Smart Boxing Glove: Anthropometry, Trajectory, and Acceleration to Estimate Punch Force

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Summary

Measuring a boxer's punching force is vital but challenging. Traditional methods, like force plates and inertial measurement units (IMUs) on punching bags, have accuracy and convenience limitations. This study combines anthropometric data, IMUs, and trajectory reconstruction to estimate punching force more effectively. Our innovate equations were proposed to compare with machine learning models. Both approaches could estimate punch forces with low mean absolute percentage error and high accuracy. Our research demonstrated the anthropometric data, trajectory, and acceleration for estimating reliable punch force.

Introduction

Punching force is critical for evaluating a boxer's performance; however, measuring it in the field or during practice is not straightforward. Commercial force plates have been used to assess boxers' punching force [1]. Alternatively, inertial measurement units (IMUs) have been used on boxing targets, such as punching bags, to estimate punching force [2]. Recently, it has been employed as Earable sensor to recognize slipping, rolling, and pulling back gestures and achieved 96% accuracy [3]. Machine learning techniques have also been applied to classify punching techniques [4]. However, neither approach is convenient or accurate enough for boxers to evaluate their punching force effectively. We aim to utilize anthropometric data and IMU data, combined with trajectory reconstruction technology, to enable participants to access their force curves quickly.

Methods

Twelve male and eight female healthy adults (age = 21.85±2.32 years, height = 169.42±7.24 cm, body weight = 61.86±10.39 kg) participated in the experiment. The protocol was approved by the Institutional Review Board of National Tsing Hua University (REC #: 11111HT111). An IMU (Vicon Blue Trident Model V2) was attached to the boxing glove, and the three markers were attached to the bony landmark of the shoulder, elbow, and wrist joints. The participants were instructed to conduct 120 straight punches with front and backhands from the right or left hands to the force plate (AMTI AccuGait OptimizedTM, Advanced Mechanical Technology Inc., USA), which was placed vertically and perpendicularly on the floor. Two approaches were employed to estimate punch force: 1) equations of anthropometry (cumulative segment mass and length with trajectory reconstruction) and acceleration and 2) LR, RF, and XGB machine learning (ML) models.

Results and Discussion

Based on the equation of anthropometry and acceleration, the MAPE across four types of straight punch forces was 32.1% in males and 35.3% in females. Figure 1 illustrates the punching trajectory and the corresponding force estimation, highlighting the final punch force in Fig 1.d. The ML models based on gender, dominant hand, and type of boxing achieved an accuracy rate of 84.25% in males and 93.78% in females.

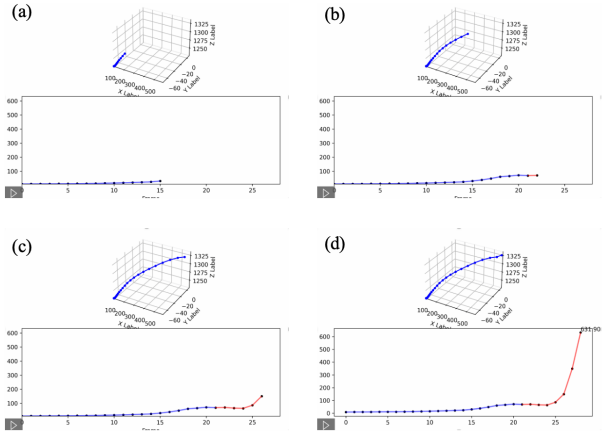

Fig. 1: Illustration of trajectory reconstruction (upper) and corresponding force (lower).

Factors affecting force estimation include the center of gravity movement, punch angle, and trajectory accuracy [2,4]. Anthropometric methods and acceleration equations provide acceptable punch force estimates with direct IMU data. Alternatively, machine learning models can identify critical features to improve the accuracy of force estimation.

Conclusions

Boxing gloves equipped with an IMU can effectively estimate punching force, achieving an average accuracy of 89.0%. Most importantly, the outcomes of equations with three parameters were comparable with the multiple features in machine learning models.

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