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# COMPARISON OF TWO MACHINE-LEARNING METHODS TO PREDICT INTERVERTEBRAL DISC PROPERTIES

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## 1. Introduction

Evolutionary polynomial regression (EPR) uses a genetic algorithm and least square regression to learn complex relationships in the form of clear transparent mathematical equations [1, 2], providing benefits over black-box artificial neural networks (ANN). EPR may help define intervertebral disc (IVD) material properties for FE modelling, which have been approximated in different ways, often generically. Improved subject-specific IVD representation would aid understanding of spinal loading. This study aimed to compare the accuracy of EPR with ANN in predicting IVD material properties.

## 2. Materials and Methods

This study used previously collected 6-axis in vitro data of six porcine IVD specimens [3]. The data contained applied translations/rotations, with corresponding forces/moments: FX (anteroposterior shear), FY (lateral shear), FZ (compression), MX (lateral bending), MY (flexion/extension), and MZ (axial rotation). EPR (EPR-MOGA-XL, v1.0 [1, 2]) and ANN (MATLAB, R2022a) were used to predict each specimen-specific force/moment output from all translation and rotation inputs, allowing coupled motions. Both methods used a 60/40% ratio for training/test data, and software parameters were optimised.

## 3. Results

The $R^2$ and normalised mean square error (NMSE) of both methods were compared for each axis (Table 1). Most models had $R^2$ values above 0.85, across all specimens and axes. Differences between the methods were limited in most axes, though ANN tended to perform better than EPR. The greatest differences were in compression (FZ), ranging from 0.024 to 0.071 for $R^2$ and 3.54 to 10.72 for NMSE. The other axes had smaller differences, at -0.003 to 0.016 for $R^2$, and -0.002 to 0.076 for NMSE.

**Table 1:** EPR and ANN test data results for each force/moment axis (medians across 6 specimens)

| | $R^2$ | | NMSE | |
|---|---|---|---|---|
| | **EPR** | **ANN** | **EPR** | **ANN** |
| **FX** | 0.992 | 0.993 | 0.178 | 0.151 |
| **FY** | 0.986 | 0.987 | 0.214 | 0.198 |
| **FZ** | 0.887 | 0.924 | 16.85 | 10.46 |
| **MX** | 0.898 | 0.910 | 0.115 | 0.110 |
| **MY** | 0.917 | 0.920 | 0.087 | 0.083 |
| **MZ** | 0.964 | 0.962 | 0.032 | 0.031 |

## 4. Discussion and Conclusions

Both ANN and EPR methods predicted IVD properties with a high degree of accuracy. The lower accuracy in some axes (e.g. FZ) may be due to IVD creep, which was unaccounted for. Although the ANN models were usually more accurate, the differences were often small. In the future, the biomechanical relevance of these differences could be assessed through FE analysis, incorporating the generated material models. Such use of the models could improve IVD representation, and knowledge of specimen-specific spinal loading.

## 5. References

1. Giustolisi O, Savic DA. J. Hydroinformatics. 2006; 8(3): 207-222.
2. Giustolisi O, Savic DA. J. Hydroinformatics. 2009; 11(3): 225-236.
3. Holsgrove TP et al., Spine J. 2015; 15(1): 176-184

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