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Bayesian network aided grasp and grip efficiency estimation using a smart data glove for post-stroke diagnosis

Debeshi Dutta [a,c,*], *Satyanarayan Modak* [b], *Anirudh Kumar* [a], *Joydeb Roychowdhury* [a,c], *Soumen Mandal* [c]

[a] *Embedded Systems Laboratory, CSIR-Central Mechanical Engineering Research Institute, Durgapur, India*
[b] *Nivedita Health Centre, Durgapur, West Bengal, India*
[c] *Academy of Scientific and Innovative Research, India*

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ABSTRACT

Stroke is one of the major causes behind the increased mortality rate throughout the world and disability among the survivors. Such disabilities include several grasp and grip related impairment in daily activities like holding a glass of water, counting currency notes, producing correct signature in bank, etc., that seek serious attention. Present therapeutic facilities, being expensive and time-consuming, fail to cater the poverty stricken rural class of the society. In this paper, on the basis of an investigation, we developed a smart data glove based diagnostic device for better treatment of such patients by providing timely estimation of their grasp quality. Data collected from a VMG30 motion capture glove for six patients who survived stroke and two other healthy subjects was fused with suitable hypothesis obtained from a domain expert to reflect the required outcome on a Bayesian network. The end result could be made available to a doctor at a remote location through a smart phone for further advice or treatment. Results obtained clearly distinguished a patient from a healthy subject along with supporting estimates to study and compare different grasping gestures. The improvement in mobility could be assessed after physiotherapeutic treatments using the proposed method.

1. Introduction

Grasping an object is all about developing a balanced coordination to pick up and hold things securely in hands. Mankind is struck with misfortune on losing the ability to grasp. It is then, when he stops enjoying a carefree life, starts depending on people to accomplish most of his daily activities, and eventually gets neglected.

Just as walking, grasping is one of the important aspects of human activity, initiated by arranged coordination of hand controlled by biomechanical constraints and neurological

* *Corresponding author at*: Embedded Systems Laboratory, CSIR-Central Mechanical Engineering Research Institute, Durgapur 713209, West Bengal, India.
E-mail addresses: debeshi.dutta@gmail.com (D. Dutta), anirudhkumar@cmeri.res.in (A. Kumar), jrc@cmeri.res.in (J. Roychowdhury), somandal88@gmail.com (S. Mandal).
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functions. The biomechanical constraints constitute the complex structure of human hand that has a unique connective architecture between muscles and articulations. On the other hand, neurological functions are actuated by central nervous system (CNS) on reception of proper sensory information leading to the movement of fingers for grasping [1]. Stroke, which is growing to be a common phenomenon in elderly people, may be defined as a sudden death of brain cells persisting for more than 24 h caused due to abnormal blood supply to the brain or spinal cord [2]. Sudden death of brain cells hinders transmission of brain signals between motor cortex and cerebellum through basal ganglia. Therefore, a cerebral vascular accident (CVA) or stroke is one of the major causes behind such disabilities among its survivors. It has been reported from study that fifty percent of survivors of stroke show permanent change in physical capability, speech, cognitive functions, etc. Such a crisis seeks proper attention and monitoring. The treatment of such deficiency in human body continues long after one's survival from stroke and it is then when trained experts called physiotherapists come into play. Regular and guided therapeutic exercises along with close monitoring of the patient's health status results into a much comfortable rehabilitation process. Treatment of a stroke survivor is therefore time consuming and varies with the nature of disability of the patient involving frequent modifications in treatment approaches (medicines or therapy).

Medical technology is slowly expanding to cover such areas of concern and researchers are not far away to come up with partial or complete recovery solutions for such grasp impairment issues. Just as in Arizona University an experiment was conducted to estimate the writing capacity of a patient several years after stroke to help him to relearn to write [3]. On the other hand, such technology often fails to cater the medical needs of the under privileged rural people due to various unavoidable circumstances such as lack of effective communication between the patient and concerned doctor, unavailability of proper resources and medical facilities in remote areas and most importantly financial constraints that prevent the poor people to avail the required treatment. Moreover, as per the data released by the Registrar General of India for the year 2010–13, more than half of the 30 million victims of cardiovascular disease such as stroke are in rural areas. Considering the above factors and the estimated time and patience necessary for such kind of treatment, therapists have reported that such cases are often left unsolved.

Moving a step ahead of the conventional treatment methods, N.G. Kataeva et al. laid the brick for automated diagnostic method for the post-stroke treatments. Walking disorders after stroke was their area of concern and the severity of improper walking was estimated for effective diagnosis [1]. Motivated by such innovation, several grasp diagnosis systems are gaining the significance of late. However each of these diagnosis systems suffer from some constraints such as requirement of complex set up, dedicated laboratory for diagnostics, need for trained personnel, gap between machine inference and domain expert knowledge and so on. Filling the existing gap in diagnosis is possible using the development of a remote diagnostic tool that monitors patient's grasp status based on previously procured domain expert knowledge, without the continuous interference of a domain expert during diagnosis, in form of a smart wearable hand data glove, thereby overcoming constraints like time and patience. Continuous monitoring of the affected part of such patients is the most appropriate parameter for correct treatment. Hence proper acquisition of such critical data generated through monitoring over a time is essential. Data collection is possible through various sources such as electronic medical records, wearable sensors, etc. [1,4,5]. Furthermore the data can be processed employing various machine learning paradigms. Many alliances have used machine learning paradigms to transform these health related data into new technologies and products which will improve the overall diagnosis system and patient recovery process [4–6]. Very limited research has been conducted on evaluation of grip kinematics for people suffering from various neuromuscular dysfunctions; still an insight to the existing literature reveals excellent discoveries in similar areas.

Variability in grip kinetics was identified by Bassma Ghali et al. using an instrumented pen which gathered sensory information from the effective areas of the thumb and fingers that interact with the pen. The authors have reported classification of grip kinematics for different participants employing classification procedures such as linear discriminant analysis (LDA), k nearest neighbour (k-NN) and neural networks (NN) [7]. However the experiments were conducted on normal, healthy subjects and no specific neuromuscular disease affecting grip kinematics was explored.

Later, Beatriz Leon et al. recognized various grasping postures using a passive exoskeleton for post-stroke rehabilitation of hand and wrist using a method based on support vector machines (SVM) [8]. The proposed methodology could classify the variation in grip well however the SVM training was based on the grasping quality of few patients and healthy subjects and no domain expert knowledge was taken into consideration. In medical technology where a domain expert or doctor plays an important role, neglecting the knowledge gained from experience of the domain expert in training of machine learning algorithms cannot be considered accurate by the medical fraternity. Furthermore SVM algorithm cannot be used to process insufficient data.

Motivated by the earlier approach and supported by recent advances in smart wearable systems that have progressively changed the landscape of healthcare [9], we have used a VMG30 motion capture hand glove to acquire sensory information from hand of the patients so as to study their grasp and grip kinetics simultaneously. In order to bridge the existing gaps caused due to data insufficiency in an uncertain domain like healthcare and to initiate a diagnosis with minimum risk by allowing incorporation of an expert's opinion into the system which is not possible in other machine learning techniques, we have used a Bayesian networks (BN) based approach to transform useful data into probabilistic grasp quality estimations in this work [1]. Such a system would therefore aim to reach the unreached and make treatment facilities available irrespective of distance and poverty.

2. Methodology

In this work, we have developed a Bayesian network based diagnostic system for grasp and grip impairment estimation of