MULTIPLE DATA RECORDING SYSTEM FOR BOXING PUNCH EVALUATION

Kien Nguyen Phan1, Tran Anh Vu1, Do Tien Dat1, Do Tuan Hai1, Pham Thanh Ha1,   
Luu Duc Lam1, Pham Thi Viet Huong2\*, Nguyen Manh Cuong3

1 School of Electrical and Electronic Engineering, Hanoi University of Science and Technology, Hanoi, Vietnam

2 International School, Vietnam National University, Hanoi, Vietnam

3Biomedical Engineering Department, Le Quy Don Technical University

\* Corresponding author: huongptv@vnuis.edu.vn

*Abstract*— The variations in impact forces of different punch techniques have not yet been particularly analysis. In a previous study, an experimental model was built using an accelerometer to detect acceleration, a load cell to measure force, and a laptop motion analysis module to monitor stance using Bluetooth protocol. The findings showed that punching velocity significantly affected punching forces, and with the same acceleration, the difference in fist rotation affected the final force value. In this research, an evaluate measuring system has been designed based on the previous one, using Wi-Fi protocol instead of Bluetooth. The aim of this study is recording multiple data of all punch components for providing standard information for boxing sport. Furthermore, we want to build a coaching system for both amateur and professional boxers. In a follow-up study, the accuracy of this model will be tested, and research will be conducted on fundamental punch types.

Keywords— Multiple data recording system, Force measurement, Boxing punch evaluation

# Introduction

Punch is a fundamental technique of martial art in general and boxing in particular. In boxing, superior attacking technique, speed, and defensive strategies are more important than just punching force to determine the winner but it is known that punch is one of the most significant keys which brings boxer victory. Punch “strength” is largely a result of excellent punching technique. In conception of a punch as a single movement many authors specify as limiting factors its speed and force, where speed is further broken down into components of reaction speed and acceleration speed [3]. Reaction speed refers to the time it takes for a boxer to perceive a target and initiate the punch, while acceleration speed refers to the rate at which the boxer can increase the speed of the punch once it has been initiated. By breaking down the speed of a punch into these components, researchers and coaches can better understand the factors that contribute to effective punching techniques and can develop training strategies to improve both reaction and acceleration speed. Similarly, by examining the force component of a punch, coaches and athletes can work to optimize their technique and improve their overall punching power.

Boxing punch is a big topic with many aspects that can be exploited to research. Although many studies have been conducted, there is still a need for reliable instruments that can provide accurate data on punching force and technique. The result of a study by Jiri et al [1] which aimed to obtain a data basis enabling to characterize various aspects of punching performance, has concluded that a various degree of dependence of the physical parameters of the strikes on the punching technique, gender, hand used, body weight, and other factors after doing research with a KISLER force plate and the last phase of the punch was recorded with a high-speed camera with a recording frequency of 2000 Hz. The time necessary for the hand to cover the last 10 cm before impact was measured and used to calculate the velocity of the punch [1], correlation coefficients of measurements ranged between 0.5 and 0.80 – not a good accuracy. In another study, a ‘Non-Embedded In-Glove Piezo-Resistive Sensor’ has been designed in [2] to measure the boxing punch parameters, tested on 31 novice boxing athletes. In the system, two sensors were utilized; a tri-axial accelerometer to measure acceleration and a piezo-resistive force sensor hand wrap to measure the impact force of a boxer’s punch, the results show high correlation coefficient of 0.85. In the study conducted in [3], unlike the above setup, the accelerometer was placed on the side of the punching bag approximately at the height corresponding with the center of the plate to measure the acceleration of the punching bag [3] whereas sufficient reliability is considered as the coefficient value greater than 0.8. The acceleration data can then be used to calculate the force of the punch using Newton's second law of motion (force = mass x acceleration). Another is “Biomechanics of the head for Olympic boxer punches to the face” in which Walilko et al put accelerometer in boxers’ hand to define its acceleration directly [4] instead of using camera for indirectly detecting. All of the studies conducted on boxing punch share the same limitation in that they rely on a single method to measure all punch parameters.

The lack of reliable instruments for measuring punching force and technique has made it difficult to establish standardized training programs for both amateur and professional boxers. By developing reliable measurement tools, researchers and coaches can better understand the mechanics of effective punching and design training programs that optimize punching technique and power. Therefore, the aim of our experiment is to develop a standard measurement system for boxing punch that utilizes video recordings, force sensors, and accelerometers simultaneously to obtain more accurate and comprehensive data. Our paper has four parts: Part I is the introduction, part II provides our proposed method, part III evaluates the experiment, and part IV concludes the paper.

# methodology

## System design

The measurement device included a punching board that measured the punch force and an acceleration sensor linked to the individuals' wrists. A Wi-Fi channel was used to link all measuring modules to the PC. To determine the punch’s angles, the motion analysis system uses the MediaPipe Pose Detection algorithm.

The system operates on the same principles as shown in the block diagram in figure 1. The measured data from the load cell is processed by the ADC HX711, then communicated over Wi-Fi to the second microcontroller. The data processed by the microcontroller is sent to the computer through the USB port, where it is processed by computer software.

A diagram of a process

Description automatically generated

1. Block diagram

## a) Acceleration measurement system

An MPU6050 accelerometer is attached to a Wemos Mini D1 Wi-Fi module, which is powered by a 3.7V lithium battery. The accelerometer records data on the punch's acceleration and transmits it to a computer via Wi-Fi protocol. This setup allows for wireless data transmission, making it easier to collect and analyze the data. The acceleration measurement system is shown in the figure 2.

A picture containing text

Description automatically generatedA picture containing indoor, person, wall, person

Description automatically generated

1. Acceleration measurement system.

## b) Force measurement system

The load cell measures the weight or force applied to it and sends an electrical signal to the HX711 module. The HX711 module amplifies and converts the signal into a digital output that can be read by the Wemos D1 mini. The Wemos D1 mini connects with NodeMCU which sends the signal to the PC through Wi-Fi protocol. The force measurement system is shown in the figure 3.

A black object on a wood surface

Description automatically generated

1. Force measurement system.

## c) Detect joint angle

OpenCV (Open-Source Computer Vision) is an open-source computer vision and machine learning software library. It was originally developed by Intel and now maintained by the OpenCV community. OpenCV provides a wide range of tools and algorithms for image and video processing, object detection and tracking, face recognition, machine learning, and more.

A person in a blue shirt

Description automatically generated

1. Measuring angle with MediaPipe.

We will record a punching video, which will then be displayed on the screen. OpenCV, using the Mediapipe library, will identify the joints in the video and export the data to an Excel file. The joints processed by the MediaPipe is shown in Figure 4. The joint angles will then be calculated and displayed on a line graph.

## d) Protocol

We used UDP protocol for communicating between laptop and three other parts because of its performance. Laptop is considered as a server and loadcell, accelerometer, camera as three clients. Figure 5 shows the system communication diagram of the whole system.

A diagram of a computer chip

Description automatically generated

1. System communication diagram.

The server (laptop) would open a UDP socket and bind it to a specific port, waiting for incoming data. It would listen for messages from any of the three clients. Each client would create a UDP socket and know the server's IP address and port number. Clients send messages to the server. The server receives the messages and processes them, possibly sending responses back.

## Load cell calibration

## a) Theoretical basis

The setup of the loadcell calibration is shown in Figure 6, we set up a simple pendulum test that acts as the fist of a straight punch. First, we fixed the load cell on a vertical plane, then hung the pendulum which is placed parallel to the plate of the loadcell board. The pendulum was taken with the mass from 0.5kg to 11.5kg, and the center of mass of the pendulum is lined in the center of the load cell. Second, we pulled the pendulum up to a known angle then released it and redo the experiment 6 times for each weight to take average value results.

Diagram of a pendulum with boxes and text

Description automatically generated with medium confidence

1. Calibration set up.

The impact kinetic energy of the pendulum is determined by:

where m is the mass of the pendulum (kg), g is gravity acceleration (m/s2), l is length wire(m), a is angle between the wire and vertical axis. In the ex

## b) Result

1. Calibration result

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ID** | **Average value** | | | |
| Weight (kg) | Kinetic energy | Load cell value | CalFactor (Loadcell/KE) |
| 1 | 0 | 0 | 20.667 | null |
| 2 | 0.5 | 6.05 | 16580 | 2740.495868 |
| 3 | 1.7 | 20.55 | 69578.67 | 3385.823195 |
| 4 | 2 | 24.18 | 79742.67 | 3297.877033 |
| 5 | 4.725 | 57.13 | 159604 | 2793.698582 |
| 6 | 5.525 | 66.799 | 192006.67 | 2874.394327 |
| 7 | 7.912 | 95.66 | 275417.67 | 2879.13095 |
| 8 | 8.525 | 103.07 | 296410 | 2875.812555 |
| 9 | 10.081 | 121.88 | 340730.33 | 2795.621376 |
| 10 | 11.536 | 139.47 | 389796.67 | 2794.842379 |
| Mean of CalFactor | | | | 2937.521807 |

Table 1 shows the calibration result. Let’s consider the mean value of CalFactor of 9 different objects with and

. A graph of a number of objects

Description automatically generated

1. Mean of CalFactor.

This sample has the 95% level of confidence interval is approximately and Then we can be 95% confident that the true population mean lies within

A graph of a load cell value

Description automatically generated

1. Calibration result graph.

## Experiment process

Two participants were selected for this experiment. Each individual was instructed to strike the target using straight punch methods in a testing sequence. The punches were thrown from the regular standard stance, with two parallel feet interacting with the ground throughout the duration of the punches.

The experiment was set up as follow in Figure 9.

A black and white illustration of a person pointing at a camera

Description automatically generated

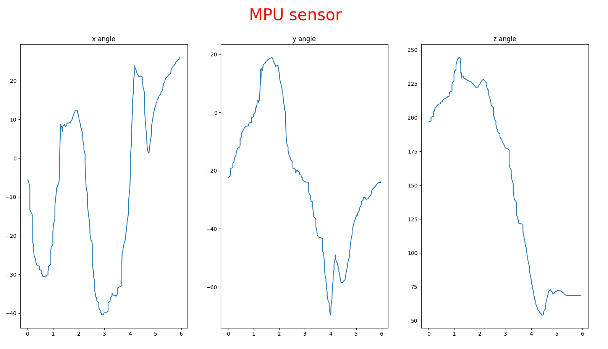
1. Experiment set up.

We connected the accelerometer and the load cell punching board to PC through UDP protocol to show and record the data for the straight punch measurement system.

# Results & Discussion

1. *Punch acceleration*

The acceleration measurement system has calculated accelerations of the boxing punch in X, Y and Z axis. The values of those are measured and presented in figure 10.



1. Punch acceleration
2. *Punch joint angle*

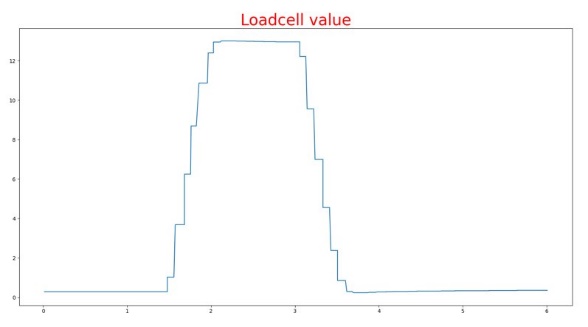
We estimated three angles in this study: the shoulder angle in the preparation position, the angle between the arm and the body, and the wrist angle when punching out. The values of those angles are presented in figure 11.

A graph of different angles

Description automatically generated

1. Punch joint angle.
2. *Punch kinetic energy*

Following the punching test, we utilized a program using loadcell to collect the kinetic energy 2 times. Figure 12 shows the kinetic energy of punchin time.

****

1. Kinetic energy of 1 punch in time graph.

Figure 13 shows the kinetic energy of 5 punches in time. In which in the first 3 punches, the hand is hold in a short time, while in the last 2 punches, the hand is withdraw immediately. The purpose of these experiments is to check the difference between punching and holding versus punching and pulling away. The results show that punching and holding transmits more kinetic energy than punching and withdrawing the hand.

**A graph of a graph

Description automatically generated with medium confidence**

1. Kinetic energy of 5 punches: 3 punches and hold in short time; 2 punches and withdraw hand immediately.

# CONCLUSION

Our study demonstrated a system of multiple data recording for boxing punch evaluation. The system now can record data in real-time and plot the data on graph and display it on monitor’s screen. This technology can be used by athletes and coaches to assess their punching techniques and receive real-time feedback. The study's results can be beneficial in designing training programs and developing competitive strategies by analyzing the technique of each subject.

Our plan is to design a complete system, improve the accuracy and response time of the system to enhance the user experience and research will be conducted on fundamental punch types. Moreover, we aim to conduct testing on a larger population and implement this technology in other training programs besides boxing sport.

##### References

1. Adamec, Jiri, et al. "Biomechanical assessment of various punching techniques." International journal of legal medicine 135 (2021): 853-859.
2. Jovanovski, Andrew, and Brad Stappenbelt. "Measuring the boxing punch: development and calibration of a non-embedded in-glove piezo-resistive sensor." Proceedings. Vol. 49. No. 1. MDPI, 2020.
3. Siska, Luboslav, et al. "Basic reliability parameters of a boxing punch." Journal of Physical Education and Sport 16.1 (2016): 241.
4. Walilko, Timothy J., David C. Viano, and Cynthia A. Bir. "Biomechanics of the head for Olympic boxer punches to the face." British journal of sports medicine 39.10 (2005): 710-719.
5. Dong, Yulin, et al. "Exercise for stroke rehabilitation: a bibliometric analysis of global research from 2001 to 2021." Frontiers in Aging Neuroscience 14 (2022).
6. Kim, Seong Eon, Yong Chul Choi, and Ji Young Lee. "Early rehabilitation after surgical repair of medial and lateral collateral elbow ligaments: a report of three cases." International Journal of Environmental Research and Public Health 17.17 (2020): 6133.
7. Gleeson, Nigel, et al. "Influence of surgery and rehabilitation conditioning on psychophysiological fitness." Journal of Exercise Science and Fitness 6.1 (2008): 71-86.
8. Alabaster, Kelsey, et al. "Exercise after Breast Reconstruction Surgery: Evaluating Current Trends and Practices of US Plastic Surgeons." Plastic and Reconstructive Surgery Global Open 9.10 (2021).
9. Hristovski, Robert, et al. "How boxers decide to punch a target: emergent behaviour in nonlinear dynamical movement systems." Journal of sports science & medicine 5.CSSI (2006): 60.
10. Kasiri, Soudeh, et al. "Fine-grained action recognition of boxing punches from depth imagery." Computer Vision and Image Understanding 159 (2017): 143-153.