PROJECT REPORT

Project ID/Title: **MULTISENSOR DATA FUSION ALGORITHM FOR CONTACT-LESS 3D POSITION MEASUREMENT FOR POST-STROKE HAND REHABILITATION**

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Author Name(s): Dr. Ali Sophian, Dr Hazlina Md Yusuf, Dr Wahju Sediono, Dr Sud Sudirman

Department/Kulliyyah/Institute/Centre: Mechatronics/Engineering

Abstract

Repetitive hand motion exercises help the patients regain their hand motor control. One of the widely used therapies of this type is the patient squeezing a flexible exercise ball in his/her hand repetitively. The exercise balls come at different levels of resistance to accommodate the different levels of limitation of the patients' hands. However, one of the challenges is to measure objectively the progress that has been made without making any contact such that no additional weights loading the affected arm or hand of the patient. The presence of the exercise ball in the hand adds a degree of difficulty to the problem when an optical solution is adopted. This research attempted to investigate the enabler technology for contactless quantitative measurement system for monitoring the progress in such hand therapy. Evaluation of potential commercial-grade stereo-vision systems have been performed and fingertip detection algorithms have been proposed and evaluated. A total of 4200 images, 2100 fingertip images and 2100 non-fingertip images, were used in the experiment. Our results show that the success rates for the fingertip detection are higher than 94% which demonstrates that the proposed method produces a promising result for fingertip detection for therapy-ball-holding hands.

Introduction

Machine vision technologies have been embraced by more and more sectors and applications thanks to the more affordable costs of their implementation. Many stroke survivors need the rehabilitation of the functionalities of their hand through therapies which use repetitive motions [1]. In one kind of the therapies, the patient has to squeeze a flexible exercise ball in his/her hands repetitively. One of the challenges is to measure objectively the progress that has been made [2].

The use of machine vision in such an application may offer benefits due to non-contact nature of the technology. The technology can be used to detect the fingers and fingertips which will then allow more objective measurement of the performance. To this point, most of fingertip detection techniques have been developed for human machine interface (HMI), where more natural ways of interaction with the machine are made possible.

In this project, fingertip detection techniques have been proposed and evaluated following data gathering from selected samples.

Background

There have been works on fingertip detection using machine vision by other researchers. An engine development for fingertip detection in real-time that is targeted at mobile devices for the Natural User

Interfaces (NUIs) [3]; system development that is capable of detecting fingertip in a reliable manner in complex environment under different light conditions, different scenes without any markers [4]; Feng et al. (2012) used Kinect sensor for fingertip detection for writing-in-the-air character recognition system; an approach that allows the detection of hand and fingertip with or without illumination in cluttered background [5]. It should be noted that not all hand gesture recognition would require the determination of the position of the fingertips. They may just rely on the overall shape of the hand [6].

The challenges that need to deal with are (1) the non-rigid nature of hands possessing a high degree of freedom that makes it difficult to match various shapes of fingers with a set of images, (2) there is a variety of orientation and appearance of finger; thus it is difficult to detect the shape and posture of the fingers accurately and robustly, and (3) slight differences may lead to substantial error in the case of fingertips that belongs to the same person [7]. These challenges get even more significant when commercial vision systems are used, instead of those of industrial grade

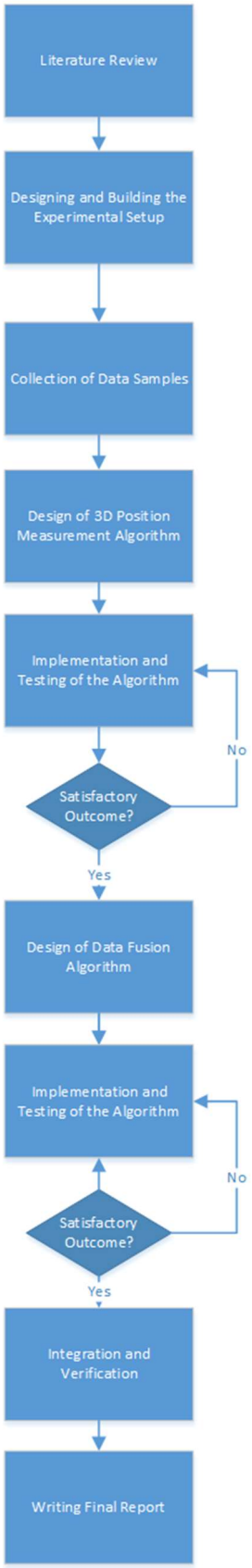
Objectives

1. To develop an algorithm for fusion of multi sensor data for contact-less 3D position measurements and tracking of the fingertips that can be used in the exercise ball therapy exercise.

2. To verify and evaluate the algorithm by using experiments

3. To recommend the sensor requirements for implementing the algorithm

Methodology



Findings

1. In many cases, the separation of the hand and the ball segments can be achieved by using the normalized RGB color spaces [8]. However, the accuracy is affected by factors, such as lighting.
2. For the 3D position or distance measurement systems, stereo vision systems may offer this functionality with the extra benefits when the images are used for other purposes, as well such as object recognition. Our results show that the webcams generally have better performance in both accuracy and precision compared to Leap Motion Controllers (LMC), however the LMC has some potential when shorter ranges are required, thanks to their shorter lens distance and wide-angle lenses [9]
3. The use of HOG and SVM in the detection of fingertip in the images obtained by using a consumer-grade webcam has been evaluated. Experimental tests have been obtained, plotted and discussed. As expected, the performance of the detection is improved as the number of training data is increased. The more data we use, the better the performance, although it's likely to hit saturation at one point. As for the size of the cell for the HOG, it was found that the 10 x 10 size would give the best results in terms of accuracy in the detection. However, even at its best, the classification accuracy obtained was less than 90% [10].
4. In this work, it has been shown that the method based on SURF and bag of words has been shown a good performance in detecting fingertips in images where a hand is holding a therapy ball that is normally used in a post-stroke hand therapy. The success rate was generally found to be increased when the number of training images were increased, especially in the correct identification of the non-fingertip, i.e. lower false positive detection rates. The success rate for the fingertip detection reached higher than 94% with the algorithm, which is reasonably high for the therapy applications, despite the use of commercial-grade cameras [11].

Conclusions

1. A study has been made on the use of stereo vision systems that can be used potentially in measuring positions and distances of fingertips and their performances were compared empirically.
2. Image data collection has been done for enabling the training
3. Algorithms for fingertip detection that can be used with commercial-grade cameras have been proposed and their performances have been studied.
4. There was not sufficient time and resources that would allow us to investigate the use of multiple cameras in order to cover the hand from different angles and applying data fusion techniques.

Output

1. A set-up for conducting the experiment
2. Collection of image data
3. 4 scopus-indexed journal publications
4. 1 MSc student (on-going)

Future Plan of the research

- To investigate the best method for
- To implement the method on a real-time system

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