ISSN 2395-1621

Continuous Passive Motion Device for Fingers

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ABSTRACT

Continuous Passive Motion (CPM) is way of providing regular physiotherapeutic exercises which are meant to increase and improve the joint movement. The targeted joints are usually subjected to regular passive movements which will remove muscle stiffness over time and also improve range of motion of the joints.

Keywords: Arthroplasty, Anthroplasty, Continuous Passive Motion, Extension, Flexion, Microcontrollers, Muscle Stiffness, Non-Invasive, Passive Motion, Physiotherapy

ARTICLE INFO

Article History

Received :13th April 2016

Received in revised form :

15th April 2016

Accepted : 18th April 2016

Published online :

20th April 2016

I. INTRODUCTION

Continuous Passive Motion Device is a machine that delivers carefully determined exercises to the targeted joint, which in this case in Fingers. In case of fingers the joints have to be precisely moved within the confines of specific flexion and extension angles. And they also have to be delivered at carefully controlled speeds and should include regular periods of stretching, to increase the current range of motion. A CPM device for fingers usually achieves this by directly residing over the back of the palm in the form of an exoskeleton which connects to each and every finger. Each of these connections can move the finger they are connected to deliver the designated exercise.

II. BASICS OF CPM

CPM stands for Continuous Passive Motion and refers to a set of exercises or joint movements which are usually used during the first phase of rehabilitation following a trauma or a soft tissue surgery.Passive Motion refers to the motion is being delivered to the joints in a non-invasive way i.e. the motion is not induced by invasive means like nerve stimuli or any chemical assistants. In Passive Motion the motion is rather is induced by simple physical actions like push and pull.The frequency, speed and range of these push-pull motions are typically determined by a physiotherapist. These factors are called the Control Factors or the Control Variables for the CPM Device and these determine the core parameters of the physiotherapeutic exercise delivered.

III.CONTROL VARIABLES FOR CPM DEVICE

a. Speed/Pace/Rate of Exercise: This Factor will decide the rate at which steps of the angle of motion are advanced. The higher the pace, the lower will be the time delay between each step of the motion. The smaller the time delay between each step the smaller will be overall time for the entire cycle, thus increasing the overall pace of the exercise.

   This setting should be changeable during the course of the exercise to provide a more dynamic exercise pattern and runtime approach.

b. Range of Motion: Range of motion is determined by two sub-factors, Flexion and Extension. Flexion is the angle of finger joints while making a fist and extension is the angle of finger joints while keeping a straight 180 degrees between the fingers and the palm.

Range asks for the maximum Flexion and Extension angles, which essentially means how much flexion and extension is induced in the finger joints during the CPM exercise.

a. Stretch or Hold Delay: This factor refers to the breaks between each half cycle of the treatment. This breaks are placed at the extremes of each cycle, i.e. the maximum flexion and extension positions. These breaks hold the joints at their extremes to extend the range of motion gradually and hence plays a very important part in the whole rehabilitation exercise.
b. Frequency of Exercise: This is mostly determined by the physiotherapist based on how aggressive the treatment needs to be. The more the frequency of the CPM exercise, the more aggressive the treatment is.Note: The first three factors of speed, range of motion and stretch delay are set in the device itself and are in a way intrinsic in nature. However, the fourth factor of frequency is external to the device in the way that it is determined by how many times the patients is subjected to wearing of the CPM device, which isn't be controlled by any setting of the device.

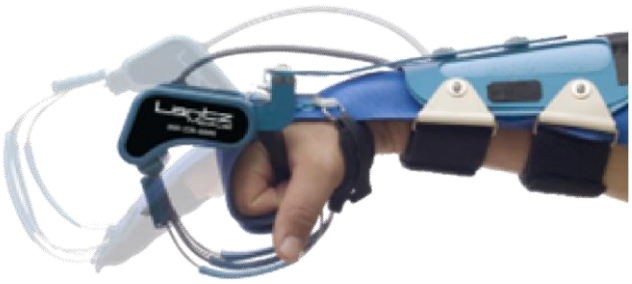
IV. TREATMENT APPROACH

The treatment approaches are very broad and can vary greatly even from one physiotherapist to other depending upon their opinions. CPM device application has no algorithmic approach to determine all the control factors/variables, and hence the control factors are often greatly specified in a range rather than precise values. So although the values of the control factors determined by different physiotherapist may be different but they lie within the same range.Speed, range of motion and frequency of exercise are the factors that affect the aggressiveness of the physiotherapeutic treatment. Increased speed, range and frequency are more aggressive but the outcome of the treatment can often deflect from the expected faster recovery to permanent muscle and tissue damage. On the other hand, a more laid back treatment will have minimal improvements or in some cases where the tissues are fighting back, no effect at all. Thus it is always checked that the aggressiveness of the treatment is balanced out properly with the expected positive outcomes.

V. BASIC DESIGN OF A CPM DEVICE FOR FINGERS

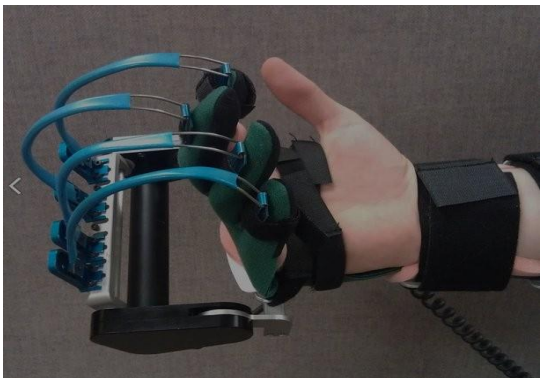
CPM device for fingers are basically some or the other form of exoskeleton which fits over the back of the palm. The exoskeleton either has a motor/actuator for each individual or a single motor/actuator for all the fingers combined. Two types of devices can provide the motion, the first one is a rotary motor and the second is linear actuator.Rotary motors in order to provide motion to the joints use a U bent frame which is attached to the shaft of the motor. The individual connections to the fingers are rigid and curved which are connected to the U bent frame on one side and to the respective finger joint on the other side. When the U bent frame is rotated along with the connected joints and the fingers are moved as a result.

(a)

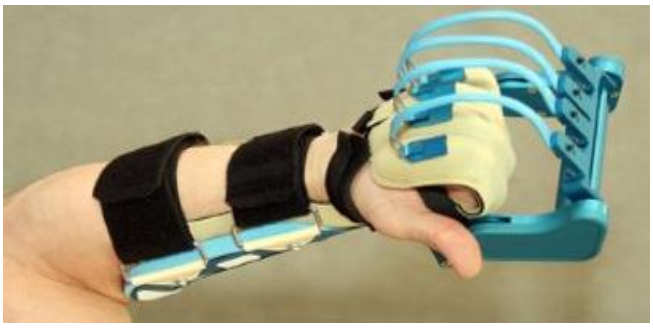


(b)

Fig 1. a) and b) shows the side view of the U bent frame and the curved connecting joints attached between the fingers and the rotary motor



(a)



(b)

Fig 2. a) and b) shows the top view of the U bent frame and the curved connecting joints attached between the fingers and the rotary motor

Actuators only provide to and fro linear motion and in order to be able to bend the fingers the connections

between the shaft and fingers have to be flexible enough to bend when pushing the fingers into a curve and straighten out while pulling the finger into a relaxed extension state.

Fig 3. An example of a CPM device which uses actuators for delivering the push and pull exercises to the finger's joints

VI. USER INTERFACE AND CONTROL PANEL

User interface in the case of a CPM Device for Fingers is typically a small control panel which takes input from the user about the control variables for physiotherapeutic continuous passive exercise. A typical control panel has a LCD or a LED Alphanumeric Display which displays the current state of the device along with showing the user with the options which could be changed or altered to increase or reduce the aggressiveness of the exercise.The most core control variables are the ones present in every CPM device for fingers. These as already mentioned are Speed, Range, Stretch Delays and Frequency. Frequency of treatment is the only control variable that is altered via the control panel's user interface.

Available Settings and their effect

- Authentication (Username and Passkey)
- Core Controls
  - Speed
  - Range of Motion
    - Maximum Flexion Angle
    - Maximum Extension Angle
  - Stretch Delay
- Other Activities
- Games
- Report Generator

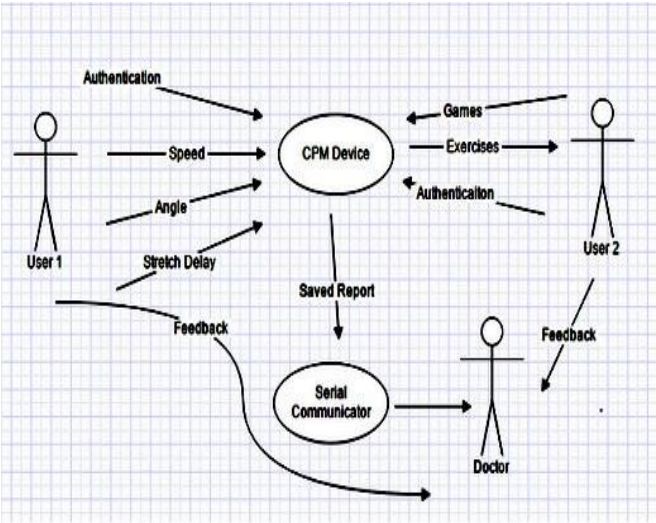


Fig 4. CPM Device and its interaction through User-Interface

Besides having the LCD/LED display for all displaying all the information, there are usually some buttons provided which can manipulate the screen the options displayed.Buttons can be push buttons, toggle buttons, or any similar type which can achieve the same functionality. There can be individual button for each function example, for increasing speed, increasing stretch delay etc., or there could be some functions that would be combined, for example the increase and decrease buttons can be common for the options and there might be a navigation button which would able to select the option needed.

VII. WORKING

The device uses the following components

- DC Motor
- Rotary Encoder
- Graphical/Alphanumeric Display
- Micro-Controller/Microprocessor
- Comparator
- Motor Driver like L293D/ L298
- Push Buttons for operation

Micro-Controller is usually preferred over microprocessor as it accomplishes the control of the DC Motor and other components more cost effectively than microprocessor.

The Micro-Controller receives the input regarding the

change of settings from the push buttons. When pressed they send an active low or active high which gets interpreted as particular function by the controller depending upon on which pin the signal is received. The function read by the controller is then executed by the corresponding block of code.Whenever a change of step of the DC Motor is encountered, the controller obtains the current step of the DC Motor by reading the Rotary Encoder and storing it in a temporary variable. The DC Motor is run in the desired direction using a Motor Driver like L293D until the desired no of steps have been taken. This is checked by the subtracting the temporary value already stored and subtracting from the current step obtained from the rotary encoder. Sometimes when the speed is low it is required that the pace of steps be slow and even take one step at any given time and then wait for some calculated time and then run again for one step.At all times the Controller continuously updates the Information and Options available for the user on the GLCD/Alphanumeric Display. Usually an Alphanumeric Display is preferred over the GLCD due to less complexity and less number of Data and Command pins required.

There are usually five push buttons, one for each direction of navigation and one for selecting the highlighted option.

The DC Motor's shaft is connected to the u-bent support frame which is in turn is attached to all the curved connecting rods. The shaft also drives the rotary encoder which generates a pulse each time after covering a certain angle. The smaller the angle, the more the number of pulses that will be generated in each rotation. The more the number of pulses the controller receives from the more accuracy with which it will be able to judge the position of the fingers which is attached to the shaft indirectly.

VIII. CONCLUSION

Thus we have successfully implemented the CPM device for fingers and we have included all the necessary control variable and factors for the operation of the device. The device is significantly cost effective and affordable by the common folk.

Our Device has the following advantages over the existing device

- Cost Effective and affordable
- Attractive and comprehensible User Interface
- Exercises provided according to strict physiotherapeutic norms
- Options for speed control, flexion and extension angle control and variable stretch and hold delays for increasing the range of movement of the fingers
- It even records its operations being performed so that they can be later reviewed by the Physiotherapist in-charge
- Also as added feature the device includes provision for leisure activities so that the patient experiences a non-monotonous exercise session

IX. ACKNOWLEGEMENT

I would like to express my deepest appreciation to all those who provided me the possibility to complete this report. A special gratitude I give to our final year project guide, Prof. Pramod D. Ganjewar, whose contribution in stimulating suggestions and encouragement, helped me to coordinate my project especially in writing this report.Furthermore, I would also like to acknowledge with much appreciation the crucial role of the staff of Department of Computer Engineering, who gave the permission to use all required equipment and the necessary materials to complete the task of research on the topic of Continuous Passive Motion. I have to appreciate the guidance given by other supervisor as well as the panels especially in our project presentation that has improved our presentation skills thanks to their comment and advices.

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