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# A Home-based Functional Hand-Extremity Assessment System for Stroke Rehabilitation

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***Abstract*—This paper presents a novel hand-grip system for evaluation and rehabilitation of individuals with stroke. This system contains a pair of hand dynamometers, which are sensors for the input of grip force, and LabVIEW VI software to translate the grip force into meaningful data. The hand-grip system requires the subjects to move a small ball on a computer screen toward a target, using the hand grip sensor to control the movement of the ball. It goes far beyond measuring maximum grip strength, a common clinical assessment, to adapt grip force and coordinate hands to perform daily functional activities. This system also provides advancement in home-rehabilitation options to improve the hand-grip control of individuals with stroke.**

## I. Introduction

The ability to modulate grip is a key component in performing daily functional activities such as brushing our teeth, opening medicine bottles, or placing groceries in the refrigerator. Following stroke, hand manipulation is reduced in speed and accuracy [1]. Grip strength and coordination has a direct relationship with motor abilities in individuals recovering from stroke. There is robust evidence showing the value of grip strength as a clinical assessment. The correlation between both maximal and sustainable grip, and ability to perform functional tasks emphasizes the need to maximize grip through rehabilitation [2]. Moreover, the ratio of paretic to non-paretic maximal hand grip strength is a predictor of upper extremity outcome following stroke [3]. These simple assessments of hand grip susustainability and maximal strength have been shown to be valuable outcome measures in stroke rehabilitation.

However, the current use of grip strength in both assessments and training are not comprehensive enough. They primarily address maximal voluntary grip force and sustainability of grip, while neglecting aspects of coordination between hands or modulating grip appropriately for a task. More elaborate systems,such as the Biometrics E-LINK EP9 Exercise and Evaluation System, include the use of electromyography (EMG) requiring more assistance from rehabilitation professionals. This system still lacks bilateral activities [4]. Other systems such as the QM-FOrMS does include bilateral rehabilitation but not the grip control [5].

To address these problems, in this paper, we propose a comprehensive solution of constructing a hand grip strength and coordination evaluation/rehabilitation system with cost effective assessments that may also be used in rehabilitation to improve grip function in individuals post stroke. It employs two main components: the hand dynamometers as force sensors for hand grip and the LabVIEW VI program for visual display and data collection. It is capable of generating a quantitative analysis which manifests and interprets the results from the grip tasks. The level of detail in the results displayed can be tailored to the clinician or patient as appropriate.

## II. Design Consideration

Many existing system lacks comprehensive analysis of functional coordination between hands. In our system, we employed a pair of hand dynamometers to gain insight of bilateral coordination, as well as grip strength. The exercises are designed so that patients can either work unilaterally or bilaterally, precisely coordinating grip strength between hands. The magnitude of grip necessary to reach a target is scaled to the participant's ability, making it possible for participants with low grip strength to perform the exercise. LabVIEW VI software is used for the user interface. The system is designed to be user friendly with an emphasis on being simple and intuitive. We are currently focusing on feedback that is appropriate for the individual with stroke. Further analysis with greater detail will be part of future data reports appropriate for clinicians.

## III. System Design

### A. System Overview

The system consists of two main parts: the hardware sensors and the software program design. The hardware part contains a pair of force sensors positioned upright in front of participants. Theses signals are generated by the hand grip force of the participant. In the next step, the analog signals are assigned as the coordinates of the controlled object (a ball) in the interface, equivalent to moving the object accordingly. The data of coordinates and time are recorded for post-analysis by MATLAB. It will be assessed based on our proposed features which give us insight into the subject's motor performance. As such, the system is expected to be valuable as both an assessment and rehabilitation tool. The overview flowchart of the system is demonstrated in Fig. 1.

### B. Handgrip Control Console with Sensors

The pair of hand dynamometers utilized the Vernier HD-BTA [6], shown in Fig. 1. It is capable of sensing grip and

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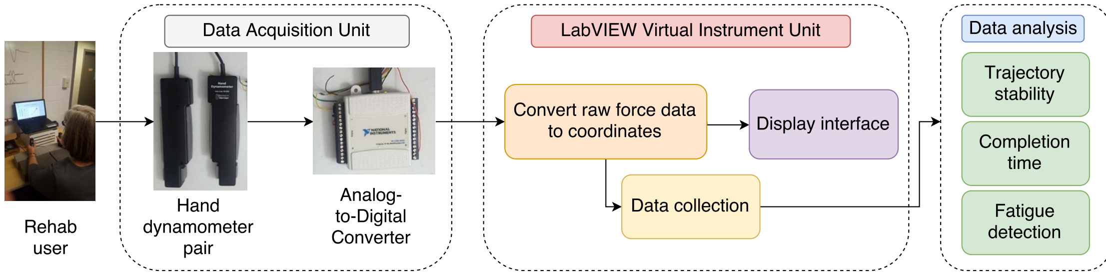


Fig. 1. The framework overview of the hand grip evaluation system.

pinch force between the range of 0-600N. The forces are converted into voltage by the strain-gauge based isometric sensors inside the sensors [6]. The pair is wired to the National Instrument NI USB-6009 data acquisition (DAQ) for Analog-to-Digital conversion [7].

For the display of interface and hardware interaction, we employ two models of laptops, the Acer E5-571 with 15.6 inch in screen and the Microsoft Surface Pro 4 with 12.3 inch in screen as demonstrated in Fig. 2. LabVIEW VI is programmed to be compatible in all types of laptops and PCs making it straightforward to install for a home program. The purpose of utilizing a variety of models is to validate the home-based characteristics and universal compatibility of the system.


Fig. 2. System setup for an experiment with a stroke patient. The Microsoft Surface Pro 4 is employed for interface display and monitor in this trial.

## *C. Rehabilitation Program Design*

The rehabilitation program is programmed in LabVIEW which receives the pressure digital signals from the National Instrument DAQ, which is translated to the position of the red ball, as presented in Fig. 3. The size bars on the left side and the sensitivity selection on the right side provides calibration parameters for the size of the object and the target as well as the rate of movement depending on the participant's ability to generate and sustain grip force.

The exercise will begin when we hit the "Run" button. Squeezing the left dynamometer will make the red ball move up the vertical axis, while releasing the force will drop it down. Similarly for the horizontal axis, applying force to the right dynamometer will cause the ball to go right and decreasing the amount of force will make the ball move to the left. When no pressure is exerted to either dynamometer, the ball will be in the original position. The system can draw a traced line, indicating the path of the ball over time as illustrated in Fig. 3. When the ball reaches the target, the trial ends, and the system stops registering data. The result is written into a file for further analyses using MATLAB.

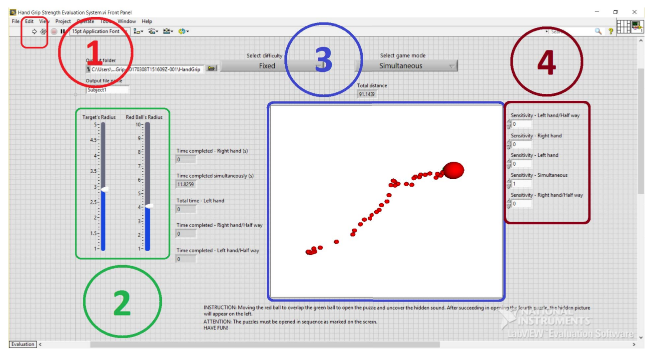


Fig. 3. An example exercise in the VI. In this exercise, the target reached and the trial stops. Main components: (1) "Run" button, (2) size calibration, (3) movement display and (4) sensitivity calibration.

Our system is designed to engage the user and assess motor performance. It will have the capacity to store data and track progress over time. This system, including data output, is valuable to clinicians guiding care and individuals with stroke using the unit and to improve their motor control. The design is straightforward to be easily understood and yet be engaging to individuals using it to improve hand function.

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