

Real-time Brain Injury Prediction Based on Machine Learning and Sports Wearables

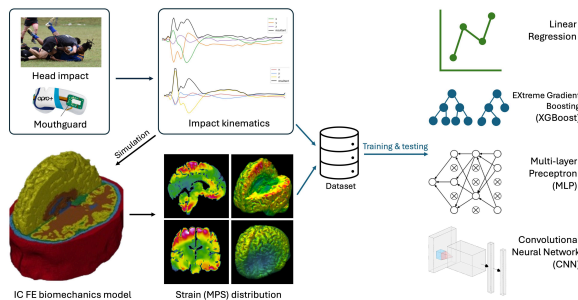
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Background

Head impacts in sports can cause traumatic brain injury (TBI). Instrumented mouthguards (iMGs) worn by athletes capture head kinematics data in both linear and rotational. Finite element (FE) brain models use this data to simulate impacts and quantify brain deformation by mechanical strain, but each simulation takes 5-6 hours on a high-performance computer.

Research Aim

To reduce the computational time, previous studies introduced two deep learning models, a convolutional neural network (CNN) and a multi-layer perceptron (MLP), for real-time brain strain prediction. However, these models require the entire kinematics signal, i.e. over 600 data points per impact, which cannot be reliably transmitted from iMGs in real-time. Therefore, models requiring fewer data points are needed for on-field real-time brain deformation prediction.



Methods

Impact kinematics Protecht iMG collected 1701 rugby impacts. Features were extracted from rotational velocity and acceleration.

Strain estimation Imperial College FE model simulated the impacts and calculate brain strain and strain rate distribution. FE-calculated strain were extracted: the max in the whole brain and regions of interest (ROIs).

ML models developed:

- A linear regression (LR) model to predict max strain in whole brain.
- An extreme gradient boosting (XGB) model to predict strain in ROIs.
- A CNN and an MLP model was developed to predict strain distribution.

We evaluated models' performances for both accuracy and efficiency.

Results

We trained and tested LR, XGB, CNN, and MLP models on the same dataset to predict brain strain.

- Prediction accuracy (R^2) were 0.73, 0.92, 0.83 and 0.90, respectively.
- Inference time were 0.08, 0.1, 0.5 and 0.6 seconds, respectively.

ML models predict strain of multiple impacts in **fraction of a second**, which significantly improve the computational time.

	LR	XGBoost	MLP	CNN
Prediction task	Strain in ROIs	Strain in ROIs	Strain distribution	Strain distribution
Input size per impact	1	4 (2 features * 2 channels)	160 (20 features * 8 channels)	624 (104ms * 6 channels)
Output size per impact	1	18	4440	73179
Accuracy (R^2)	0.731	0.924	0.837	0.905
Inference time (s)	0.08	0.1	0.5	0.6

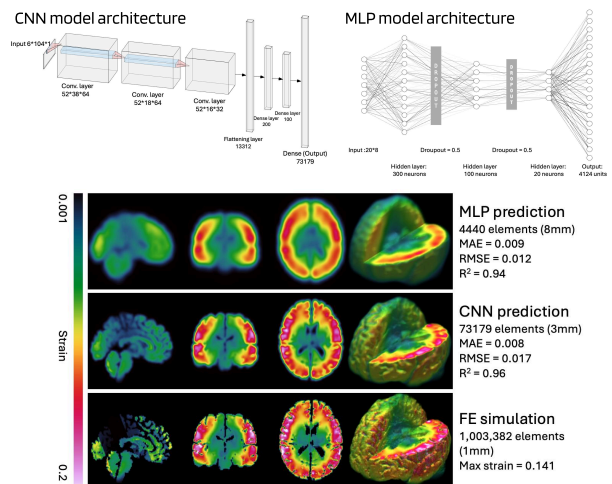
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This novel model enables **pitch-side** surveillance systems to immediately assess **brain deformation** in sports collisions.

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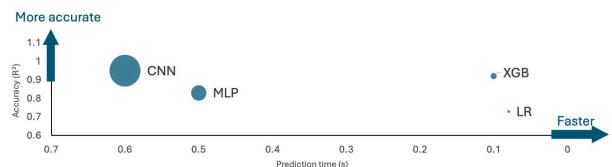
Discussion

- All four ML models quickly and accurately predicted strain at different resolutions: max in whole brain, in ROIs and high resolution distributions.
- With simple input requirements, LR and XGB models can integrate with iMG-based injury surveillance systems for near real-time predictions.
- With high resolution of the predicted distribution, the CNN and MLP models can be used for more detailed post-impact analysis.



Conclusion

The proposed XGB model can allow integration with iMG-based injury surveillance systems for near real-time estimation of brain deformation, which can guide pitch-side decision making in both professional and grassroots sports. Different ML models can be used at various stages of TBI analysis.



Bio



Emily is a PhD student whose current project is focusing on traumatic brain injury (TBI) caused by sports impacts, which is funded by Sports and Wellbeing Analytics (SWA)/Cellbond/Royal Academy of Engineering Senior Research Fellowship. Emily received her master's degree in the Department of Computing, Imperial College in 2022. She studied electronic engineering and computer science for her undergraduate in Queen Mary University of London.

References

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