Predicting High-Performance Concrete Compressive Strength with Machine Learning

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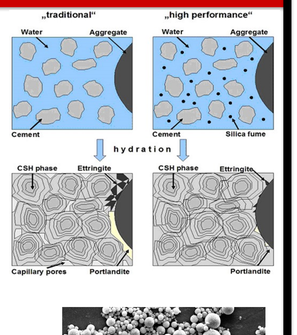
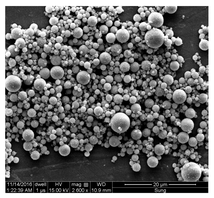
Background

- Concrete is a very common material used by the construction industry to create long lasting, durable structures and consists of cement, aggregates, and water.
- The hydration of cement yields C-S-H (calcium-silicate-hydrate) and portlandite (calcium hydroxide), that act like the “glue” of concrete.

- High performance concrete (HPC) can include the addition of fly ash, blast-furnace slag, silica fume, superplasticizers, and other compounds into the normal concrete mixture.
- Fly ash reacts with the portlandite to form more CSH.
- Silica fume fills in any gaps, allowing for a denser, stronger structure.
- Superplasticizers allow for a lower water content and increased workability.

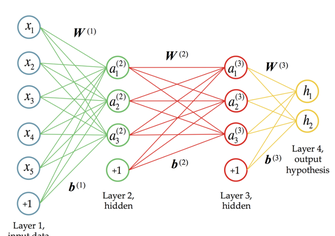
- Codes set by ASTM (American Society for Testing and Materials), ACI (American Concrete Institute), etc., already specify predetermined mix ratios for desired strengths.



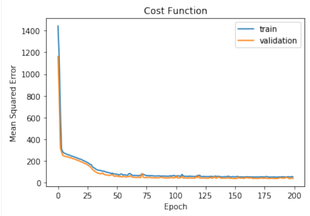


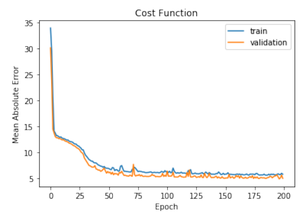
Methodology

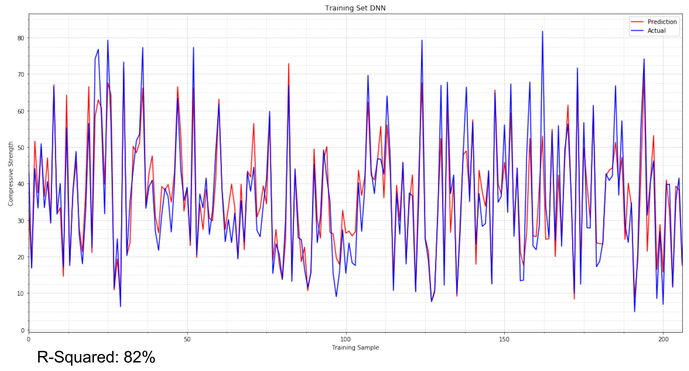
- Supervised machine learning can be used to predict compressive strengths from mix ratios.
    - Multilayer Perceptron (Neural Network)
- Doesn’t require any scientific knowledge on the cement hydration process.
- 80% of data is used to train, 20% is used to test
- Coded in Jupyter Notebook (Python) with Keras and Tensorflow libraries.
- Adam optimizer (optimize neural network weights with stochastic gradient descent).
- Loss function – Mean Squared Error, Mean Absolute Error
- Metric for grading of neural network was Coefficient of Determination (R^2).



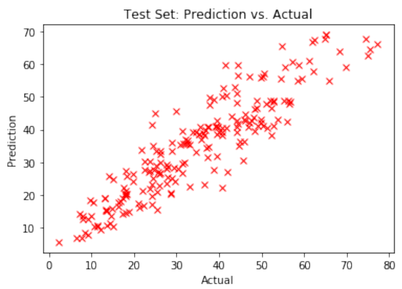
Results

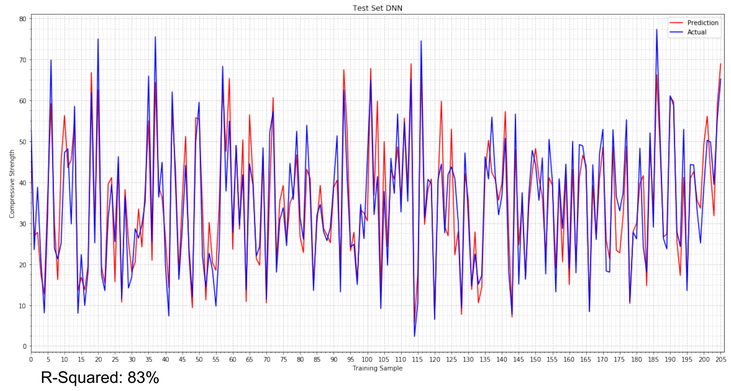






R-Squared: 82%





R-Squared: 83%

Conclusions

- Deep neural networks (DNN) are a viable method of determining concrete strength of a mix design and can be used to improve the existing mix design codes.
- DNN used in this research had R-squared of above 80%.
- Possible application of machine learning to other concrete problems
    - Can predict slump, the workability of a concrete mix.
- Next step is to improve code to achieve higher predictability and try other supervised learning methods such as support vector machines.

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References

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