. 3

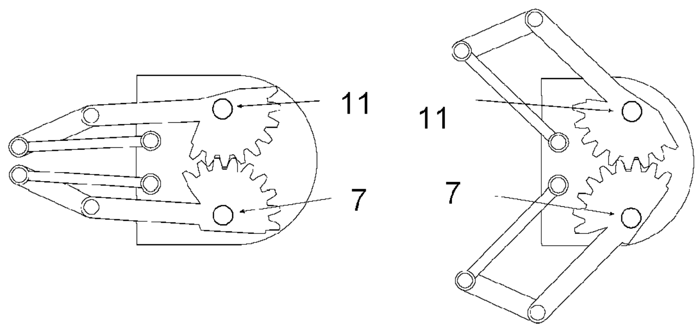

Fig. 4

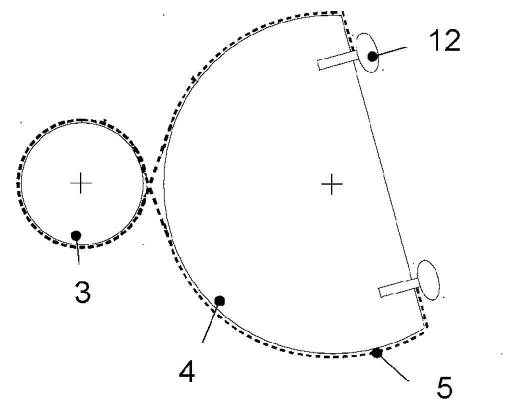

Fig. 5a

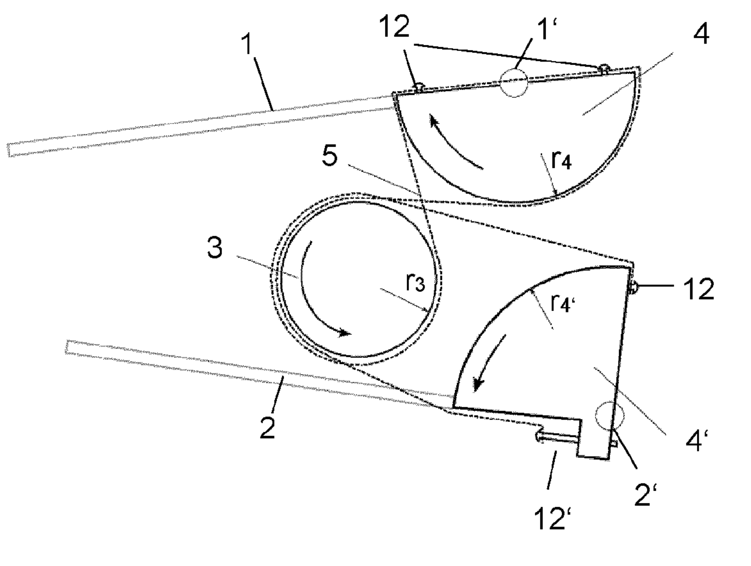

Fig. 5b

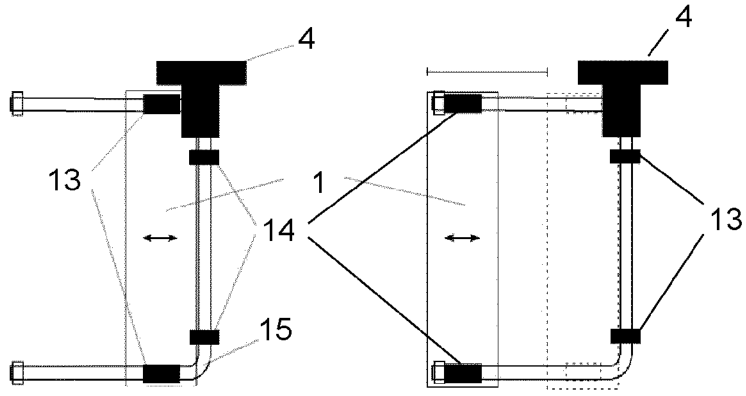

Fig. 6a

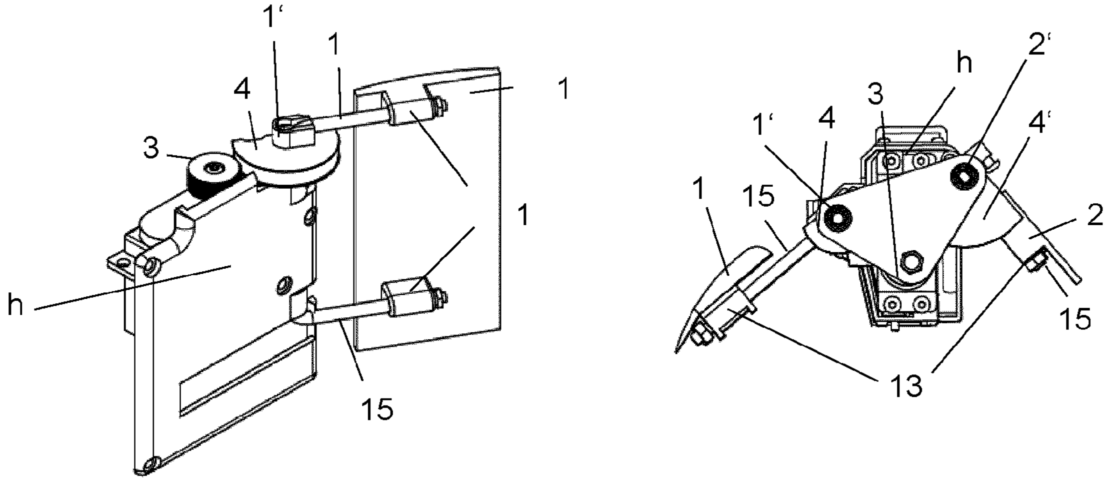

Fig. 6b

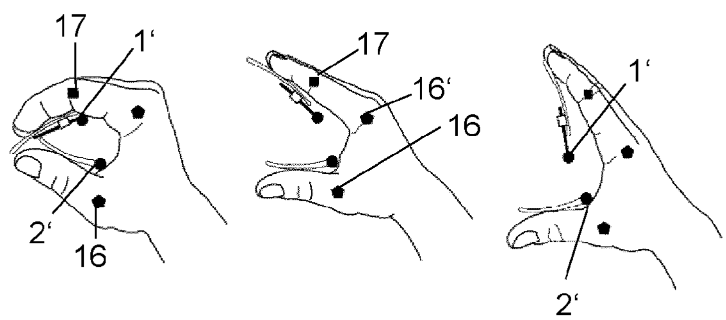

Fig. 7a

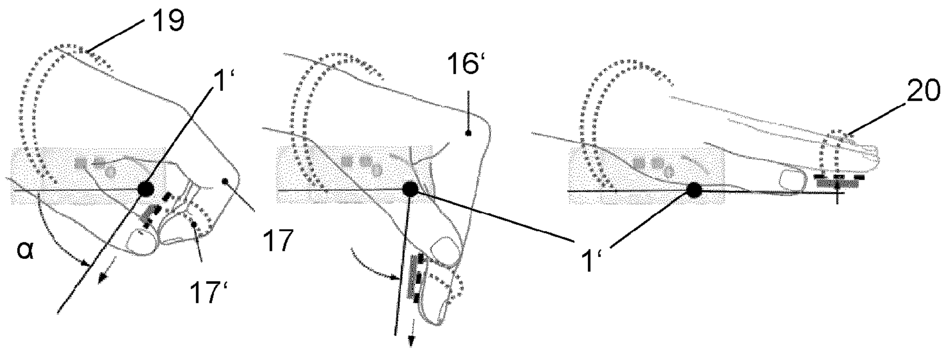

Fig. 7b

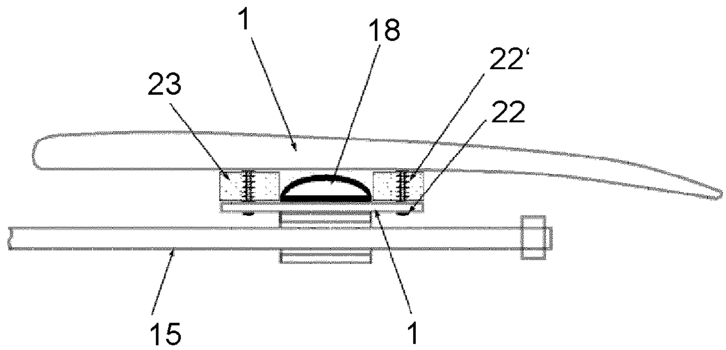

Fig. 8

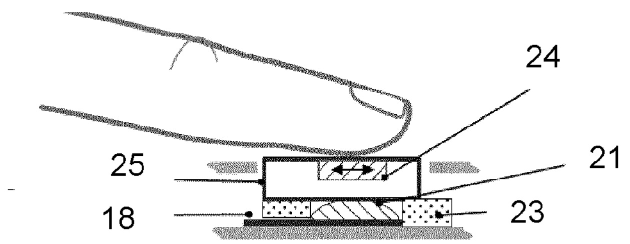

Fig. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 20 16 9582

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2015/057162 A1 (UNIV SINGAPORE [SG]) 23 April 2015 (2015-04-23)	1-8, 10-12, 14-16	INV. A61H1/02 A61H3/00 A61H23/02 A63B21/00 A63B21/005 A63B23/16
A	* paragraphs [0017] - [0050]; figures * * *	9,13	
X	EP 3 023 086 A1 (UNIV SOONCHUNHYANG IND ACAD COOP FOUND [KR]) 25 May 2016 (2016-05-25) * paragraphs [0016] - [0054]; figures *	1-5,7, 11,12	
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TECHNICAL FIELDS SEARCHED (IPC)
A61H
A63B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	25 September 2020	Teissier, Sara

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 20 16 9582

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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25-09-2020

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REFERENCES CITED IN THE DESCRIPTION

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