Prediction of facial overpressure using body worn sensors and machine learning algorithms in military blast environments

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Wearable sensors are increasingly being worn by soldiers to quantify the overpressure experienced in training and battlefield environments with the goal to characterize effects to the brain. One challenge with using wearable overpressure sensors is that they are typically worn or attached at locations near the chest, shoulder and rear or side of helmet which limits the direct usage of the overpressure data in computational models of the brain. Numerical models of the brain provide insight into mechanisms of brain injury, thus there is great interest to transform the overpressure sensor measurements into actionable data. In this presentation we assess various machine learning (ML) algorithms aimed at accurately predicting boundary conditions to be prescribed for biomechanical finite element models.

In order to generate data for training the ML models, Computational Fluid Dynamic (CFD) simulations were carried out of a soldier in the midst of an explosive detonation. Since obstacles in the environment, the soldier’s posture, type of explosive, etc., all modify the pressure experienced by the soldier, we examined a number of these features. Soldier anatomy and overpressure scenarios were developed using Blender, an open-source geometric modeling tool. Time histories of the overpressure were recorded for each CFD simulation at four different locations on the soldier – the chest, left shoulder, posterior surface of the helmet, and the nose. The pressure-time histories were used as input to train the ML models using Sagemaker from Amazon Web Services (AWS). Specifically, we examine ML-based predictions for the peak blast overpressure magnitude and peak blast overpressure duration at the nose of the soldier exposed to an explosive environment, when given the peak blast overpressure magnitudes and peak blast overpressure durations at the chest, shoulder, and helmet locations as input.

Linear regression, ridge regression, and deep learning neural networks are evaluated. A total of 1944 different environmental scenarios were developed using a full three-dimensional blast code and the resulting data was used to train the models. We examined the prediction of both peak pressure and peak pressure duration. The deep neural network yielded an accuracy of 88% for the peak pressure and 71.2% for the peak duration. This process could be used to apply boundary conditions to biomechanical finite element models of the head and brain. Based on this preliminary study the predictive power of machine learning models can be harnessed in order to improve computational efficiency and speed in the next generation of computational biomechanics research.