**35th Annual International Conference of the IEEE EMBS**
**Osaka, Japan, 3 - 7 July, 2013**

# A New Virtual Instrument for Estimating Punch Velocity in Combat Sports*

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*Abstract*— **For improving the performance in combat sport, especially percussion, it is necessary achieving high velocity in punches and kicks. The aim of this study was to evaluate the applicability of 3D accelerometry in a Virtual Instrumentation System (VIS) designed for estimating punch velocity in combat sports. It was conducted in two phases: (1) integration of the 3D accelerometer with the communication interface and software for processing and visualization, and (2) applicability of the system. Fifteen karate athletes performed five *gyaku zuki* type punches (with reverse leg) using the accelerometer on the 3rd metacarpal on the back of the hand. It was performed nonparametric Mann-Whitney U-test to determine differences in the mean linear velocity among three punches performed sequentially ($p < 0.05$). The maximum velocities measured varied in the range of 10 and 10.2 m/s and the mean velocities from 6 to 6.8 m/s. There was no difference on the mean velocity for the tested punches. The VIS demonstrated regularity and proper functionality for assessing punches in combat sport.**

## I. Introduction

Combat sports (CS) are classified in: domain, percussion [1] and mixed (mixed martial arts - MMA). The domain mode involves techniques of grip, projections, immobilize and strangle. The percussion mode includes techniques such as kicks and punches [2]. And the MMA is based on percussion and domain actions [3].

Especially in combat sport´s percussion mode, researchers have observed that for obtaining high performance on punches and kicks, the athlete needs performing them in high velocity [4,5,6,7].

However, it is hard reproducing in laboratory similar condition as that found in competition, mainly when the athlete's movements depend on the unexpected behavior of the opponent. Typically such analysis requires expensive equipment and is carried out only in laboratories of large urban centers, which undermines the use of these instruments for most athletes and coaches.

Improvements in the control of the speed parameter, and the development of new equipment and training techniques may help to produce better quality in sports performance [8] and thus assist in the prevention of injuries [9].

* Research supported by the Graduate Program in Health Technology. Pontifical Catholic University of Paraná (PUCPR) and CNPq.

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The development and validation of tests and procedures for measuring speed in combat sport´s percussion mode could be an important part of planning the training, because with the control of physical variables, the fitness trainer or coach may optimize the athlete's physical preparation. [1].

The development of a Virtual Instrumentation System (VIS) that integrates wireless micro sensors (3D acceleration sensor) with graphical interface and software for data processing and visualization to estimate the instantaneous velocity when performing punches (*gyaku zuki*) in combat sport´s percussion mode could bring facilities for improving athletes´ performance. It could be used daily for diagnosis, prescription and monitoring in combat sports.

The VIS developed for this research can measure the speed of different techniques of punches and kicks performed in CS´s percussion mode. But for the study described in this paper we analyze the reverse punch (punch opposite the front leg), as illustrated in Figure 1. It is the stroke most frequently used in sports such as boxing [10, 11], karate [12] and MMA [3]. Due to technical differences among modalities for the reverse movement during the punch (*gyaku zuki*), the present study was based on karate. In the future we intend to broaden the use of VIS for different techniques of kicks and punches, as well as for percussion mode in different combat sports.


Figure 1- Reverse movement of the punch (*gyaku zuki*).

The aim of this study was to evaluate the applicability of 3D accelerometry in a Virtual Instrumentation System (VIS) designed for estimating punch velocity in combat sports, especially for karate percussion techniques.

## II. Methods

The study was conducted in two phases: (1) integration of the 3D accelerometer with the designed graphical interface and with the software developed for communication, processing and visualization, and (2) experimental application of the developed system.

For the 3D measuring system, it was used a MEMS technology capacitive accelerometer CMA3000 D01-3-AXIS model, manufactured by VTI Instruments, working with interface SPI (Serial Peripheral Interface) and $I^2C$.

Data were processed in Labview environment by means of the integral of the input signal using the trapezium rule in order to determine the instantaneous velocity from acceleration data obtained in the 'Control Center' software. Both the data acquisition and signal processing were performed in real time.

The block diagram of the virtual instrumentation system developed (Figure 2) shows details of its functional structure such as the input 3-axis acceleration signals (x, y and z) and its trajectory through the filter, which can be configured as low-pass, high-pass or band-pass as required.

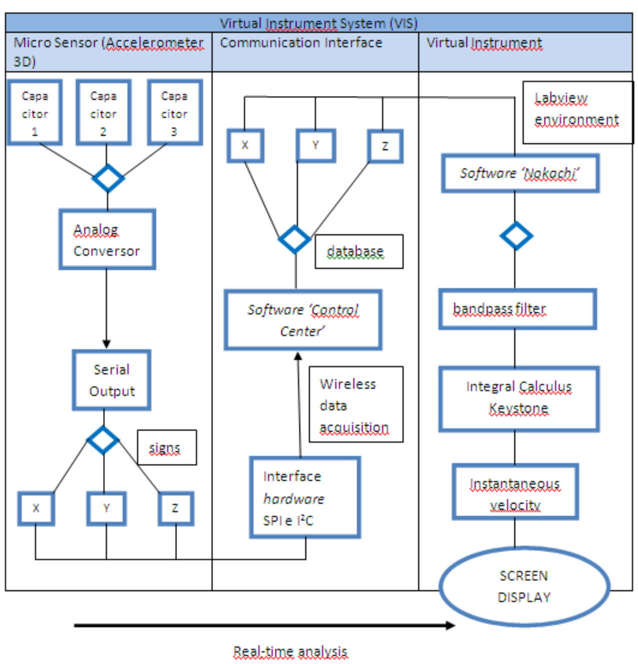


Figure 2 – Functional Diagram of the Virtual Instrumentation System developed.

The calculation for instantaneous velocity can also be configured to different mathematical models of integration such as trapezoidal rule, Simpson's rule or and Bode method (diagram). The possibility of choosing one of these approaches provides autonomy to the system operator who fits the best way to evaluate the performed gesture.

To evaluate the application of the developed VIS on combat sport, we performed an experimental protocol in human model in order to measure velocity of punches by means of the 3-axis accelerometer. The sample consisted of fifteen athletes, federated in Karate Federation of Paraná (FPRK), males aged 21.3 ± 6.3 years old, body mass 76.4 ± 13.1 kg, height of 1.78 ± 0.07 m, practice period of 11 ± 6 years and competition time of 6.9 ± 3.6 years.

The athletes were instructed to not perform physical activities for a period of 24 hours before testing. The experimental protocol was designed to assess the parameter velocity. The 3D accelerometer was fixed with adhesive tape (micropore) on the 3rd metacarpal of the posterior side of the hand. The athlete wore a neoprene glove used in a similar competitive situation of karate to cover the accelerometer in order to ensure no displacement of it on the skin.

In the experimental protocol environment, it was placed a wooden board (*makiwara*) generally used as a training tool in traditional karate, with 1.5 m of height and 1.5 cm of thickness, in front of the athlete. The athlete was instructed to perform five reverse punch to the distance adjustment and adaptation of the movement amplitude. The base distance was measured according to the length of the upper limb [13].

For 3D acceleration signal acquisition, we adjusted the sampling rate on 400 Hz. On the virtual instrument, the band-pass filter and the method for integral calculus were selected in order to obtain the best results.

The present study was approved by the Ethics Committee of the Pontifical Catholic University of Paraná according to the protocol number 38400/2012. The athletes were instructed to perform five reverse punches with the dominant upper limb (all volunteers are right-handed) at maximum speed, similar to the situation of real competition in elongated base, removing the heel of the back foot. Punches 1 and 5 were not considered for analysis.

Statistical analysis was performed using descriptive analysis, followed by Kolmogorov-Smirnov normality test ($p = 0.05$). In order to determine differences in the mean linear velocity among the punches 2, 3 and 4 ($p < 0.05$), it was applied the Mann-Whitney U-test. For statistical treatment, we used the software SPSS for Windows v.18.0.

## III. Results

For evaluating the applicability of the developed VIS in the measurement of punches speed we analyzed the instantaneous linear velocity and the maximum velocity. The instantaneous linear velocity can be defined as the limit of the relationship between the path distance travelled and the time interval when the latter tends to zero [14], or the speed of a body in the exact moment it had been chosen, since the maximum linear velocity was set as the maximum value found during the execution of the reverse punch (*gyaku zuki*).

For the analysis of maximum linear velocity of carpus, the developed instrument calculated the highest speed achieved for each punch (table 1).

Table 1 – Maximum carpal linear velocity (m/s).

| | Measured velocity (m/s) |
|---|---|
| Punch 2 | 10.2±0.4 |
| Punch 3 | 10.2±0.8 |
| Punch 4 | 10.0±1.2 |

As a criterion for setting speed variations, we chose only punches 2, 3 and 4 [7]. There were no statistically significant differences among the mean linear velocity of the punches 2, 3 and 4, as illustrated in Figure 3.

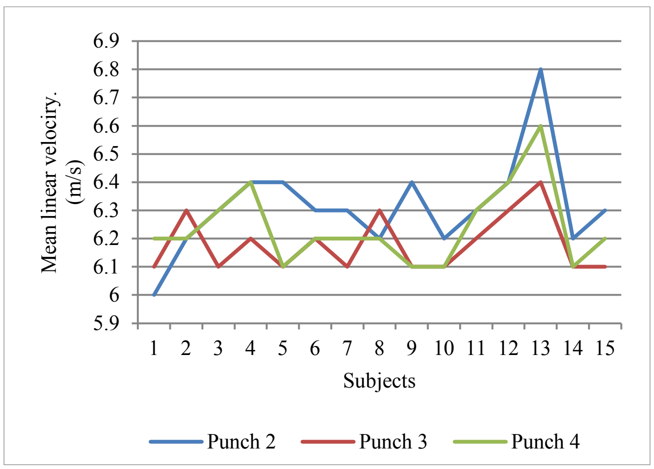


Figure 3 – Mean Linear Velocity (m/s).

## IV. Discussion

Literature presents different methodological approaches for measuring speed punch as biomechanical analysis or other accelerometer type.

The maximum linear velocity measured in our study (5.7 to 13 m/s), as described in Figure 3, is in accordance with the following researchers. Gulledge and Dapena [15] assessed 12 martial artists and found variations of velocity values reverse punch between 4.09 ± 0.52 to 6.43 ± 0.82 m/s. In assessing the speed of reverse punch in 21 Polish karate athletes, Dworak et al. [16] found values between 10 and 12.4 m/s. In a similar situation, Gianino [17] found 13 m/s.

Differently from Dworak [16], Gianino [17] and from our results (Table 1), Gulledge [15] found velocities practically 50% lower. The discrepancy is probably due to different assessment techniques employed on their research.

The lack of difference on the mean linear velocities of the punches 2, 3 and 4 indicates standardization of measurement between the punches, and attest the reliability of the designed equipment. These results ensure VIS applicability on combat sports, particularly for punches in karate.

Despite the preliminary results obtained, the virtual instrument implemented may be replicated and used with a larger number of athletes. Thus, we will obtain a more robust statistical analysis with parametric tests. Correlations between sizes of segments (upper and lower limbs) should be considered for the result of maximum linear speed. Reproducibility tests and analysis with other patterns of movement speed will be done.

## V. Conclusion

The virtual instrumentation system (VIS) developed allows the measurement of the maximum and mean linear velocities of punches similar to values found in literature when performed punches as *gyaku zuki* as well as reproducible values presented on three situations of evaluated punches. It is easy to use, cheap, portable and versatile.

The successful application of 3D accelerometry technique in a virtual instrument for the study of blows percussion indicates it as an important technology for athletes training and performance analysis especially studying reverse punch in karate. The technology developed for this study can be transferred for other fighting modalities and coups and constitutes a promising evaluative tool for sportive output in combat sports.

## Acknowledgment


The authors are grateful to the athletes and coaches who participated of the experimental protocol, and to CNPq, Brazil, for financial support.


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