Proceedings of the Canadian Society for Mechanical Engineering International Congress 2021
CSME Congress 2021
June 27-30, 2021, Charlottetown, PE, Canada

APPLYING MACHINE LEARNING PRINCIPLES TO THE STUDY OF MILD TRAUMATIC BRAIN INJURY AND BRAIN STRAIN METRICS

Luke Patterson[1], Yanir Levy[2], Haojie Mao[1,2]
[1]Mecahnical and Materials Engineering, Western University, London, Canada
[2]Biomedical Engineering, Western University, London, Canada

ABSTRACT

A mild traumatic brain injury is usually caused by a kinematic impact to the head or upper body, where the impact can cause significant and damaging strains in the tissue cells of the brain. Impact severity can be qualified by average maximum principal strain (MPS) and cumulative strain damage measure (CSDM) values, such as $CSDM_{25}$ which is calculated by dividing the volume of elements of MPS over 0.25 by the total volume of the elements in a finite element model. This study intends to specify which kinematic input metric or combination is best able to predict accurate MPS and $CSDM_{25}$ values.

Previously collected kinematic data, including linear acceleration, rotational acceleration, and rotational velocity values, were input into a kinematics processing pipeline, of which MPS and $CSDM_{25}$ values were output. Then, using SPSS Statistics, an artificial neural network (ANN) model predicted which kinematic data inputs were most accurate in forecasting real MPS and $CSDM_{25}$ values from collected data. Different combinations of kinematic data inputs were tested. The ANN-predicted MPS and $CSDM_{25}$ values were plotted against the actual values, with an R-squared value subsequently generated. The R-squared value of each combination tested was used as the comparator for which combinations of kinematic inputs were most accurate, and the combinations were then ranked in order.

Fifteen combinations of covariates were used in the analysis. The strongest correlated kinematic input variable combination, as expected, involved using average x, average y, average z, and peak x, y and z for each of linear acceleration, rotational velocity, and rotational acceleration to predict MPS and $CSDM_{25}$ values (R-squared: 0.988).

Four of the best five kinematic input variable combinations contained average rotational velocity, which aligns with the currently accepted scientific consensus that average rotational velocity should be given higher weight than average linear or rotational acceleration, and that rotational velocity was the best predictor of brain strain. The data showed that when rotational velocity was not included in the set of kinematic inputs to the ANN, the ANN's prediction ability decreased significantly.

A kinematic input variable combination using only peak kinematic values was found to be an unexpectedly efficient way of predicting MPS and $CSDM_{25}$ values (R-squared: 0.955). This shows that high quality kinematics predictions can still be made with fewer overall data variables collected from each individual test, which may be useful if testing is scaled up significantly in the future.

Word count: 394