**Abstract**

Conventional methods of evaluating brain deformation caused by head impacts: **Finite Element Analysis (FEA)** can be both time-consuming and difficult to model efficiently. In this work, a novel method of characterizing brain deformation in the head impact with deep neural network trained on mouthguard kinematics signals is proposed. To model the brain as an entity, our model gives comparable results to previous publications. To show the element-wise brain strain, our models show similar results to those of FEA but with a significant speed increase (on the order of 3,500x faster). This project could potentially help those engaging in contact sports better detect brain injury.

**Data Preprocessing**

1. **Label Reference**: Calculated by KTH modelling.
2. **Signal Padding**: Length 200ms, Peak at 100ms.
3. **Dimensionality Reduction**: PCA(Label data, 10 PC)
4. **Feature Extraction**: Maximum Value; Minimum Value; Integral of Signal; Integral of Absolute Value of Signal; Exponential Moving Average of Signal Derivative(Max & Min)

**Neural Network Modeling**

1. **Single-metric prediction**
   
   **DNN (engineered features)**: 36-60-30-1

2. **Strain for every brain element**
   
   **DNN (engineered features)**: 36-120-480-4124
   
   **DNN (padded signals)**: 600-200-50-4124
   
   **DNN+PCA (padded signals)**: 600-200-50-10
   
   **LSTM+PCA (padded signals)**: 201×3-LSTM(100)-FC(50)-FC(10)

3. **Modified Loss Function**

   \[ L(Y_{PCA}, f(X)) = Var \times ESS \times (Y_{PCA} - f(X))^2 \]

**Result**

1. **Time cost for one impact**
   
   Deep Learning: ~0.5 s   KTH Model: ~30 min

2. **Single-metric prediction**

**Comparison with paper published[1]**

<table>
<thead>
<tr>
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<th>Previous Publication</th>
<th>Our Result</th>
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</thead>
<tbody>
<tr>
<td>( R^2 )</td>
<td>0.6-0.9</td>
<td>0.85</td>
</tr>
<tr>
<td>( RMSE )</td>
<td>0.03-0.06</td>
<td>0.3</td>
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</tbody>
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**Conclusion**

The neural-net-based method is much faster (by a factor of approximately 3,500x) and able to give similar brain deformation profiles, making it easy to interpret brain damage for players.

**Reference**