MEASURING AND ANALYZING FINE MOTOR SKILLS

Part 1: Motion Tracking and EMG of Fine Movements

Part 2: High-Fidelity Capture of Hand and Finger Biomechanics

Abstract

This white paper discusses an example of particularly challenging fine motor skill measurement and the motion tracker and EMG system integration that simplifies the process.

Seth Kuhlman
info@noraxon.com

NORAXON
MOVEMENT • DATA • PEOPLE

Neil Schell
sales@polhemus.com

POLHEMUS
INNOVATION IN MOTION™

Measuring and Analyzing Fine Motor Skills

Part 1: Motion Tracking and EMG of Fine Movements

Introduction

The measurement and analysis of fine motor skills often requires the simultaneous measurement of a movement profile and the associated muscle activity. The measurement of the minute changes in kinematic position and muscle activity in fine motor skills creates difficulties not found in traditional full-body biomechanics. Many researchers in biomechanics, rehabilitation, neurology and human factors need to perform this important analysis on a regular basis as part of their ongoing research.

In decades past, researchers often had to create “homemade” measurement methods and instrumentation for these tests. Companies responded by designing reliable and accurate systems for each task: motion trackers, electromyography (EMG) systems, force plates, etc. And while this has freed up researchers to spend more time on their core research (rather than tinkering with do-it-yourself systems), challenges remain. Selecting the optimal tool for each type of measurement can sometimes be difficult, as can integrating all these systems so they are synchronized in time and space.

This white paper discusses an example of particularly challenging fine motor skill measurement and the motion tracker and EMG system integration that simplifies the process.

Challenges Involved With Capturing Finger Motion and Muscle Activation

One of the most important and widely studied fine motor skills involves hand and finger movement, for obvious reasons. Nearly all activities of daily living (ADLs) require the use of hands and fingers. But measuring finger movement with traditional biomechanics motion trackers can be extremely difficult, or, in some cases, not acceptable at all.

Measuring hand movement is not too difficult with traditional optical motion trackers used for biomechanics measurements such as gait analysis. But finger tracking is extremely challenging with these systems due to line-of-sight occlusion problems. “Data gloves” designed primarily for virtual reality applications lack accuracy, and wearing a glove interferes with the normal movement of fingers.

A motion-tracking technology that is particularly well suited for finger tracking uses electromagnetics. Magnetic trackers have been around for more than 40 years and are used in a variety of applications, including biomechanics. Magnetic tracking does not require line of sight, yet it measures a full six degrees of freedom (6DOF) with sub-millimeter accuracy. The sensors are now so small that their size and weight do not affect the natural movement of the hand or fingers.

- Measures position and orientation (6DOF)
- No line of sight required
- Very accurate
- Low latency

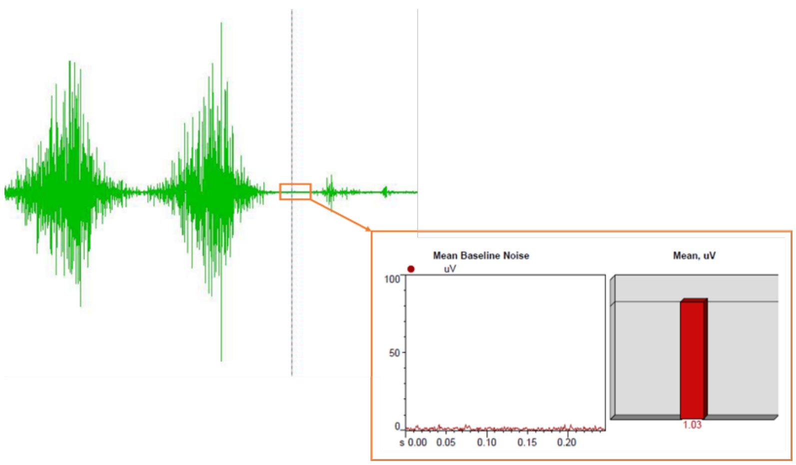
Polhemus *Micro Sensor 1.8*

- No calibration required
- No drift
- Not affected by ambient light

EMG Challenges/Discussion

The measurement of EMG for fine motor movement plays a role in diverse fields, including ergonomics, rehabilitation, biofeedback and many other areas, which poses many challenges from the standpoint of both hardware design and patient-sensor interaction. A myriad of factors drive the hardware design for EMG sensors; most important are the factors linked to the amplitude, frequency and phase of the EMG signal.

- High-fidelity baseline noise level – This is especially important when monitoring smaller muscle groups associated with finger and hand motion due to the relatively small signal amplitude. Typically, a baseline noise of a few microvolts RMS is needed.



- A/D sampling rate – The frequency range for EMG is typically within the range of 5–450Hz for surface electrodes and 2–1000Hz for fine wire electrodes. Based on the sampling theorem of Nyquist, and to reduce aliasing, the EMG sensor should be capable of 1500–3000Hz.
- Signal range and A/D resolution – The sensor must provide an input range large enough to avoid clipping, which can be as high as 5000 microvolts. In addition, the A/D resolution must be able to provide adequate resolution that is less than 1 microvolt.

In addition to the intrinsic design of the EMG sensor, the physical interaction between the patient and sensor poses its own set of challenges and sources of error. The primary source of error in any EMG system is motion artifact, or the relative movement between the sensor/electrode and the patient, and the movement of any cables associated with the sensor. In recent years, much of the motion-artifact error has been reduced by the use of wireless EMG sensors. Due to the compact size and lightweight characteristics of the wireless EMG sensors, much of the movement artifact between sensor and patient is also reduced.

Measuring and Analyzing Fine Motor Skills

Part 2: High-Fidelity Capture of Hand and Finger Biomechanics

Introduction

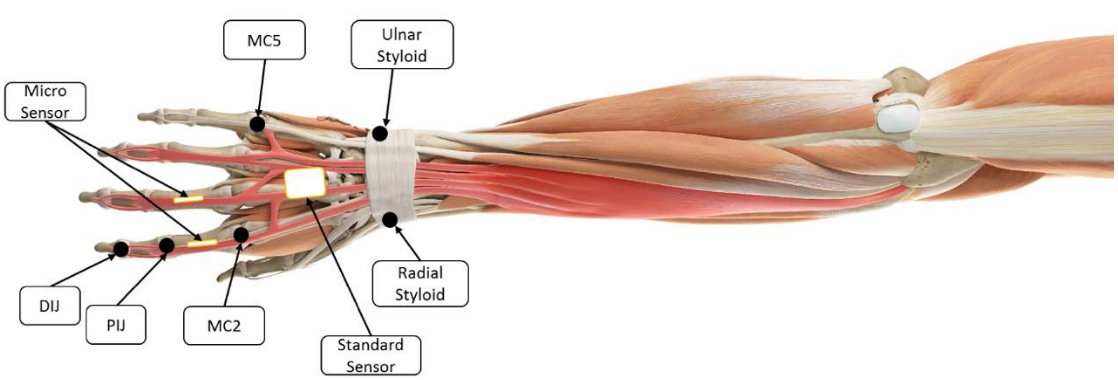
Of all the segments of the human body, the hands and fingers are the most likely to interact with external stimuli. Unfortunately, the mechanics of the hand, both motion and EMG, can be very difficult to capture accurately. The challenge simply comes down to the relatively small size of the fingers and the number of segments involved: 15, including the hand and all finger segments. Due to these constraints, the biomechanics of the hand and finger require specialized hardware for capturing fine movements.

The following material outlines several key advantages of using the Polhemus Micro Sensor 1.8™ and the Noraxon Direct Transmission System (DTS) wireless EMG sensors to overcome several of the obstacles for capturing hand and finger biomechanics. The advantages are outlined through the example of capturing motion and surface EMG data of the index finger.

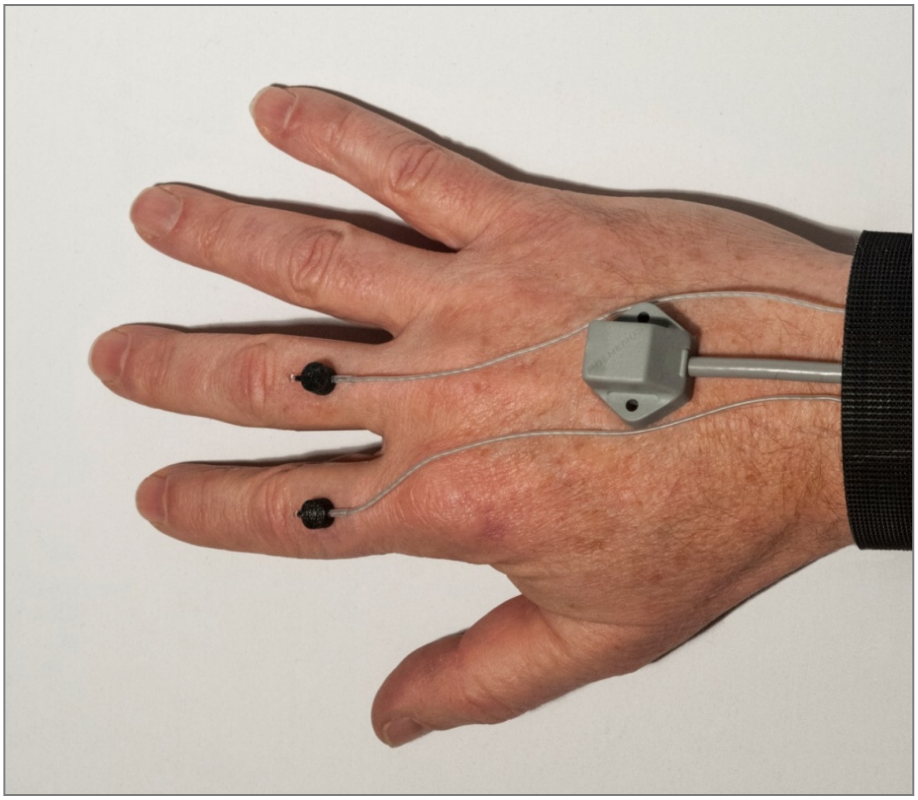
Motion Capture

Biomechanics of the index finger can cover a vast array of topics, from haptic feedback to ergonomic load considerations and many injury-related metrics. At the base of these analyses is motion capture of the index finger range of motion and joint position, which requires high accuracy and repeatability of measurement. As shown in Figure 1, the sensors required for this measurement must be sized in relation to the small scale of the finger itself. Depending on the resolution of the required model, Micro Sensors can be placed on each individual finger segment or a single segment. A standard-size sensor or Micro Sensor can also be placed on the hand as the base of the kinematic chain. Once the sensors are placed, additional landmarks can be digitized to fulfill the requirements of the kinematic model for the hand and fingers.

Fig. 1



DIJ	Distal Interphalangeal Joint		MC2	Metacarpal Joint 2
PIJ	Proximal Interphalangeal Joint		MC5	Metacarpal Joint 5



Polhemus Micro Sensors attached to fingers with Micro Mounts and standard sensor on back of hand

EMG Capture

To truly understand the mechanisms that drive finger and hand movements, knowledge must be gathered about the muscles which either react to or drive motion from interacting with external perturbations. As with motion, this requires EMG sensors small enough and sensitive enough to monitor the fine motor outputs of the muscles associated with the index finger and other digits. Many of the muscles associated with finger motion are situated within deep tissue and cannot be easily monitored; however, two superficial muscles are the extensor digitorum and flexor digitorum superficialis, shown in Figures 2 and 3, respectively.

Wireless DTS sensors can be placed directly on the skin, allowing ample room for the electrode pad monitoring the muscle of choice. The wireless DTS sensors allow for a full range of motion throughout most any activity being measured.

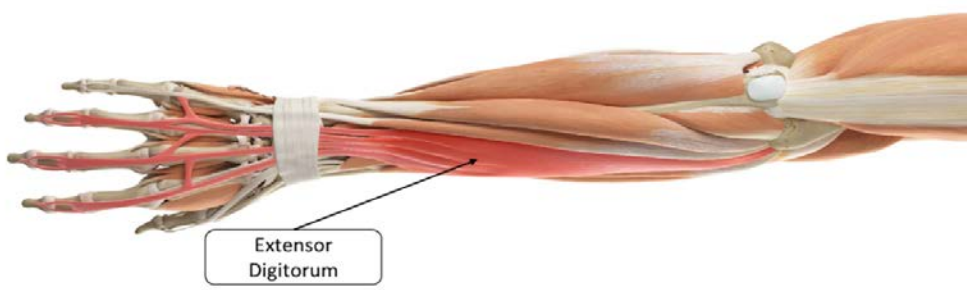


Fig. 2

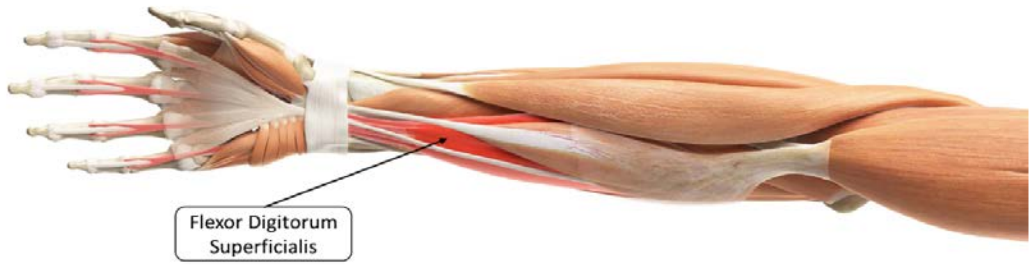


Fig. 3

Hardware and Software Synchronization

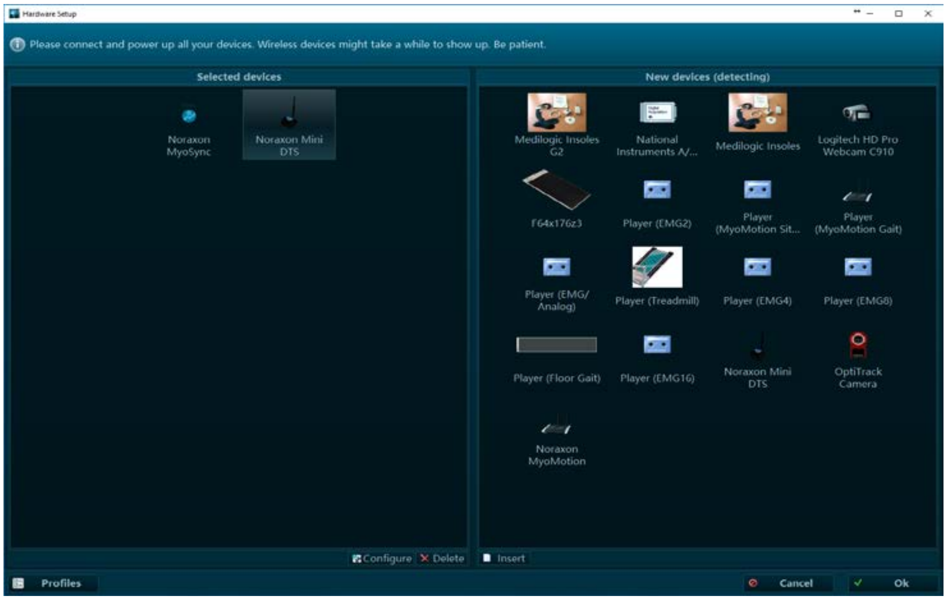
The next step in the process brings both data streams together and allows for synchronized data between two hardware and software sources.

EMG data will be collected through Noraxon's myoRESEARCH® 3 (MR3) software, and motion data will be collected through Polhemus PiMGR software.

To synchronize the systems, a sync pulse is output from the Noraxon myoSYNC™ hardware and MR3 software, which is received by Polhemus LIBERTY™ hardware. Using this setup, any hardware that is available through the MR3 software can be synced with the Polhemus data stream. The setup is illustrated in the following section.

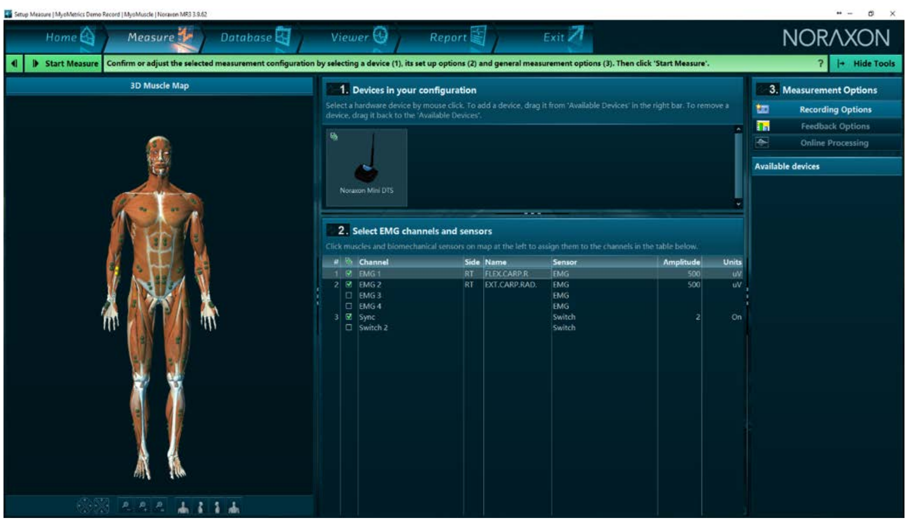
myoRESEARCH®3 Software Set Up

Noraxon's MR3 software needs to be set up to collect data from the wireless DTS sensors. The sensors can be connected to Noraxon's Mini DTS receiver or full Desktop DTS receiver. A myoSYNC device is also required to provide the synchronization pulse between the two hardware systems.



Hardware configuration for MR3

Once the hardware has been configured, the measurement configuration can be specified. Here, the user can select which muscles are to be measured for EMG signals.

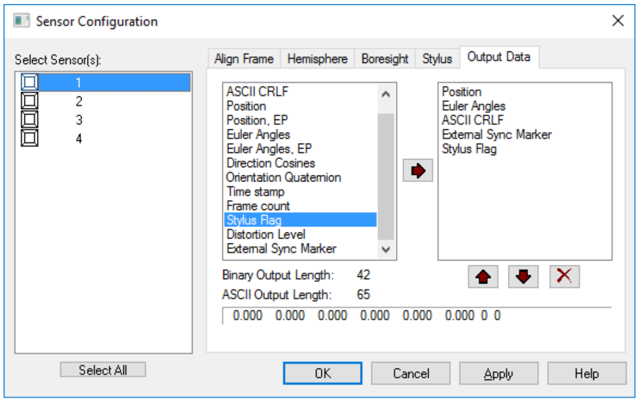


Measurement configuration in MR3

Once the configurations are set, a record can be measured and exported for analysis alongside the Polhemus motion data.

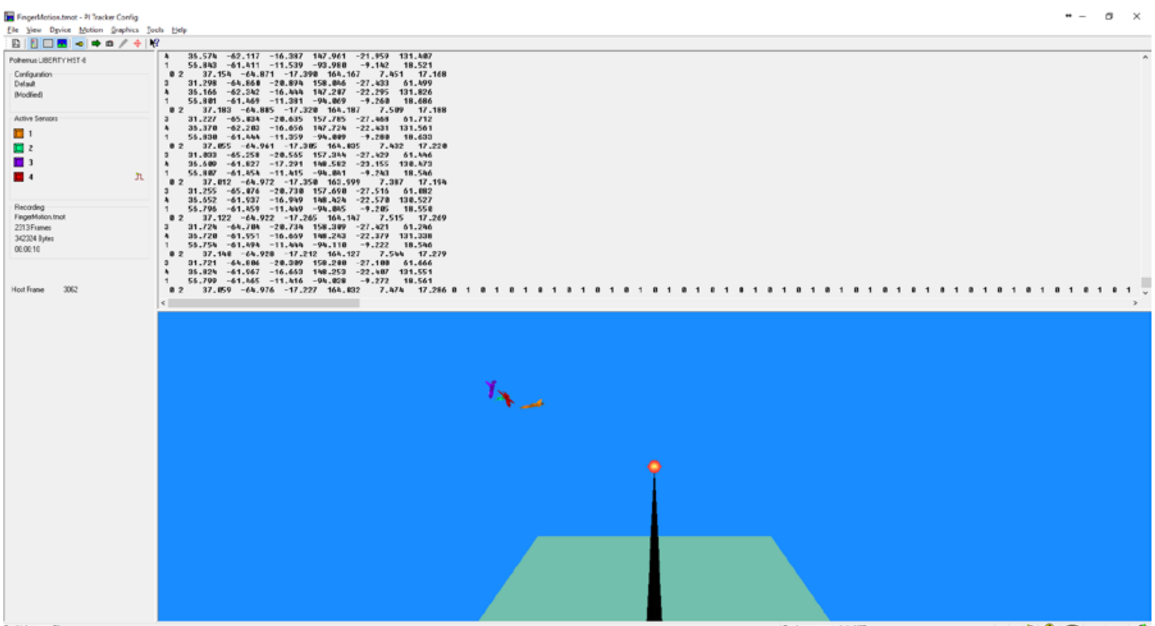
Polhemus Software Set Up

To set up the Polhemus software, the sensor configuration must first be set to accept an External Sync Marker. The marker will be part of the data stream for each sensor being measured.



Sensor configuration in Polhemus software

After the sync marker has been set up, the data stream from the Polhemus sensors can be started. The data will be displayed in the Pi Tracker software and can be saved as a text file.



Capture of 6DOF data from Polhemus software

Data Analysis

Once the data streams from both systems have received the sync pulse, data can be collected and exported from both software packages. The user can then select the best method for analysis, whether that is Matlab, Excel or another method.

Summary

The integration of Noraxon's DTS EMG system and the Polhemus LIBERTY™ motion tracker provides a seamless solution for measuring and analyzing fine motor skills. These two systems not only overcome the unique challenges of measuring fine motor skills, but do so with easy setup while providing consistent, high-quality data.

About the Authors

Seth Kuhlman *(MS Mechanical Engineering, PE) currently serves as the principal Biomechanical Engineer at Noraxon USA, where he applies his background in mechanical engineering, biomechanics, and robotics to Noraxon's biomechanics research and development initiatives. Prior to joining Noraxon, Seth was responsible for robotic and machine vision projects in R&D engineering at Praxis Resources. He also spent 5 years as an R&D engineer and Lab Manager with the Center for Orthopedics and Biomechanics Research at Boise State University, where he also received his MS in Mechanical Engineering.*

Neil Schell *(BS Electrical Engineering) currently leads the Polhemus business unit for healthcare and biomechanics. He is responsible for the company's growth in the commercial, medical, and research markets while leveraging the leadership in electromagnetic technology for which Polhemus is well known. Prior to this role, he spent 20 years in the semiconductor equipment industry, holding positions in engineering, product marketing and sales.*

About Noraxon

Noraxon USA Inc., based in Scottsdale, Arizona, is an industry leader in human movement metrics and biomechanics research solutions. Noraxon's patented and FDA-approved hardware technology includes high-fidelity electromyography (EMG), 3D motion analysis, pressure, force, and video capture equipment, all of which are fully integrated with its myoRESEARCH®3 biomechanics data analysis software platform. Through its innovative, precise and reliable modular approach to a fully equipped, portable and customizable biomechanics lab, Noraxon enables the study of human movement in its most natural environment, and serves the global research community across academic, ergonomic, clinical, and human-performance applications. Learn more at www.noraxon.com.

About Polhemus

Headquartered in Colchester, Vermont, Polhemus is the premier motion measurement technology company. They have been helping customers break new ground with best-in-class 6 Degree-Of-Freedom electromagnetic tracking systems for over 40 years. Polhemus products are widely used in such areas as medical applications, university research, military training and simulation, military aircraft, computer-aided design, virtual reality, and high-tech entertainment. Learn more at www.polhemus.com