

(51) International Patent Classification:
A63B 23/16 (2006.01)(21) International Application Number:
PCT/US2014/045103(22) International Filing Date:
1 July 2014 (01.07.2014)

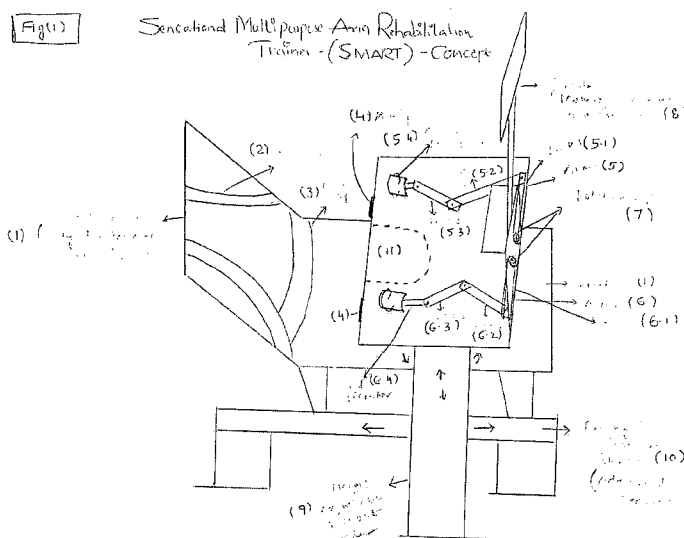
(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/842,251 2 July 2013 (02.07.2013) US(71) Applicant: NEW YORK UNIVERSITY [US/US]; One
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3000 K Street NW, 6th Floor, Washington, District of
Columbia 20007 (US).(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,
BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,
DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR,
KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME,
MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,
OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,
SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM,
TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM,
ZW.(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ,
UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,
EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,
MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,
TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
KM, ML, MR, NE, SN, TD, TG).**Published:**

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the
claims and to be republished in the event of receipt of
amendments (Rule 48.2(h))

(54) Title: MODULAR MULTI-JOINT REHABILITATION TRAINING SYSTEM AND METHOD



(57) **Abstract:** The present invention relates to a device or apparatus for aiding in upper extremity rehabilitation treatment. The apparatus is a portable mobile rehabilitation device which has first and second arms attached to the central fulcrum of a tabletop platform which is supported by a height adjustable side pillar and base piece. Each arm has 3 links or segments attached at the ends by detachable and adjustable rotating support which are termed as joints. The distal end of each arm has an end-effector which is a hand hold module that is attached to the distal part of the subject arm. The proximal end of each arm is attached to the central fulcrum. The arms along with the modules will provide support for the patient to move the arm at different joints either by passive movement or active assist movement.

Modular Multi-joint Rehabilitation Training System and Method

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application No. 61/842,251 filed July 2, 2013, reference of which is herein incorporated in its entirety.

FIELD OF THE INVENTION

[0002] Certain embodiments of the present invention provides a novel approach to train isolated joint movements in the upper limb for individuals with muscle weakness from any cause using a specially designed device. More specifically, the certain embodiments of the invention is for a mobile, portable, manually controlled multi-purpose upper limb rehabilitation trainer.

BACKGROUND OF THE INVENTION

[0003] Hand movements require that the arm and shoulder are relatively stable. When there is generalized weakness in the arm, it is difficult to perform exercises to train hand movements as there is instability further up in the shoulder. The present invention provides a means for self- or manually assisted-rehabilitation to train individual joint movements for individuals with muscle weakness.

Causes of upper limb weakness:

[0004] Upper limb weakness is a common problem. Weakness is defined as loss of strength or power manifesting as an inability to generate normal forces. Muscle weakness can lead to incoordination, and incoordination can present as weakness. Determining the true cause of muscle weakness is critical for planning a treatment approach.

[0005] Upper limb muscle weakness can be caused by various neurological or musculoskeletal problems. Neurological muscle weakness may occur due to damage to the brain or spinal cord as after a stroke, traumatic brain injury, cerebral palsy, multiple sclerosis etc, or after damage to the peripheral nerves as with polyneuropathy, radiculopathy, brachial plexus injury, Guillain-Barre syndrome etc. Diseases of the neuromuscular junction such as myasthenia gravis and muscle diseases such as muscular dystrophy also produce weakness.

[0006] Muscle weakness may also be seen in orthopedic conditions, especially after trauma or surgery due to prolonged immobilization of the limb. It is also a presentation of congenital conditions such as Arthrogryposis. Upper limb muscle weakness is also a common manifestation in critically ill patients and ICU survivors due to prolonged immobilization. The weakness may persist for months and years after discharge from the ICU.

[0007] Regardless of the cause of the muscle weakness, common consequences are disuse, muscle atrophy, shortening of the muscles, and finally permanent contractures.

Mechanisms of recovery of upper limb function:

[0008] Upper limb range-of-motion training exercises and strengthening are necessary to maximize functional outcomes. Range of motion training is necessary to preserve muscle length and prevent contractures which can lead to abnormal posturing. Strengthening exercises and neuromuscular re-education help improve movement quality and performance during functional daily activities.

[0009] It is well known that there is a complex exchange of information between the two limbs. Bilateral upper limb training using symmetric movements (when both arms are moving together) or alternating movements (one arm moves first followed

by the other arm) may be effective approaches to restore sensorimotor coordination when one limb is partially paralyzed.

[0010] Several factors contribute to the success of rehabilitation therapy. The first and foremost factor is the patient's motivation and level of engagement in the treatment.

[0011] Rehabilitation professionals include physiatrists, physical therapists, occupational therapists, speech therapists, social workers, rehabilitation nurses and neuropsychologists, who work as a team in order to accomplish the therapy goals set for the patient. The most important aspects of motor rehabilitation are facilitating gross motor and fine motor skills by physical and occupational therapists. The challenge for the therapists is not being able to effectively assist at the bedside when patients are very sick and bed bound. The therapist must exert significant effort to provide manual assistance and often cannot get the patient properly positioned to deliver effective therapy. This can be physically challenging to the patient as well and lead to fatigue, which diminishes the patient's participation and engagement in therapy.

[0012] In most acute situations in-hospital, the therapy and nursing staff have to be very careful about emergency equipment attached to the patient. The therapist often spends more time focusing on logistics of therapy rather than delivering therapy in these situations. Many of the available rehabilitation devices focus on delivering therapy in an outpatient setting, but cannot be easily adapted for the acute care or inpatient setting and are thus not useful for a bedside therapy approach.

[0013] Existing rehabilitation devices are complex, therefore not suitable to use in acute care settings as in the ICU or in a home environment. One goal of the current health care system is to decrease the length of stay in the hospital and discharge the patient early into the community. There is a need for multi-functional devices that can be useful in diverse environments.

[0014] Present devices are designed to train one or the other movement, but not all movements. For example, a device may train shoulder and elbow movements, but not wrist and hand movements also at the same time. This requires that there be several devices requiring large spaces.

[0015] Improving sensory feedback is one of the most important aspects of rehabilitation training and also one of the most challenging. Improving sensation will automatically improve the signals reaching the brain; so that the brain can effectively send appropriate motor impulses to aid improved function. Lack of sensation can promote disuse. The present invention is designed with a sensory re-education kit to improve tactile and kinesthetic feedback to further enhance motor recovery.

SUMMARY OF THE INVENTION

[0016] One embodiment of the invention relates to a rehabilitation system comprising a platform. The system further includes a first arm comprising a plurality of links connected by a plurality of corresponding joints, the first arm connected at a first end to the platform. The first arm is configured to accept an end effector for therapy.

[0017] In another embodiment, the invention relates to a rehabilitation system comprising a tabletop platform. The tabletop platform comprises a folding portion. The system further includes a height adjustable side pillar supporting the tabletop platform. A first arm of the system comprises a plurality of links connected by a plurality of corresponding joints. The first arm is connected at a first end to the tabletop platform. The first arm is configured to accept an end effector for therapy.

[0018] In another embodiment, the invention relates to a rehabilitation system comprising a tabletop platform. The system further includes a height adjustable side pillar supporting the tabletop platform at a first end and having a base at a second end. A first arm of the system comprises a plurality of links connected by a plurality of

corresponding joints, the first arm connected at a first end to the tabletop platform. The first arm is configured to accept an end effector for therapy.

[0019] Additional features, advantages, and embodiments of the present disclosure may be set forth from consideration of the following detailed description, drawings, and claims. Moreover, it is to be understood that both the foregoing summary of the present disclosure and the following detailed description are exemplary and intended to provide further explanation without further limiting the scope of the present disclosure claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] The foregoing and other objects, aspects, features, and advantages of the disclosure will become more apparent and better understood by referring to the following description taken in conjunction with the accompanying drawings, in which:

[0021] Figure 1 shows the general perspective of the invention. This view shows the trainer with the therapy table (workspace) and two arms, two hand hold modules, a hospital type bed and a monitor which can be used to control the device and also can be used to provide virtual reality interface for therapy (such as games).

[0022] Figure 2 shows a detailed view of the trainer with tabletop design, twin arms, links within each arm, end-effectors (handhold modules), detachable center piece and a base piece connecting the table by a height adjustable pillar.

[0023] Figure 3 shows partial detail of the trainer as depicted in figure 2, but shows the folding mode when the trainer is not in use or when it is mobile or during transportation.

[0024] Figure 4 shows a detachable end-effector which is a handheld module which can be attached to the arms and which is useful for shoulder movements in the longitudinal axis.

[0025] Figure 5 shows detachable end-effectors which are handheld module which can be attached to the arms and which are useful for shoulder and elbow movements in the sagittal and frontal axes.

[0026] Figure 6 shows detachable forearm support splint which can be attached to the arm support splint (not shown in the Figure) which in turn is attached to the front edge of the therapy table.

[0027] Figure 7 shows detachable end-effectors which are handheld module which can be attached to the arms and which are useful for forearm movements – pronation and supination.

[0028] Figure 8 shows detachable end-effectors which are handheld module which can be attached to the arms and which are useful for wrist movements – flexion and extension.

[0029] Figure 9 shows detachable end-effector which is a handheld module which can be used to train finger movements and also shows a sensory re-learning kit. Together this module serves as a hand therapy module.

[0030] Figure 10 illustrates a height adjustable pillar with rotatable metal plates engageable with the table.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0031] In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative

embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented here. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the figures, can be arranged, substituted, combined, and designed in a wide variety of different configurations, all of which are explicitly contemplated and made part of this disclosure.

[0032] **[0033]** The present invention will be discussed in the context of patients with neural, neuromuscular, musculoskeletal disorders and ICU-related weakness. It can also be used in an otherwise healthy aging population. The invention may be utilized in inpatient, outpatient, nursing home or home care environments.

[0034] The present invention is helpful in delivering focused active, or active-assisted or passive manually-assisted repetitive range-of-motion training and strength training at isolated joints and during functionally important movements to preserve muscle length, prevent contractures, and restore muscle strength. Importantly, the invention does not require external power, although it may be motorized. The invention will be particularly useful at early stages of weakness-causing conditions to mitigate the effects of immobilization. The device may be used with one or both hands.

[0035] In one embodiment, the present invention is designed to facilitate practice of symmetric or alternating movements with both limbs. Hence this multipurpose mechanical rehabilitation trainer can train both limbs together or each limb independently.

[0036] In one embodiment, the present invention is particularly aimed at enabling the patient with very limited movement to function optimally using a structured physical therapy approach. The device has been developed to give the patient maximum physical and psychological autonomy and to improve quality of life.

[0037] In one embodiment, the present invention has been developed to be used even when the patient is in bed and in any position, recumbent, seated or standing, and in any orientation, so that the alignment of the patient to the device is always maintained. This can save valuable therapy time as the patient will not be required to transfer out of bed just to initiate therapy.

[0038] In one embodiment, the present invention is particularly suited for very early therapy in an acute medical setting such as in an intensive care unit or in a stroke unit, or even in a nursing home. The portability of the trainer and its adjustable position and orientation can enable the therapist to deliver therapy rather than worry about the logistics of emergency equipment and transferring a patient from the monitored setting. The trainer is portable, easily movable from place to place, can be taken to the patient room, and is also modular and multi-functional.

[0039] In one embodiment, the present invention meets important criteria for multi-environment use such as light-weight frame, portability, affordability, adaptability for a variety of arm and hand movements, and sensorimotor integration. The present rehabilitation trainer can be used in any kind of setting – ICU, inpatient, outpatient, nursing home or home environment. The compact version of this trainer is designed in such a way that it can be easily carried in the trunk of a car. The device has a very simple and easy to assemble design. Anyone who can read and follow simple instructions from a manual will be able to use the device. The modular design will enable practice of a variety of movements with just one device rather than requiring a separate device for each movement.

[0040] In one embodiment, the present invention has been designed to be multi-functional. The jointed arms with locking capability of each arm segment, along with strategically placed straps will enable training of all movements of the upper limb joints with a single compact device. The devices will enable a therapist or a trained caregiver to work efficiently and consistently with reduced inter-individual variability.

Frequent repetitive practice of isolated joint movements will be possible early in the course of rehabilitation which will improve functional outcome.

[0041] The main objective of the current invention is to increase patient's accessibility to rehabilitation-which includes but are not limited to cost of the device, ease of use, portability and be able to use in any kind of environments-inpatient, outpatient, nursing home or at home.

[0042] Another objective is to develop a low cost rehabilitation device that can bridge the gap in health care disparities and aid in health care equality in low - resource settings especially in middle and low-income countries.

[0043] The goal of the present invention is to develop a compact rehabilitation trainer that is convenient to carry to any place in a car trunk. The present design or platform can be easily modified to develop this type of compact version. The future goals using the current invention are to develop a high-end robotic device with advanced features which include but are not limited to automatic controls, resistance controls, EMG biofeedback, virtual reality platform for task –specific training and cognitive intervention, performance tracking system, pain detection platform, joint and trunk alignment sensors and sensory feedback.

[0044] Certain embodiments are illustrated by way of example below and in FIGs 1 through 9. As depicted in Fig 1, one embodiment relates to a portable, height adjustable, easily rotatable mobile multipurpose rehabilitation system 100 includes an easily rotatable and table 110 (serving as a therapy workspace) supported by a height adjustable side pillar 121 with a base piece 122, the first arm 130, second arm 140 and an easily mountable, detachable end-effector 131, 132. The first arm 130 and second arm 140 are made up of several segments, termed as links 132, 142 which are pivotally attached such that the segments or links 132, 142 of each arm 130, 140 can rotate about a communication point 133, 134. The first arm 130 and second arm

140 are attached to a central fulcrum 111 situated on the rear margin at the center of the table 110.

[0045] Although certain embodiments are discussed herein in the context of specific diseases producing weakness, using a manual version, such is not intended to be limiting. Rather, other embodiments can be utilized in patient populations such as traumatic brain injury, spinal cord injury and musculoskeletal rehabilitation of the upper extremity in the context of other environments such as inpatient, outpatient, nursing home or home care.

[0046] **Figure 1** shows the general perspective of the invention. This view shows the trainer with the therapy table (workspace) 110 and two arms 130, 140, two hand hold modules, 131, 141, a hospital type bed 10 and a monitor 102 which can be used in certain embodiments to control the device, track the performance and also can be used for cognitive aspects of task-specific training (e.g.: Virtual Reality games).

[0047] As further shown in Figure 1, the system 100 is adaptable for positioning with respect to the hospital bed 10 (only for general perspective) whose head end is elevated. However, certain embodiments of the system 100 are a purpose unit that can be used in standing mode, in a sitting mode, or using a wheel chair. Shoulder straps 11 may be provided for trunk balance. Belly straps 12 along with the shoulder straps 11 control the balance of the trunk while the patient is working on the trainer. One or more arm support splints 150 are provided in one embodiment on either side to support one right and/or left arm. One or more arm splints 150 are attached to a bar 150 which is attached to the front edge of the table 110. The arm splints 150 are detachable and can be slid towards or away from the patient's trunk as per the need. These arm support splints 150 (illustrated as two arm support splits 150 in Figure 1) are especially useful when the patient is using a pronation-supination module and also for other movements to hold the arms 130, 140 in position and to isolate the joints during movements. They are provided with arm straps 153 which keep the arm in position. The

base of the splint 150 is provided with slots for screws which can be used to attach forearm support splints 180 (Figure 6) as needed during the therapy sessions.

[0048] In one embodiment shown in Figure 1, the arm 130 is attached to a rotating support 114 on a first the first link 142a which is attached at the center by a fixed support. In one embodiment, the proximal end of the first the first link 142a which is attached rotating support 114 can be moved vertically to adjust the height as per the patient's needs. In one embodiment, the arm 130 is made of magnet free metal. The embodiment illustrated in Figure 1 has three links 132 (illustrated as first the first link 132a, second the first link 132b, and third the first link 132c) and three joints 133 (illustrated as first the first joint 133a, second the first joint 133b, and third the first joint 133c). In one embodiment, the center of each link 132 is hollow and can have circular slots (not shown) to adjust the total length of the arm depending on the patient's needs. For example, set screws (not shown) may be used to secure the position of the link within a slot.

[0049] In one embodiment, the first the first link 132a is fixed. The proximal end of it is attached to the rotating support 114 and can be moved vertically to adjust the height from the table 110. The distal end of the first the first link 132a is attached to the proximal end of the second link 132b by a first joint 133a which has horizontal rotational movement.

[0050] In one embodiment, the second link 132b is mobile. The proximal end of second link 132b is attached to the first joint 133a and the distal end is attached to the third link 132c by the second joint 133b which has horizontal rotational movement.

[0051] In one embodiment, the third link 132c is mobile. The proximal end of the third link 132c is attached to the second joint 133b and the distal end is attached to end-effector 131, which may be a handheld module, by the third joint 133c which is fixed.

[0052] In one embodiment, a second arm 140 is utilized. The second arm 140 may have the same structure as the first arm 130 or may have an alternative structure. The second arm 140 is attached by a first link 142a which is attached at the center by a rotating support 114 or a fixed support 115. The proximal end of the first link 142a which is attached to pivot can be moved vertically to adjust the height as per the patient's needs. It is made of magnet free metal. It has three links 142 (illustrated as first the first link 142a, second the first link 142b, and third the first link 142c) and three joints 143 (illustrated as first the first joint 143a, second the first joint 143b, and third the first joint 143c). In one embodiment, the center of each link 142 is hollow and can have circular slots to adjust the total length of the arm 140 depending on the patient's needs.

[0053] In one embodiment, the first link 142a is fixed. The proximal end of it is attached to the center pivot fixed support 115 and can be moved vertically to adjust the height from the table 110. The distal end of the first link 142a is attached to the proximal end of the second link 142b by the first joint 143a which has horizontal rotational movement.

[0054] In one embodiment, the second link 142b is mobile. The proximal end of the second link 142b is attached to the first joint 143a and the distal end is attached to the third link 142c by the second joint 143b which have horizontal rotational movement.

[0055] Different embodiments of an end-effector 131 may be utilized. Further, where two arms 130, 140 are provide, two end effectors 131, 141, one corresponding to each arm, are utilized. The end effector 131 is selected based upon the therapy, for example for shoulder, forearm, wrist, or hand. Figures 4-9 illustrate nonlimiting examples of end effectors 131 that may be used as modules for specific types of therapy.

[0056] The fixed support 115 is attached to the one or more arms 130, 140 by a pivot joint at the center by means of the first link 132a, 142a. The arms can be

vertically movable and thus the height of the arms from the base (surface of the table) can be adjusted.

[0057] In one embodiment, the system may include or be in communication with a console 102 that may be a computer or connected to a computer in order to control the system 100 or to train the patient using task-specific cognitive training exercises (virtual reality games).

[0058] The system 100 includes a supporting structure 120 that elevates the table 110 for proper position with respect to the patient and also provides stability and support.

[0059] One embodiment of the supporting structure 120, best shown in Figure 10, includes a height adjustable support pillar 121 that supports the table 110 which is attached to a the pillar support base 122. In one embodiment, two hollow non-magnetic metal pillars 124, 125 are in a “telescoping” or nesting arrangement and attach to the base 122 and support the table 110 to act as main vertical support to the entire system. The table 110 is connected to either the inner pillar or the outer pillar 125, such as through the use of plates 128. One of the inner pillar 124 and the outer pillar 125 may rest on a resistance spring to provide a bias to the pillar 121. In one embodiment, one or both of the inner pillar 124 and the outer pillar 125 is provided with slots which correspond to the slots on the inside pillar. The height can be adjusted by locking the inner pillar 124 relative to the outer pillar 125 (or the outer pillar 125 relative to the inner pillar 124, in another embodiment) at a certain height. In one embodiment, the outer pillar 125 connects to the bottom of the therapy table by a first plate 128 which in turn is connected to second plate 129 which attaches to the table. One or more of the plates 128, 129 may be circular and/or metal (non-magnetic). The second metal plate 129 is fixed to the table 110 and the first plate 128 is attached to second plate 129, such as by a fixed support 126 or by a rotating support at the center. Preferably, the table 110 can be rotated at least 90 degrees and a rotating table lock 127 is provided

which can be used to lock the table 110 in a specific position. In one embodiment, the rotating table lock 127 comprises a lock button 127a that is attached to the second plate 129 and corresponding lock button slots 127b are provided on the first plate 128. The button 127a automatically locks in to the slot 127b on the first plate 128 when rotated and can be set in a specific position. Thus, embodiments of the height adjustable pillar 121 utilizing rotating plates 128, 129 allows for adjustment and securing of the vertical height and horizontal rotation of the table 110.

[0060] As mentioned above, the system 100 may be used with various types of furniture, including, for example, a hospital bed 10. In one embodiment, the pillar base 122 comprises a railing provided to connect to the bed (Figure 2).

[0061] Figure 2 shows a detailed view of the system 100 with a tabletop design, twin arms 130, 140, links 132, 142 to each arm 130, 140, end effectors 131, 141 (handhold modules), detachable center piece 112, and a base piece 122 connecting to the table 110 by a height adjustable pillar 121. The device of Figure 2 is shown without railing 122 for connecting to a bed, but includes the base piece 122, which may include, for example, wheels 123 to aid in movement of the system 100 from one patient to another.

[0062] The table 110 includes, in one embodiment shown in Figure 2, a detachable center piece 112. In the illustrated embodiment, the detachable center piece 112 is semicircular shaped, but it should be appreciated that various shapes and sizes may be utilized. The detachable center piece 112 of the system 100 that can be detached when the patient is working on movements of the shoulder joint (example: shoulder abduction) or when the system 100 needs to be close to the patient. Removal of the detachable center piece 112 allows a user to position their torso within a portion of the table 110.

[0063] In the embodiment illustrated in Figure 2, the base piece 122 is provided. The base piece 122 couples the table 110 of the system by the height

adjustable pillar 121 on one side. On the other side, the base piece 122 is provide with a lock mechanism 118 for the foldable half 117 of the therapy table, when the system 100 is not in use. The system 100 is designed to be easily mobile with a provision to lock in position during therapy sessions. In one embodiment, the base piece 122 includes auto-locking wheels 123. The wheels 123 are connected to the bottom of the base piece 122 and aid in the mobility of the system 100 but when the system 100 is in use, the wheels 123 can be locked to secure the system 100 in the place.

[0064] In one embodiment, a kit can be provided for various therapies. The kits may include specific links 132, joints 133, end-effectors 141 and sensitubes 250. Once all the links are attached, the length of each arm needs to be adjusted as per the dimensions of the patient's arm. Both arms 130, 140 of the system 100 are length adjustable. This means that the attachment of the links 132 can be changed based on the measurements of the patient's arm there by optimizing the workspace in which the patient will be practicing the movements. In order to determine the length of each arm 130 of the trainer, the length of the patient's arm and forearm are to be determined. In one embodiment, the length of the arm is measured from the acromion process of the scapular bone to the lateral condyle of the elbow joint. The length of forearm is measured from the lateral condyle of the elbow joint to the radial styloid process at the wrist joint. For certain embodiments, once the length of the trainer's arms 130 is determined and adjusted, the distance between the first arm 130 and the second arm 140 has to be determined. This can be calculated by measuring the distance between two acromion processes of the scapular bones of the patient. Now the distance between the arms 130, 140 can be adjusted accordingly. One another final setting that needs to be done before starting the therapy, is adjusting the location of the arm support splints 150. The arm support splints 150 are detachable and easily adjustable structures that are attached to the system 100, such as at a front edge of the table 110. The position of the arm support splints 150 is adjusted and fixed depending on the patient's arm position. The arm supports 150 are provided with straps, such as utilizing hook and loop

fasteners, to secure the patient's arm in position. If necessary, the lower end of the patient's bed 10 can be lowered before start of the therapy session. This will make it more comfortable for the patient while working on the system 100.

[0065] Depending on the assessment of the patient's hand function by a certified therapist and as per the recommendations of the attending physician, the therapist (OT or PT) can determine which movements need to be trained or which joint movements need to be facilitated. It is advised that the patient is given 5-10 minutes of stretching and warm up exercise by the skilled therapist before practicing the movements on the trainer. Also the therapist should take in to consideration the general condition of the patient, cognitive abilities, pain, and all other presenting symptoms before determining the appropriate therapy protocol for the patient using the trainer. The movements can be trained starting with the proximal joints and progressive towards distal joints in the order – shoulder, elbow, wrist and hand or the movements can be trained starting with the distal joints and progressing towards proximal joints in the order – hand, wrist, elbow and shoulder. All movements need not be necessarily trained in the same session. The training protocol is at the discretion of the attending rehabilitation specialist and the therapist. It is to be noted that the trainer can be used to train one arm only or both arms simultaneously or alternatively as explained in detail elsewhere in this document. So, while performing the movements the therapist may encourage the patient to perform similar movements on both sides at the same time.

[0066] **Figure 3** shows partial detail of the trainer as depicted in Figure 2, but shows the folding mode when the system 100 is not in use or when it is mobile or during transportation. In one embodiment, a locking mechanism 118 of the table 110 provides a locking mechanism when the system 100 is unfolded during the therapy session. In one embodiment, best illustrated in Figure 3, the table 110 is divided into foldable 117 and non-foldable areas 116. The foldable parts 117 can be folded and lock on to the base piece 122 by means of locking mechanism 119 provided on the sides of the base piece 122. The non-foldable part is attached to the inner supporting pillar by

rotating twin non-magnetic metal plates (described above) and is also supported by a non-magnetic metal frame at the bottom.

[0067] The system 100 is unfolded by unlocking the side locking mechanism 119 on the base piece 122 of the system 100 and the table 110 is locked in flat position by using the safe locking system 118 provided on front and rear margins of the system 100. The table 110 is easily rotated using a specially designed mechanism to adjust the orientation of the table 110 and can be locked in that position throughout the session. The first link 132a attached to a central fulcrum is fixed but can be moved up or down vertically to adjust the height of the arm from the table top surface. In order to determine the height of the trainer arms 130, from the tabletop 110, the patient's arms are placed such that the shoulders are at zero degrees, and forearms are at 90 degrees. Now the elbow on each side is lined up with the table 110. If the tabletop 110 is not in line with the elbow, the height of the system 100 is adjusted easily by using height adjusting locking and unlocking mechanism of the pillar 121 to makes sure that the system 100 is at appropriate height comfortable to the patient. In one embodiment, if the patient is not able to sit erect and is in a semi-recumbent position, the system 100 will allow tilting the table 110 forward slightly using a locking and unlocking mechanism at the pillar 121 underneath the table 110 which will enable the patient to work on the system 100 more comfortably. Once the height, tilt and the distance of the system 100 are adjusted and fixed, now the height of the trainer's arms 130 are adjusted by sliding the attachments at the support 114 and securing in place to maintain the same height throughout the session. Once the distance of the system 100 from the patient is determined, the trainer's wheels 123 are locked in position, so that the system 100 remains stable and fixed throughout the training session. It is to be noted that while training on certain movements like shoulder abduction, adduction, shoulder internal rotation, external rotation and shoulder extension, the system 100 needs to be brought closer to the patient than when training on the elbow, wrist and finger movements. Before training the patient on shoulder movements in sagittal axis in a transverse plane,

the trainer's wheels 123 are unlocked and the system 100 is moved close to the belly of the patient and the wheels 123 are locked again to secure the system 100 in position. The distance, height and tilt of the system 100 can be adjusted if needed during the course of the therapy session.

[0068] In one embodiment, the support pillar 121 is foldable or otherwise collapsible to reduce the height of the system 100 when not in use, such as described with respect to Figure 10.

[0069] **Figure 4** shows a detachable end-effector 131 which is a handhold module which can be attached to the arm 130 (or both arms 130, 141) and which is useful for shoulder movements in longitudinal axis. Although Figure 4 illustrates one end effector 131, it should be appreciated an identical end effector could be utilized with the second arm 140 and that certain end effectors 131, such as shoulder modules, may provide better therapeutic results when used in tandem. With respect to the end effector, the proximal end of the third link 132c is attached to rotating the second joint 133b and the distal end is attached to fixed detachable joint 133c of the end-effector 131. The third link 132a is movable by means of rotating the second joint 133b. The second joint 133b is present between the second link 132b and the third link 132c. The second joint 133b couples the distal end of the second link 132b and the proximal end of the third link 132c. The second joint 133b can be locked or unlocked depending on what movement the patient is performing. The proximal end of the second link 132b is attached to the first link by means of the first joint (not shown in the drawing) and the distal end is attached to the third link by the second joint which has horizontal rotational movement. Both the first joint and the second joint can rotate in horizontal plane which moves the second link. The joints can be locked and unlocked depending on what movement the patient is performing.

[0070] In the embodiment of Figure 4, the end-effector 131 is designed to train the shoulder movement in longitudinal axis (forward and upward, downward and

backward movement). The shoulder module 170 is provided with a base 172, such as a wooden base, to support the module 170 and T shaped handle 174 which is attached to pivot joint 176 inside the module 170. A horizontal arm 177 of the handle 174 is used to hold the module 170 by the patient and straps (not shown) are used to secure the hand to the handle 174. The therapist will assist the patient in placing the hand on the horizontal arm 177 of the handle 174 and aid in moving the arm in longitudinal axis to train the shoulder flexion and extension movements.

[0071] Figure 5 shows detachable end-effectors 131 which can be attached to the arms 130, 140 and which are useful for shoulder and elbow movements in sagittal axis and frontal axis, i.e. a sagittal plane movement module 190. The connection between the arm 130 and the end effector 131 may be universal between the various therapeutic modules. Grasping handle 191 connects the hand support 192 to the detachable the third joint 133c. The grasping handle 191 is, in one embodiment, made of non magnetic metal and is used by the patient to grasp the hand hold module 190. Forearm straps 184 and/or hand straps are used (not shown in the picture) if necessary to keep the patient's hand in place.

[0072] Hand support 192 is a base, for example wooden, that supports the patient's hand while grasping the handle 191. It also attaches the handle 191 to the third joint 133c of the distal end of the third link 132c.

[0073] Forearm support 185 may be a forearm splint 180 and include padding 183 (best shown in Figure 6) that may be used in one embodiment. The hand hold module 190 includes a base which is flat narrow and rectangular which acts as a forearm support 185. It is provided with hard cushioning with forearm straps 184 to keep the forearm in position. It is very useful in isolation of joint movements. The forearm splint 180 is used with the arm support splint 150.

[0074] Figure 6 shows detachable forearm support splint 180 which can be attached to the arm support splint 150 (Figure 1) which in turn is attached to the front

edge of the table 110. The forearm splint 180 is useful for providing the forearm support especially while the patient is performing forearm movements like pronation and supination in transverse plane, shoulder movements in longitudinal plane. It should be appreciated that a forearm splint 180 may be used with each arm 130 where more than one arm 130 is utilized. In one embodiment, the forearm support splints 180 provided elevated sides for proper forearm position-The forearm support splints 180 hold the forearm of the patient and, in one embodiment, a surface of the splint 180 is contoured and the edges 186 are elevated for proper alignment of the forearm on the splint. In one embodiment, the surface of the forearm splint 180 is provided with hard cushion and enough padding 183 for the comfort of the patient. The forearm splint 180 may be attached to the arm support splint 150, for example by screws 187.

[0075] Figure 7 shows detachable end-effectors 131 which can be attached to the arms 130, 140 and which are useful for forearm movements – pronation and supination module 200. The hand module 200 is useful for performing forearm pronation and supination movements. The module 200 consists of a T shaped structure. One end of the longitudinal arm 202 of the module 200 fits into the third joint 133c at the distal end of the third link 132c and can be fixed tight. In one embodiment, the distal end of the longitudinal arm 202 of module 200 is provided with a slot (not shown) into which the rotating handle 201 is fixed. The patient holds the rotating handle 201 which is attached to the distal end of the lateral arm 203. The proximal end of the lateral arm 203 is attached to the longitudinal arm 202 which in turn couples with the third joint 133c at the distal end of the third link 132c. In one embodiment, the grasping handle 201 is made of non magnetic metal and is a hollow rectangular frame like structure and the grasping side is provided with cushion and padding for additional comfort of the patient. Hand straps (not shown) can be used to hold the hand in position attached to the handle 201.

[0076] Figure 8 shows detachable end-effectors 131, 141 which are handhold wrist module 210 which can be attached to the arms 130, 140 and are useful

for wrist movements – flexion and extension. The proximal end of the third link 132c is attached to a rotating the second joint 133b and the distal end is attached to a fixed detachable joint 133c of the end-effector (the third joint). The third link 132c is movable by means of the rotating the second joint 133b. Grasping handle 211 connects the hand support 212 to the detachable the third joint 133c. The grasping handle 211 is, in one embodiment, made of non magnetic metal and is used by the patient to grasp the hand hold module 210. Hand straps are used (not shown in the picture) if necessary to keep the patient's hand in place. A hand support 212 is provided, for example as a wooden base that supports the patient's hand while grasping the handle 211. A moving track 213 is provided so that the handle can be moved along the track forwards and backwards, the track 213 may be a slot for engaging the third link 132c via the third joint 133c. The distal end of the grasping handle 211 is attached to the moving track 213, in one embodiment semi-circular or semi-elliptical. The movement of the handle 211 forwards and backwards causes the movement at the wrist joint.

[0077] Figure 9 shows detachable end-effector 131 which can be used to train finger movements as a finger module 220. Further, the finger module 220 is configured, in one embodiment, to utilize sensittubes 250, which may be one or more different types of sensory devices for hand therapy. The hand hold module 220 of Figure 9 is specifically designed to train finger movements. It has three movable finger splints 221 and one thumb splint 227. The distance between the individual finger splints 221 and the position of each finger splint 221 as well as that of the thumb splint 227 can be adjusted depending on the dimensions of the patient's hand. Each finger splint 221 is a vertical hollow structure provided with elastic loops 222, such as four. In one embodiment, each loop 222 can hold one finger in position. The four finger loops 222 will hold the index, middle, ring and little finger in position. The thumb splint has two thumb loops 228 for each segment of the thumb. Each finger splint 221 is mean for each segment of the finger. Each finger is divided into three segments – Proximal, middle and distal. A first finger splint 222a will hold the proximal segments of all the

four fingers in position. A second, finer, splint 222b will hold all the middle segments in position and a third finger splint 222c will hold all the distal segments in position. The finger splints 222 are designed as vertical tubes for two reasons – 1) to eliminate the effect of gravity when the patient is performing the finger movements and 2) to provide training close to the functional usage of the fingers. The tension in the elastic loops 222 can be adjusted using finger tension knobs 223 provided for each loop 222. Depending on which finger segment is moving, the tension in the loops 222 can be adjusted to provide training to specific finger segments or to all finger segments at the same time.

[0078] In one embodiment, the hand module 220 has one thumb splint 227. The thumb splint 227 has two finger loops 228 for each segment of the thumb. Thumb finger is divided into two segments – Proximal and distal. A first thumb loop 228 will hold the proximal segment of the thumb and a second thumb loop 228 will hold the distal segment in position. The thumb splint 227 is attached to a base piece 224 of the finger trainer and is positioned in relation to the position of the thumb. It is provided with two tension adjustable knobs 229 to adjust the tension in the elastic loops 228.

[0079] Three rows of slots (not show) are provided on the surface of the finger module 220 to fit the sensitubes 250. In one embodiment, the slots have metal threads to fix the sensitubes 250 for sensory training. Sensitubes 250 are hollow tubes with different shapes, sizes, weights and different surface textures that will help the patient with sensory training especially during acute recovery phase. There can be any number of sensitubes. The bottom of each tube 250 is provided with a screw and threads that can be fixed into the slots provided on the surface of the finger module 220. The sensitubes 250 will help the subject to feel different textures, shapes and weights during the finger training process. The finger module 220 together with sensitubes 250 is called the hand therapy module 220.

[0080] In one embodiment, the finger module 220 has a base piece 224 which acts like a forearm and wrist support. The surface is provided with padding and

cushion and there are slots 251 for sensitives, for example 3 rows of slots. The finger module 220 is provided with a pair of wrist straps 225 to keep the wrist in position and to maintain proper alignment when the patient is performing the finger movements. The base portion 224 of the finger module 220 is provided with a pair of forearm straps 226 to keep the forearm in position and to maintain proper alignment of the elbow and wrist joints when the patient is performing the finger movements.

[0081] The device described herein enables patients to perform upper extremity strengthening and range of motion training exercises at shoulder, elbow, wrist and finger joints in order to maximize the functional outcomes. The special design of the device enables the patient to practice repetitive arm movements in a more intense and co-ordinated fashion very early in the course of rehabilitation which is essential for functional recovery. Portability and mobile features will allow the patient to practice their exercises even at home in a supervised or semi-autonomous environment providing continuum of rehabilitation care, and maximizing functional outcomes and reducing complications such as contractures, stiffness and further impairment of hand function. Upper extremity strengthening exercises using the current invention will help to improve the quality of movement and overall performance of functional daily activities in patients. Sensory retraining using the Sensilearn module of the present invention will improve the overall sensory feedback to the brain, further helping in the recovery of hand motor function and overall well being of the patient. Certain embodiments of present invention allows the therapist to start the therapy early in the acute phase, thereby increasing the interaction with the patient, which will improve self-confidence and creates sense of well-being, reducing depression and other negative mood disorders. The device with additional advanced features can be used to quantitatively diagnose upper limb function disorders in relation to range of motion, upper limb muscle strength and co-ordination between different joints in a hospital or clinic setting by a qualified therapist.

[0082] The device is intended to be used by anyone who needs upper extremity rehabilitation. A skilled therapist or a skilled attendant would be present during the course of treatment to set up the device, give proper instructions to the patient and also to help the patient move the device practicing movements at different joints – shoulder, elbow, wrist and fingers. The device can be used for in-bed therapy, bedside therapy, inpatient therapy, outpatient therapy or as a home rehabilitation device. The attendants of the patient and care givers should be adequately trained before using the device in a home environment. The device can be used to train the patient in a semi-recumbent position when the head end of the bed is elevated, in standing position, in sitting position comfortably seated in a chair or in a wheel chair.

[0083] Before the trainer can be used, the therapist or the skilled attendant must calibrate the work space and set up the device as per the needs of the patient. The trainer is easily mobile, so when a patient is unable to move out of his/her bed due to various reasons but still is eligible to get the therapy as per the recommendations of the attending physician, then the physician can order bed side or in-bed therapy to the patient using certain embodiments of the present invention. The therapist then may take the mobile trainer to the patient's room. It should be noted that, during the transportation, the trainer is in a folding mode to make it compact and easy to navigate through the hallways. Also the links of each arm and the end-effectors are easily detachable.

[0084] When in patient's room, the therapist may raise the head end of the patient's bed before proceeding with the system settings. The trunk balance and position of the patient should be assessed properly. It is important to make sure that the patient is maintaining proper trunk position. If necessary shoulder straps and/or belly straps may be used to maintain proper alignment and stability of the upper body. The side rails of the patient's bed are lowered.

[0085] The end-effectors are designed to help train specific movements. In the present description we will start with the more proximal joints and proceed towards distal joints. As mentioned in the above paragraph, the training of movements at different joints and the order of training may differ from patient to patient and the best training protocol needs to be determined by the rehabilitation team comprising of a Physiatrist, physical therapist, occupational therapist and other team members. Before starting the therapy session using the system, the specific hand module needs to be mounted to the distal end of each arm and secured and fixed (locked) in place. At this point, the therapist has to once again make sure that all the system settings are appropriate and specific to that patient. The system along with all the modules are carefully and specially designed keeping in view the specific needs of each patient in order to provide maximum comfort to the patient during therapy. However, if the patient feels uncomfortable because of improper positioning or settings of the trainer, the therapist in charge should stop the training session and adjust the settings before resuming the session.

[0086] To train the shoulder flexion movements, the shoulder flexion module needs to be mounted to the distal end of each arm of the system and secured in place. It is to be noted that the module is coupled to the distal end of the arm by a fixed attachment, so that there is no rotating or oscillatory movement at the joint of the end-effector. At this point, the therapist in-charge should once again assess the position of the tabletop platform of the system in relation to the patient and if necessary can be adjusted by unlocking the system wheels and by moving the trainer close to or away from the patient. Once the distance is properly adjusted, the trainer is locked and secured in position. Before helping the patient to stretch the arms, the range of motion of the shoulder joint especially on the affected side has to be determined by the therapist and patient is asked for any pain or discomfort while stretching the arm forward. Once the approximate range is determined at the shoulder joint, now the patient is asked to actively stretch the arms forward or the therapist can provide

assistance by passively stretching the arm on the affected side, so that the shoulder joint is flexed and elbow is extended. Now both arms are placed on the horizontal handle of the end-effector and hand is secured in position using soft velvet straps. The vertical arm of the 'T' shaped handle of the shoulder module is attached to the axis inside the module, which will allow the movement of the handle in a vertical plane. The shoulder module has a base which is supported on the tabletop surface. Now the therapist will attach the forearm support splints to the base of the arm support splints. But it is to be noted that the position of the arm support splits should be horizontal or might be kept pointing in the downward direction while practicing shoulder movements in vertical axis in order to avoid interfering with the movement. The forearm of the patient is rested on the forearm support splints.

[0087] Each time the patient performs the shoulder movement in the vertical axis and returns to the starting position, the forearm support splints will serve as the resting or landing platforms. Using the forearm support splints is optional as per the discretion of the therapist. The patient is allowed to practice the shoulder movements in a vertical plane in the range permitted as determined by the therapist before start of the movement. The patient practices movements on both sides by bimanual training either by active movement of both arms, active movement of the unaffected arm and active assist of the affected arm or active movement of the unaffected arm and passive assistance on the affected side by the therapist. The number of coordinate repetitions is determined by the therapist. Frequent rest breaks should be given to the patient during the course of the therapy session. The module along with the forearm support splint will allow the patient to grasp the handle of the end-effector and also properly position and support the arm while performing the movements at the shoulder joint. When the patient moves the hand in the vertical plane holding the horizontal handle, the vertical arm of the 'T' will rotate along the pivot enabling the movement. The base of the module will provide the support to the module and the fixed joint at the distal end of the arm will hold the module in position during the movement. After enough number of repetitions, the

shoulder flexion module can be detached very easily and the next module can be mounted to the arms.

[0088] The second module termed the shoulder and elbow module as depicted in figure 5 is used to train the shoulder and elbow movements in a sagittal plane for forward reaching movements and in a transverse plane in a frontal axis for sideward movements. Using this module as shown in figure 5, shoulder flexion, shoulder extension, elbow flexion, elbow extension movements can be trained in a sagittal plane and shoulder abduction, shoulder adduction, shoulder internal rotation and external rotation movements can be trained in a transverse plane.

[0089] To train shoulder movements using the shoulder and elbow module, the module needs to be mounted to the distal end of each arms and secured in place. It is to be noted that the module is coupled to the distal end of the arm by a fixed attachment, so that there is no rotating or oscillatory movement at the joint of the end-effector. At this point, the therapist in-charge should once again assess the position of the tabletop platform of the trainer in relation to the patient and if necessary can be adjusted by unlocking the wheels and by moving the trainer close to or away from the patient. Once the distance is properly adjusted, the trainer is locked and secured in position. Before helping the patient to place the arms on the module, the range of motion of the shoulder and elbow joints especially on the affected side has to be determined by the therapist and the patient is asked for any pain or discomfort while stretching the arm forward. Once the approximate range is determined at the shoulder and elbow joint, the position of the patient and the trainer is adjusted such that the shoulder joint is at zero degrees and the elbow joint is at 90 degrees and the forearm of the patient on both sides is comfortably rested on the forearm support of the module. The therapist can provide assistance to the patient to get in to proper position. Now the forearms on either side are secured in position using forearm straps and the grasping handle is grasped by the hand. The patient's hand is held in position using soft velvet straps and supported by a quadrangular base of the hand module. The patient is asked

to move the modules on both sides in sagittal plane performing forward reaching motion on the table top platform. If the patient has little or no movement on the affected side, the therapist can hold the module on the top by means of the end effector knob on the affected side and help the patient in reaching movements. When the patient attempts to move the shoulder and elbow module by active movement or by active assist movement, the ball joints between the first link and the second link and between the second link and the third link will rotate in synchrony to provide smooth movement of the arm.

[0090] However, it is to be noted that the joint at the end-effector to the distal end of the arm is fixed and there will be no rotational movement. The patient is allowed to practice the forward reaching movements in sagittal plane in the range permitted as determined by the therapist before start of the movement. The patient practices movements on both sides by bimanual training either by active movement of both arms, active movement of the unaffected arm and active assist movement of the affected arm or active movement of the unaffected arm and passive assistance on the affected side by the therapist. The number of coordinate repetitions is determined by the therapist. Frequent rest breaks should be given to the patient during the course of the therapy session. The module along with the forearm support will allow the patient to grasp the handle of the end-effector and also properly position and support the forearm while performing the movements at the shoulder and elbow joint. Using this type of reaching movements, shoulder flexion, elbow flexion and elbow extension can be trained in a co-ordinate fashion. After enough number of repetitions, the shoulder and elbow module can be used to practice other shoulder movements.

[0091] The shoulder and elbow module is also used to train extension, abduction, adduction, internal and external rotation at the shoulder joint. Before training the patient, it is important to make some adjustments to the trainer. Firstly, the patient's arms are slowly removed from the module by untying, for example, the hook and loop straps. Now the semi-circular center piece of the table top platform is slowly detached

creating a semi-circular space which will enable the therapist to move the trainer closer to surround the patient. Once the therapist makes sure that the trainer is sufficiently surrounding the patient evenly on both sides, the wheels are locked securing the trainer in place. The patient is instructed to grasp the handle of the module on both sides. The therapist assists the patient grasping the handle on the affected side. Now once again, the forearm and hand are secured in position by using, for example, hook and loop or velvet straps such that the shoulders are at zero degrees and elbows on both sides are at 90 degrees. The patient is asked to move the modules on both sides in a sagittal plane performing forward and backward motion on the table top platform. If the patient has little or no movement on the affected side, the therapist can hold the module on the top by means of the end-effector knob on the affected side and help the patient with shoulder flexion and extension movements. When the patient attempts to move the shoulder and elbow module by active movement or by active assist movement, the ball joints between the first link and second link and between the second link and the third link will rotate in synchrony to provide smooth movement of the arm. However, it is to be noted that the joint at the end-effector to the distal end of the arm is fixed and there will be no rotational movement.

[0092] The patient is allowed to practice forward reaching and backward movements in a sagittal plane in the range permitted as determined by the therapist before start of the movement. The patient practices movements on both sides by bimanual training either by active movement of both arms, active movement of the unaffected arm and active assist movement of the affected arm or active movement of the unaffected arm and passive assistance on the affected side by the therapist. The number of coordinate repetitions is determined by the therapist. Frequent rest breaks should be given to the patient during the course of the therapy session. The module along with the forearm support will allow the patient to grasp the handle of the end-effector and also properly position and support the forearm while performing the movements at the shoulder and elbow joint. Using this type of reaching movements,

shoulder flexion, shoulder extension, elbow flexion and elbow extension can be trained in a co-ordinate fashion. After enough number of repetitions, the shoulder and elbow module can be used to train other shoulder movements.

[0093] In order to perform shoulder internal and external rotation movements, the ball joint between links 1 and 2 of the arms on either side of the trainer are fixed, so that the horizontal rotational movement is only around the communication point between links 2 and 3. The trainer is close to the patient so that it completely surrounds the patient on both sides. Now the patient holds the handles with the forearms resting on the forearm support. The shoulder is at zero degrees and the elbow is at ninety degrees. Shoulder internal and external rotations are performed in frontal axis in a transverse plane by moving the hand module close to or away from the body by rotating the shoulder joint. In order to perform shoulder adduction and shoulder abduction movements, the ball joint between the links 2 and 3 is fixed on both sides and the horizontal rotational movements are performed only around the point between links 1 and 2. The position of the patient and the arms on both sides remain the same but now the patient tries to move the arms close to or away from the body in such a way that the shoulder and elbow move in synchrony at the same time, in order to practice shoulder adduction and abduction movements.

[0094] The patient is allowed to practice the movements in transverse plane in the range permitted as determined by the therapist before start of the movement. The patient practices movements on both sides by bimanual training either by active movement of both arms, active movement of the unaffected arm and active assist movement of the affected arm or active movement of the unaffected arm and passive assistance on the affected side by the therapist. The number of co-ordinate repetitions is determined by the therapist. Frequent rest breaks should be given to the patient during the course of the therapy session. The module along with the forearm support will allow the patient to grasp the handle of the end-effector and also properly position and support the forearm while performing the movements at the shoulder and

elbow joint. Using this type of movements in frontal axis in a transverse plane, shoulder adduction, shoulder abduction, shoulder internal and external rotation can be trained in a co-ordinate fashion. After enough number of repetitions, the shoulder and elbow module can be detached very easily and the next module can be mounted to train other joint movements.

[0095] A pronation-supination module as shown in figure 7 is very useful to train the patient on rotation movements of the hand and forearm wherein the surface of the palm is facing upward (supination) or downwards (pronation). The ideal position of the arm in order to perform these movements is by the side with the angle of shoulder at zero degrees and the elbow at 90 degrees at right angles to the arm. Before training the patient on pronation and supination movements, it is important to make some adjustments to the trainer. Firstly, the patient's arms are slowly removed from the module by untying, for example, the hook and loop, straps. Now the semi-circular center piece of the table top platform is slowly attached to the platform and the trainer is moved little away from the patient so that the front margin of the trainer is just touching the belly of the patient but not completely surrounding the patient. Now the wheels are locked securing the trainer in place. The position of the arm support splints is adjusted on either side, such that it supports the patient's arm and is held in position using, for example, hook and loop straps. The forearm support splint is attached to the base of the arm support splint on either side and screws are tightened. The patient's forearms are placed on the forearm supports and secured in place using, for example, the hook and loop, straps. The patient is instructed to grasp the handle of the module on both sides. The therapist assists the patient grasping the handle on the affected side. Now once again, the forearm and hand are secured in position by using, for example, the hook and loop or velvet straps such that the shoulders are at zero degrees and elbows on both sides are at 90 degrees. The patient is asked to move the modules on both sides in sagittal plane performing rotation movements of the hand and forearm wherein the surface of the palm faces upwards (supination) or downwards (pronation). If the patient

has little or no movement on the affected side, the therapist can hold the module on the top by means of the end-effector knob on the affected side and help the patient in performing the movements. When the patient attempts to move the pronation-supination module by active movement or by active assist movement, the shaft of the handle rotates within the shaft of the end effector in both forward and backward directions to provide smooth rotational movement of the forearm and hand. However, it is to be noted that the ball joints between the first and second links and the second and third links are fixed during the course of the movement. The joint where the end effector is attached to the distal end of the arm is also fixed and there will be no rotational movement.

[0096] The patient is allowed to practice the movements in the transverse plane in the range permitted as determined by the therapist before start of the movement. The number of co-ordinate repetitions is determined by the therapist. Frequent rest breaks should be given to the patient during the course of the therapy session. The module along with the forearm support will allow the patient to grasp the handle of the end-effector and also properly position and support the forearm and arm while performing the rotational movements of the forearm. After enough number of repetitions, the pronation and supination module can be detached very easily and the next module can be mounted to train other joint movements.

[0097] A wrist module as shown in figure 8 is very useful to train the patient on movements of the wrist joint wherein the hand is bend forward and backwards in a transverse plane or upwards and downwards in a vertical plane while holding the forearm in mid-prone or neutral position. The ideal position of the arm in order to perform these movements is by the side with the angle of shoulder at zero degrees and the elbow at 90 degrees at right angles to the arm. The forearm and hand is held in mid-prone or neutral position.

[0098] Before training the patient on wrist movements, it is important to make some adjustments to the trainer. Firstly, the patient's arms are slowly removed

from the module by untying, for example, the hook and loop, straps. Make sure the semi-circular center piece of the table top platform is in place and the position of the trainer is adjusted so that the front margin of the trainer is just touching the belly of the patient but not completely surrounding the patient. Now the wheels are locked securing the trainer in place. The position of the arm support splints is adjusted on either side, such that it supports the patient's arm and is held in position using, for example, the hook and loop straps. The forearm support splint is attached to the base of the arm support splint on either side and screws are tightened. The patient's forearms are placed on the forearm supports and secured in place using for example, the hook and loop straps. The patient is instructed to grasp the handle of the module on both sides. The therapist assists the patient grasping the handle on the affected side. Now once again, the forearm and hand are secured in position by using, for example, hook and loop or velvet straps such that the shoulders are at zero degrees and elbows on both sides are at 90 degrees. In order to train the wrist flexion and extension movements, the patient is asked to move the modules on both sides in a transverse plane along the semi-circular track performing the forward and backward bending movements at the wrist joint. If the patient has little or no movement on the affected side, the therapist can hold the module on the top by means of the end-effector knob on the affected side and help the patient in performing the movements. When the patient attempts to move the wrist module by active movement or by active assist movement, the top of the handle moves along the semi-circular track of the end effector in both forward and backward directions to provide smooth movements of the wrist in a transverse, gravity eliminated plane. However, it is to be noted that the ball joints between the first and second links and the second and third links are fixed during the course of the movement. The joint where the end-effector is attached to the distal end of the arm is also fixed and there will be no rotational movement. To train the wrist ulnar and medial deviation movements, the handle of the end-effector is locked in the semicircular track allowing movements only in the vertical plane along the vertical axis without any transverse motion. The patient is instructed to lift the handle of the wrist module in a vertical axis by performing

upward or downward movement at the wrist joint which will cause the deviation of the wrist towards ulnar (medial side) or radial (lateral) side of the wrist joint.

[0099] The patient is allowed to practice movements in the transverse or vertical plane in the range permitted as determined by the therapist before start of the movement. The number of co-ordinate repetitions is determined by the therapist. Frequent rest breaks should be given to the patient during the course of the therapy session. The module along with the forearm support will allow the patient to grasp the handle of the end-effector and also properly position and support the forearm and arm while performing the movements at the wrist joint. After enough number of repetitions, the wrist module can be detached very easily and the next module can be mounted to train other joint movements.

[0100] Hand therapy module as shown in figure 9 can be used to train finger movements. It also has a sensory re-learning kit consisting of sensotubes - together this module serves as a hand therapy module. Hand therapy module is specifically designed to train finger movements. It has three movable finger splints and one thumb splint. The distance between the splints and the position of each splint can be adjusted depending on the dimensions of the patient's hand. Each finger splint is a vertical hollow structure provided with four elastic loops. Each loop can hold one finger in position. The 4 finger loops will hold the index, middle, ring and little finger in position. The thumb splint has two finger loops for each segment of the thumb. Each finger splint is meant for each segment of the finger. Each finger is divided into 3 segments – Proximal, middle and distal. A first finger splint will hold the proximal segments of all the four fingers in position. A second finger splint will hold all the middle segments in position and third finger splint will hold all the distal segments in position. The tension in the elastic loops can be adjusted using the knobs provided for each loop. Depending on which finger segment is moving, the tension in the loops can be adjusted to provide training to specific finger segments or to all finger segments at the same time. The base portion of the finger trainer is provided with a pair of forearm and wrist straps to keep

the forearm in position and to maintain proper alignment of the elbow and wrist joints when the patient is performing the finger movements. Three rows of slots are provided on the surface of the finger trainer to fit the sensetubes. The slots have metal threads to fix the sensetubes for sensory training.

[0101] Before training the patient on finger movements, it is important to make some adjustments to the trainer. Firstly, the patient's arms are slowly removed from the module by untying, for example, the hook and loop straps. Make sure the semi-circular center piece of the table top platform is in place and the position of the trainer is adjusted so that the front margin of the trainer is just touching the belly of the patient but not completely surrounding the patient. Now the wheels are locked securing the trainer in place. The position of the arm support splints is adjusted on either side, such that it supports the patient's arm and is held in position using, for example, the hook and loop straps. The patient's forearms are placed on the base piece and secured in place using for example, hook and loop, straps. The patient is instructed to place the fingers in to the elastic loops and the loops are gently tightened to keep the fingers in position. If the patient has little or no movement in the finger joints, the therapist can assist the patient to stretch the fingers before helping the patient to place the fingers in to the elastic loops. Depending on which segments of the fingers need to be trained, the therapist will use the knobs to adjust the tension in the loops there by allowing the movement of the fingers in specific joints or all the joints at the same time. Because of the elastic nature of the loops, the loops will not only provide enough tension while performing the movements but also will automatically recoil to bring the finger segment back to the resting position allowing the patient to move the joint again. Improving the sensation in the hand is also considered as one of the important aspects of improving hand function through sensorimotor integration. The Sensilearn tubes are specifically designed to provide sensory feedback to the patient while the patient is practicing movements at the finger joints. These Sensilearn tubes are hollow non-magnetic metal tubes that have different surface textures, different weights, and different shapes. These tubes can be in

any number and will help the patient to identify different surface textures, different shapes, different weights of the objects, different sizes. The patient also can perceive the sensation on the unaffected side first and then can try to learn different sensations on the affected side. The therapist can develop a customized protocol using different combinations of these sensitubes to provide sensory re-education to the patient.

[0102] The patient is allowed to practice movements in the transverse plane eliminating the effect of gravity, in the range permitted as determined by the therapist before start of the movement. The number of coordinate repetitions is determined by the therapist. Frequent rest breaks should be given to the patient during the course of the therapy session. The module along with the forearm support will allow the patient to properly position and support the forearm and arm while performing the movements at finger joints. While practicing the finger movements, the therapist will use different combinations of sensitubes to provide sensory feedback to the patient. These tubes can be conveniently fixed in the slots provided on the module. After enough number of repetitions, the module can be detached very easily and the next module can be mounted to train other joint movements. At the end of the therapy session, enough precaution is taken to remove the patient's arms from the module. The links of the arms are detached and the tabletop platform is unlocked on the side margins, to fold the table and locked again using the locking system on the base piece. Because of the portable and mobile nature of the trainer, the trainer can be easily moved around like a therapy cart and can be stored easily in a safe place.

[0103] The patient does not necessarily need to be in a bed. All the above movements using various modules can be practiced by a patient in a sitting position comfortably seated in a chair, or a wheel chair or even in a standing position. These modules will be very helpful for the therapist to practice intensive coordinate repetitive movements with the patient at arm, forearm, hand and finger joints without significant effort or manual assistance. The device can be easily used by a skilled caregiver to practice movements with the patient at home using different modules.

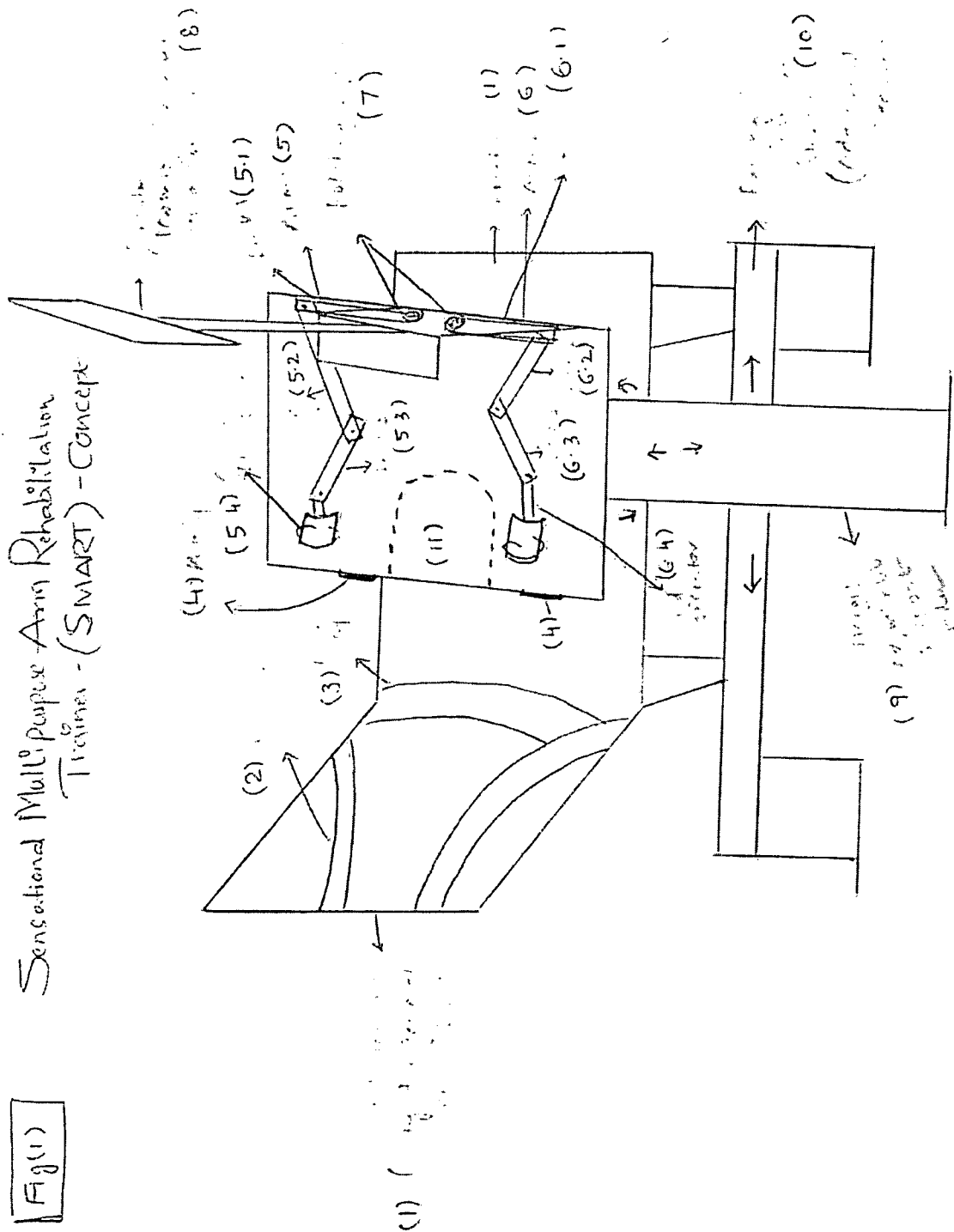
[0104] The foregoing description of illustrative embodiments has been presented for purposes of illustration and of description. It is not intended to be exhaustive or limiting with respect to the precise form disclosed, and modifications and variations are possible in light of the above teachings or may be acquired from practice of the disclosed embodiments. It is intended that the scope of the invention be defined by the claims appended hereto and their equivalents.

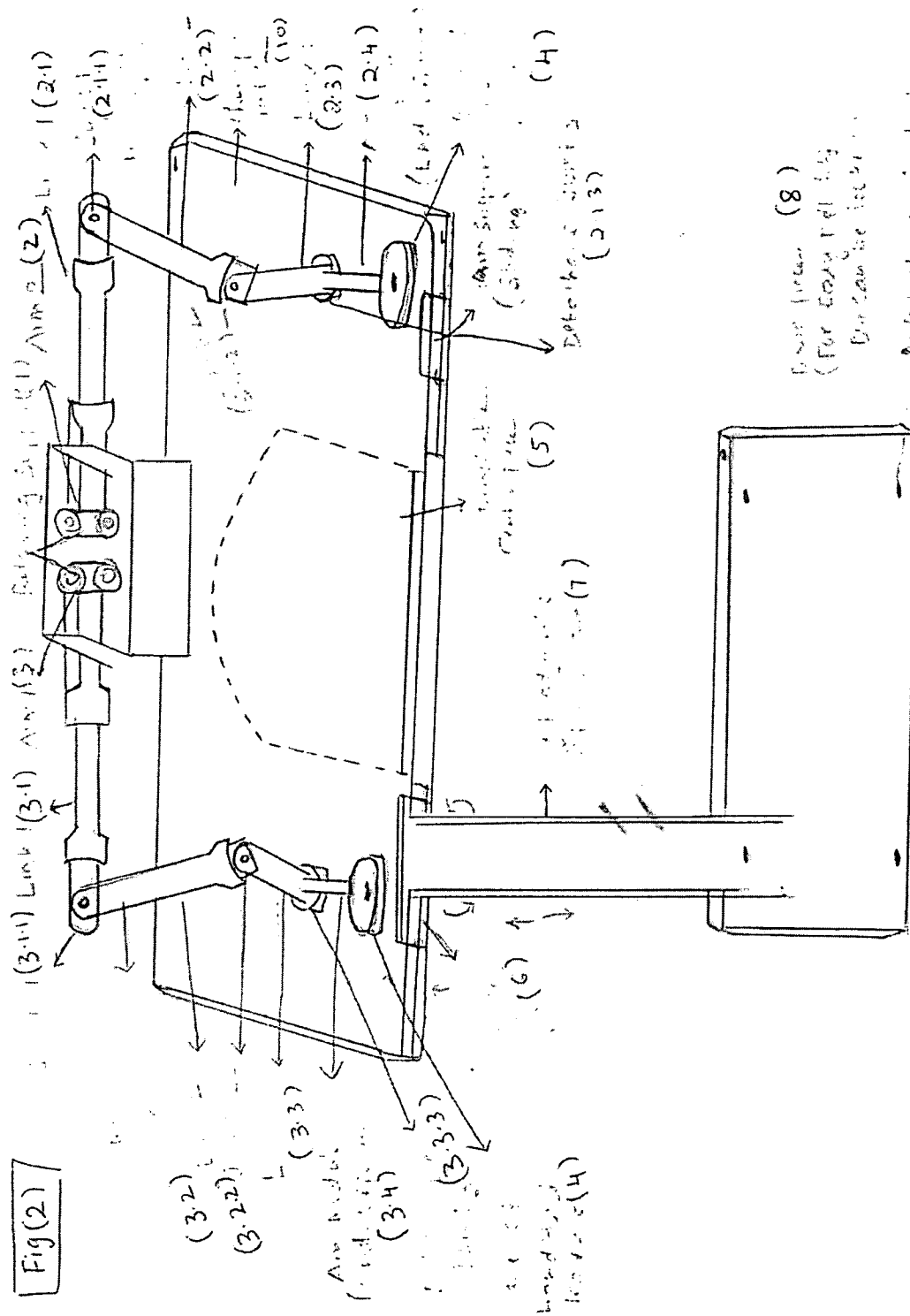
WHAT IS CLAIMED IS:

1. A rehabilitation system comprising:
a platform;
a first arm comprising a plurality of links connected by a plurality of corresponding joints, the first arm connected at a first end to the platform; and
the first arm configured to accept an end effector for therapy.
2. The rehabilitation system of claim 1, further comprising a second arm having a plurality of second arm links connected by a plurality of corresponding second arm joints.
3. The rehabilitation system of claim 1, wherein the platform further comprises a tabletop.
4. The rehabilitation system of claim 3, wherein the tabletop platform includes a detachable center piece.
5. The rehabilitation system of claim 3, wherein the tabletop platform is foldable.
6. The rehabilitation system of claim 1, further comprising a first arm splint.
7. The rehabilitation system of claim 1, wherein the end effector is selected from a group consisting of a shoulder module, a sagittal plane movement module; a hand supination module, a wrist module, and a finger module.
8. The rehabilitation system of claim 6, wherein the finger module comprises a sensitives.
9. The rehabilitation system of claim 1, further comprising a height adjustable side pillar supporting the platform.
- 10.10. The rehabilitation system of claim 1, where the arm links are lockable to enable movements at some links and not at others.
11. A rehabilitation system comprising:
a tabletop platform, the tabletop platform comprising a folding portion;
a height adjustable side pillar supporting the tabletop platform;

- a first arm comprising a plurality of links connected by a plurality of corresponding joints, the first arm connected at a first end to the tabletop platform; and
- the first arm configured to accept an end effector for therapy.
12. The rehabilitation system of claim 11, further comprising a second arm having a plurality of second arm links connected by a plurality of corresponding second arm joints.
13. The rehabilitation system of claim 11, wherein the tabletop platform includes a detachable center piece.
14. The rehabilitation system of claim 11, further comprising a first arm splint.
15. The rehabilitation system of claim 11, wherein the end effector is selected from a group consisting of a shoulder module, a sagittal plane movement module; a hand supination module, a wrist module, and a finger module.
16. The rehabilitation system of claim 15, wherein the finger module comprises a sensitives.
17. A rehabilitation system comprising:
- a tabletop platform;
 - a height adjustable side pillar supporting the tabletop platform at a first end and having a base at a second end;
 - a first arm comprising a plurality of links connected by a plurality of corresponding joints, the first arm connected at a first end to the tabletop platform; and
 - the first arm configured to accept an end effector for therapy.
18. The rehabilitation system of claim 17, further comprising a second arm having a plurality of second arm links connected by a plurality of corresponding second arm joints.
19. The rehabilitation system of claim 17, wherein the tabletop platform includes a detachable center piece.
20. The rehabilitation system of claim 17, further comprising a first arm splint.

21. The rehabilitation system of claim 20, wherein the end effector is selected from a group consisting of a shoulder module, a sagittal plane movement module; a hand supination module, a wrist module, and a finger module.



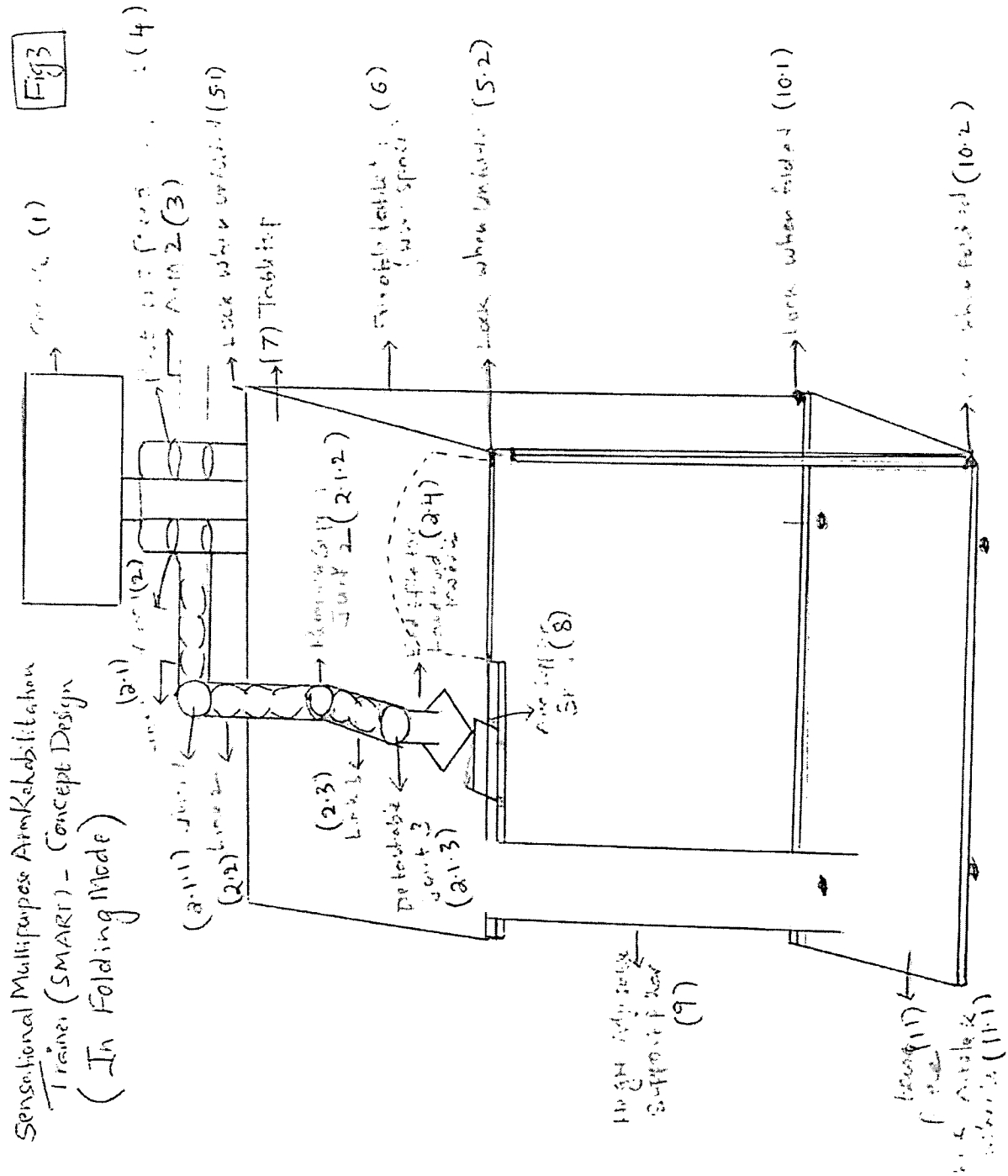


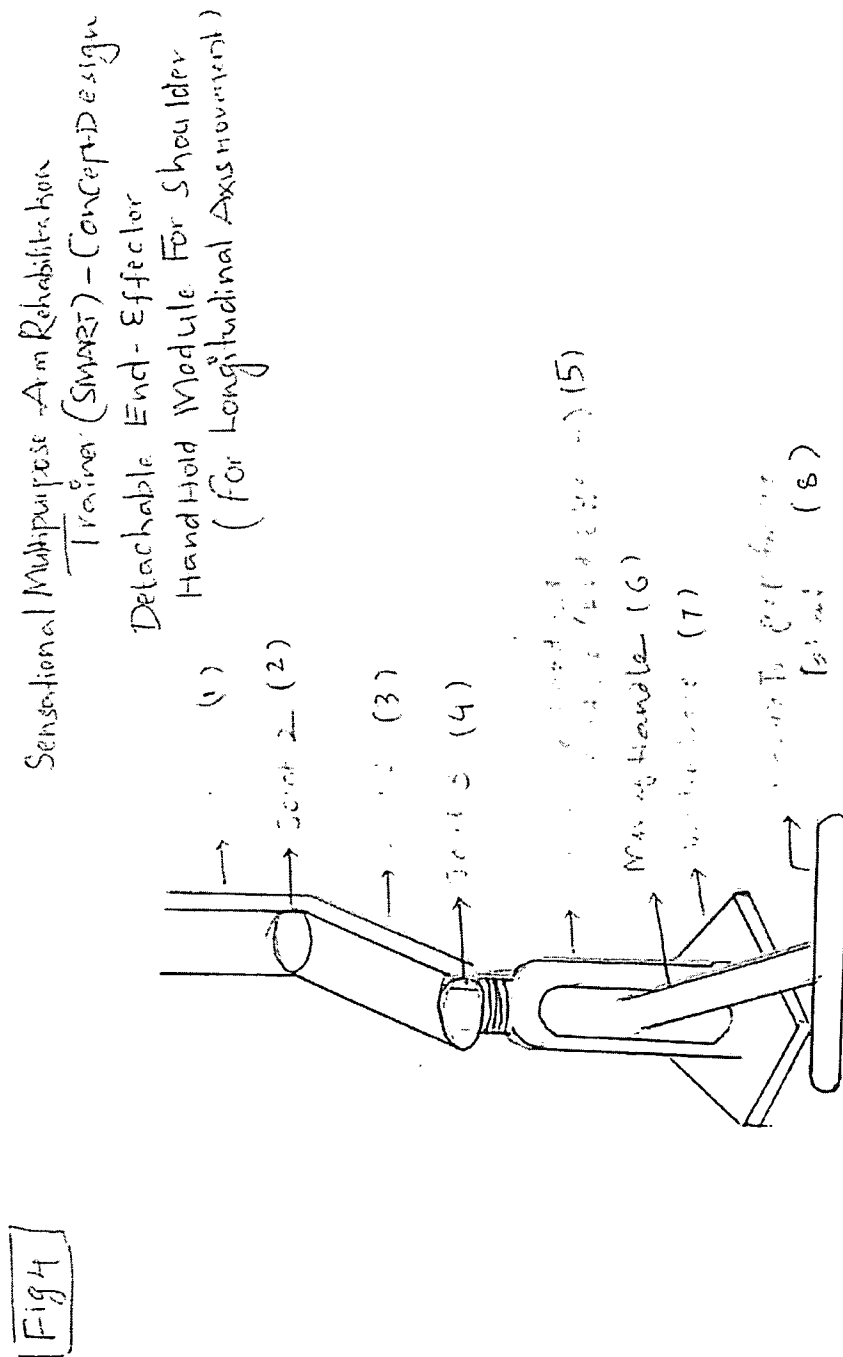
(8)

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Attachment (b)

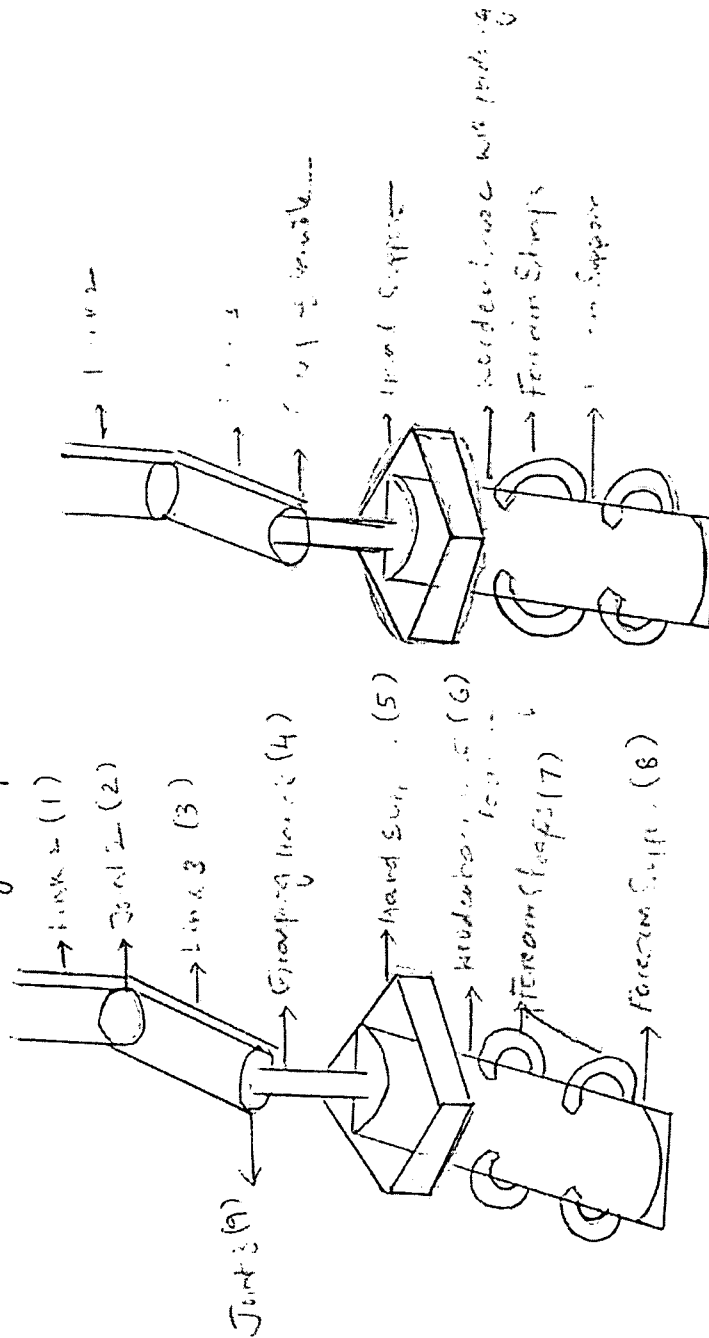
TWIN ARM SMART (Sensational Multi-purpose Arm
(MANUAL version) Rehabilitation Trainer)





Sensational Multipurpose Arm Rehabilitation Trainer
(SMART) - Concept
Detachable End-Effector (Hand Hold Module For
Sagittal plane movement).

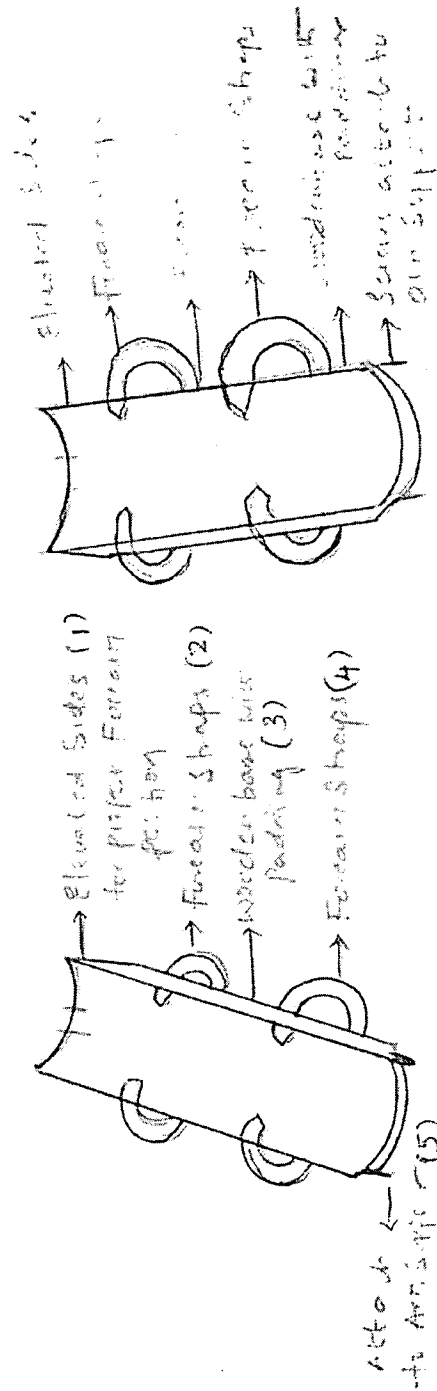
Fig 5



SMART is a multi-purpose arm rehabilitation trainer. It includes a detachable end-effector (hand hold module) for sagittal plane movement.

Sensational Multipurpose Arm Rehabilitation Trainer
(SMART) - Concept
(Forearm Support Splint)

Fig 6



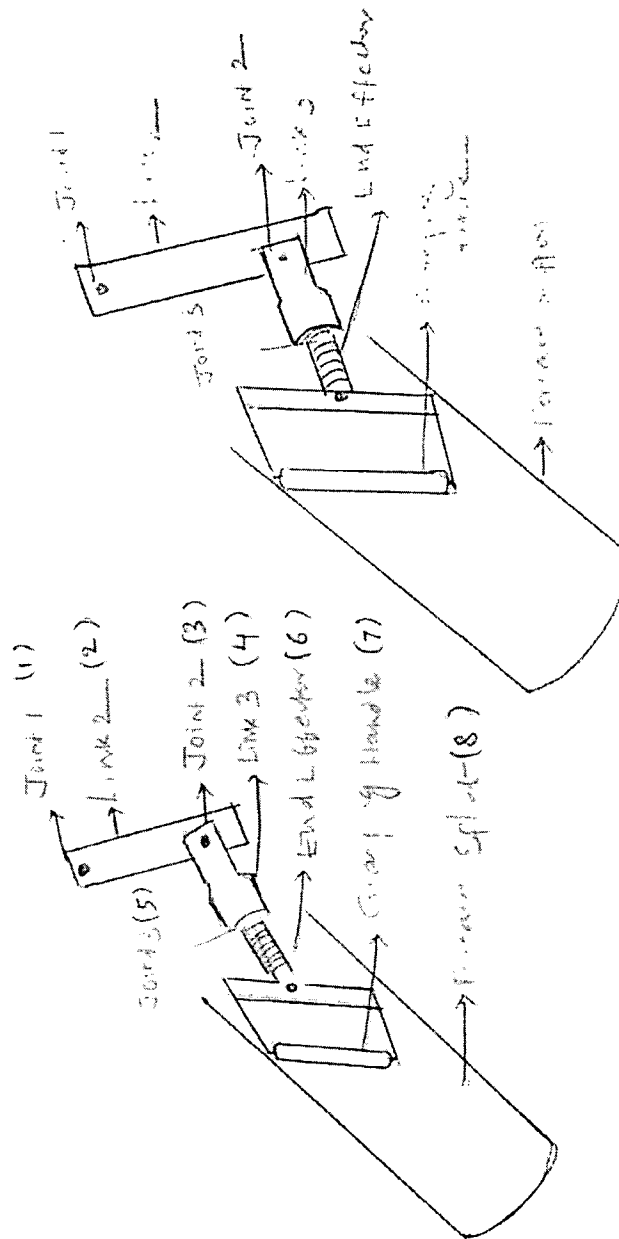
FOREARM COMPONENT (Support Splint)

Especially useful to support forearm
during Pronation, Supination
and shoulder flexion movements

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Sensahand Multipurpose Arm Rehabilitation Trainer
 (SMART) - Concept -
 Detachable End-effector (Hand hold module for
 forearm movements)

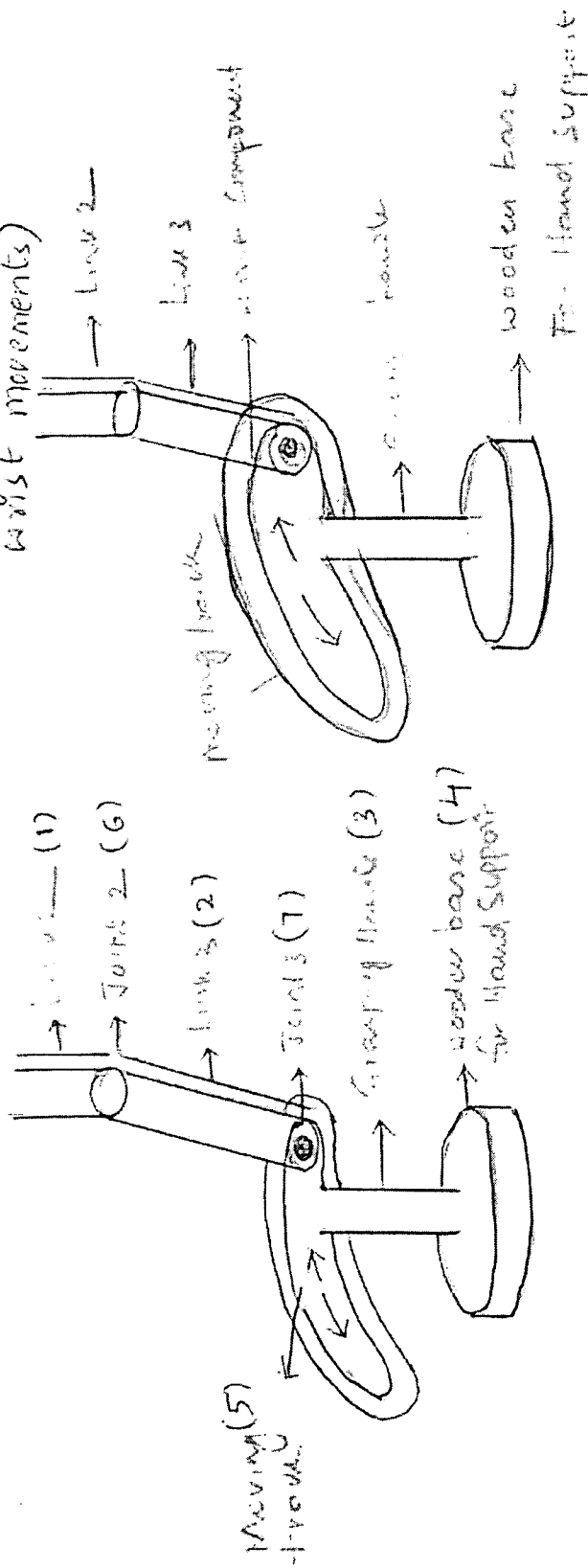
Fig 7



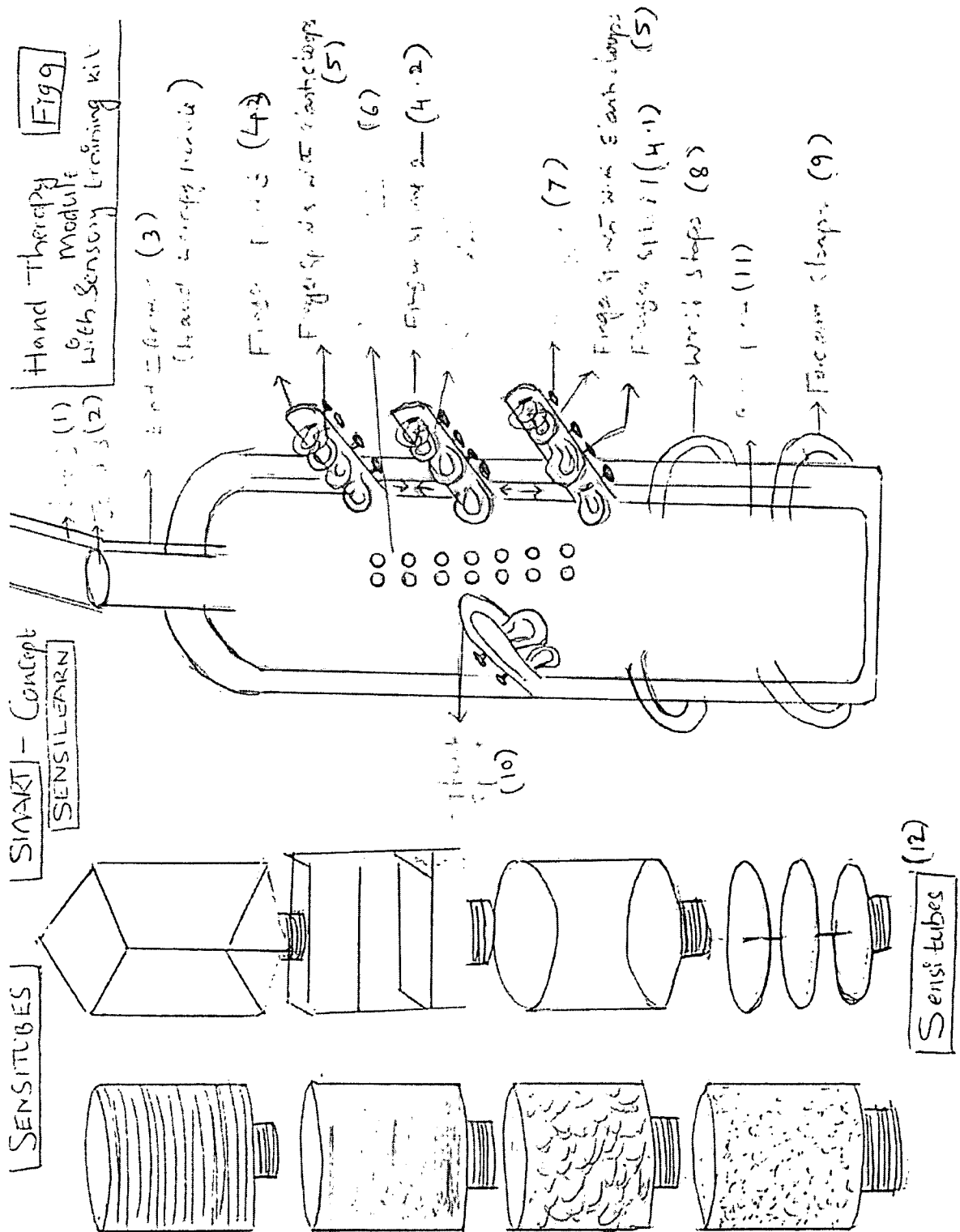
Pronation/Supination Component
 (Forearm Pronation and Supination)

Sensational Multi-purpose Arm Rehabilitation Trainer [Fig 8]

(SMART) - Concept
Detachable End-Effector (HandHold module for
wrist movements)



Wrist Module (for Wrist flexion and Extension)



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Sensational Multipurpose Arm Rehabilitation Trainer (SMART) - Concept
Supporting Side Pillar (Telescoping) with rotating plates.

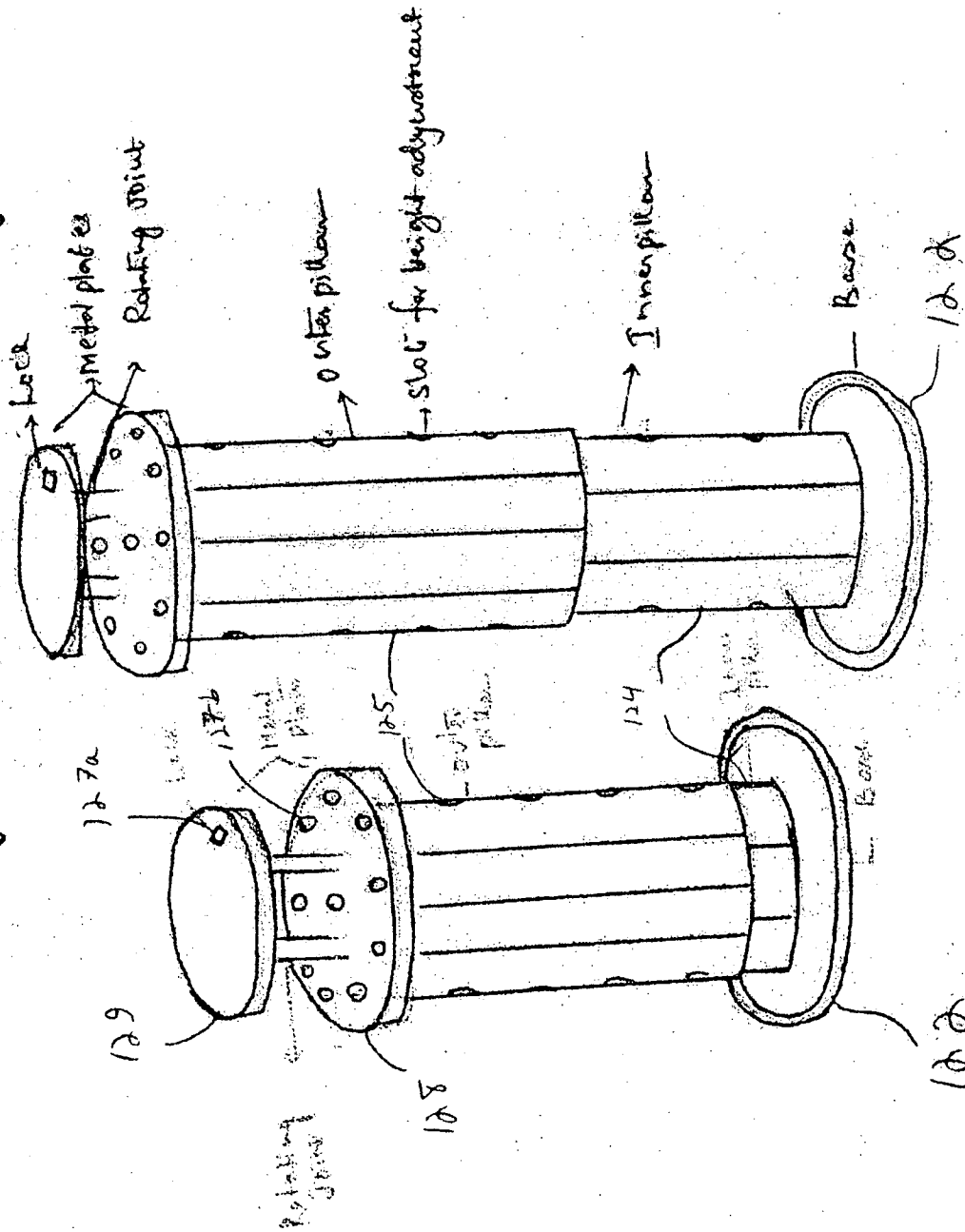


Fig 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2014/045103

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A63B 23/16 (2014.01)

CPC - A63B 23/16 (2014.10)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - A63B 23/16 (2014.01)

CPC - A61H 1/0285, 1/0288; A63B 23/16 (2014.10)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 108/11, 83; 312/239; 482/44, 47, 48, 130, 134; 601/23, 33, 40

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatBase, Google Scholar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/0300994 A1 (VERKAAIK et al) 08 December 2011 (08.12.2011) entire document	1-3, 6-8
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Y		4, 5, 9-21
Y	WO 96/36306 A1 (ROTTINGHAUS et al) 21 November 1996 (21.11.1996) entire document	4, 9, 11-21
Y	US 1,902,694 A (EDWARDS) 21 March 1933 (21.03.1933) entire document	5, 11-16
Y	US 2008/0304935 A1 (SCOTT et al) 11 December 2008 (11.12.2008) entire document	10

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

04 October 2014

Date of mailing of the international search report

06 NOV 2014

Name and mailing address of the ISA/US

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