BIRTH OF THE SUPER PEN: AN INNOVATIVE APPROACH TO STUDYING HANDWRITING KINETICS

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INTRODUCTION

The seemingly simple act of handwriting is one of many marvels of the central nervous system. Whether writing a word or drawing a basic shape, we are able to generate a sort of code that is both universally recognizable, yet individually unique. Many previous researchers have investigated the kinematic aspects of handwriting with objectives ranging from understanding handwriting motor control to searching for a reliable quantification of various neuropathies. Instrumentation limitations have prevented these studies from being extended to the kinetic aspects of the motion (Latash et al. 2003). More specifically, the physical size of even the smallest force transducers inhibits the ability to cluster them at the grip site while maintaining a realistic and comfortable writing grip. The goal of this study was to resolve this issue by designing a "super pen," capable of measuring the individual forces between each individual contact of the hand with the writing utensil.

INSTRUMENT DESIGN

This "super pen" contains four, six-component sensors (Nano-17, ATI Industrial Automation, Garner, NC, USA) countersunk into the pen's body. Each sensor is equipped with a moment arm running along the long axis of the pen such that its only contact point with the body of the pen is at its attachment point on the sensor. At the writing end the pen, each moment arm has a rounded grip pad. Each grip pad corresponds to a single, unique contact point with the hand. The four points making contact with the pen were the tip of the thumb, the tip of the index finger, the lateral surface of the middle finger's distal phalanx, and the webbing between the metacarpophalangeal (MCP) joints of the thumb and index finger. The moment arms are made of titanium and aluminum and are very rigid, withstanding bend under forces

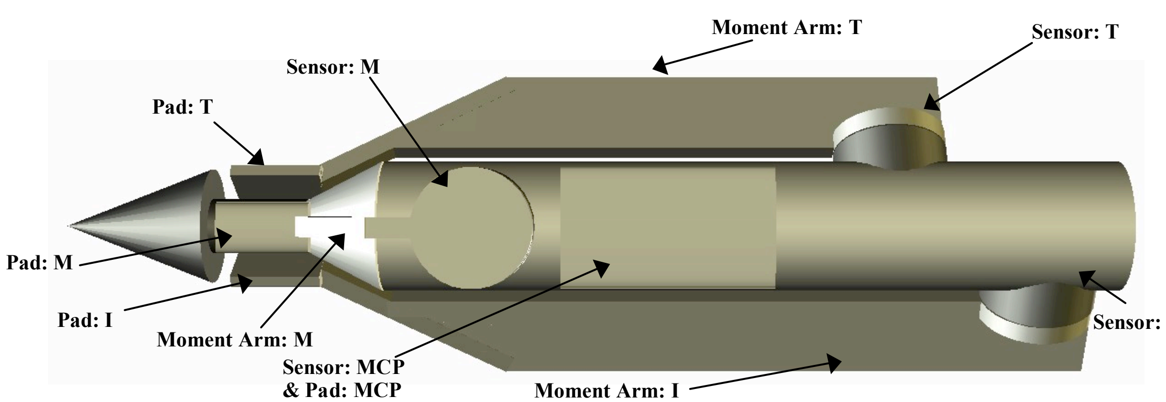

Figure 1: Schematic of pen with sensors, moment arms, and grip pads labeled by contact point. T = thumb, I = index, M = middle, MCP = metacarpophalangeal webbing

used in normal handwriting. Because each moment arm has only two contact points, one at the sensor and one at the sensor's respective digit, the reading detected by the sensors represents the forces of each contact point, individually, at its respective grip site.

The reference systems are aligned locally at each sensor such that z-axis is normal to the surface, the x-axis is tangential to the curve of the pen's body, and the y-axis is tangential to the pen's body along its long axis.

The mass of the pen with all of the sensors attached is 155g. The body is approximately 1.75cm in diameter and 18cm in length. The writing implement is interchangable with plastic, brass, and working ink stylus attachments.

METHOD

The pen was dissembled such that only a single moment arm remained. The pen's body was then fastened in place such that one of the three local axes of the sensor in use was parallel to gravity. A series of 20 different masses were hung from the moment arm such that the force of gravity pulled exclusively along the single, desired axis. This process was repeated for each of the axes on each of the moment arms. The force at the grip pad measured by the sensor was then compared to the actual force graphically, as seen in Figure 2.

RESULTS

In the case of the thumb sensor, the measured values had a nearly one-to-one linear relationship with the actual forces, as seen by the example figure in which of the slope of the thumb sensor's F_y values of 0.9749. This also showed a high linear correlation with an R^2 value of 0.9998. The linearity of the other force components was similar both across and within sensors.

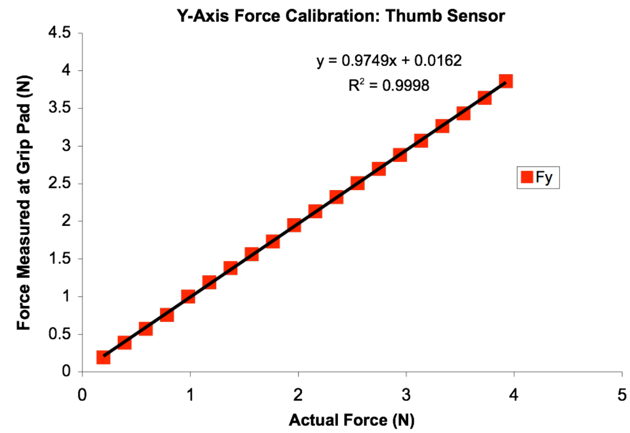

Figure 2: A sample calibration graph comparing the force measured at the thumb's grip pad to the actual force along the y-axis.

CONCLUSIONS

As seen in the results, this new super pen is capable of reliably measuring the individual contact forces between the hand and the writing utensil. The deviations between the different axes' slopes was likely caused by minor flexion in the moment arms, however this does not have a large impact on the instrument's capabilities due the still present strong linear relationship between the measured and known forces.

As we become more familiar with this tool's capabilities, there are a plethora of possible directions to study further. A few we plan to specifically investigate are possible synergies between the different contact points on the pen itself as well as between the pen and the writing surface.

REFERENCES

Latash ML, Danion F, Scholz JF, Zatsiorsky VM, and Schoner G. Approaches to analysis of handwriting as a task of coordinating a redundant motor system. *Hum Mov Sci* 22: 153-171, 2003.