Artificial intelligence in predicting properties of brittle matrix composites

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Summary

The paper is dedicated to possibilities of automatic design in technology of brittle matrix composite materials. In a way it is also connected with new techniques of management and exploitation of data extracted from experimental tests results. New techniques of Artificial Intelligence (AI) were applied to analyse certain strength features of concrete-like materials. Contrary to the previous attempts, not only quantitative, numerical test results can be utilized to predict quantitative responses, but also various qualitative descriptors of the mix composition can be taken into account, as well as test conditions, etc.

While previously applied ANNs (Artificial Neural Networks) enable construction of a kind of virtual reality in the domain of composite materials design, offering new optimisation possibilities, they not only can hardly utilize any qualitative data, but also are unable to use imperfect data. The results of their application cannot easily be transferred into sets of rules comprehensible for humans. In this situation ML methods (Machine Learning) open new possibilities.

In the experiments on the test data concerning properties of conventional concrete, of HPC (High Performance Concrete) and of SFRC (Steel Fibre Reinforced Concrete), applied were three AI solutions: ***Fuzzy ARTMAP*** and ***aiNet*** (ANNs programs) and ***aq18*** (ML program). Employed were also PCA (Principal Components Analysis), and conventional Regression Analysis.

It was concluded that the techniques of AI (Artificial Intelligence) can be applied successfully to analyse databases on the composition, on the properties, and on the applied experimental techniques, in testing of engineering materials.

Various applied AI procedures give competitive results, and seem to be complementary to each other. In particular it is possible to improve technique of optimisation of the concrete materials composition that was suggested previously, by combining ANNs and ML techniques. This will be a virtual reality type of search for the optimal solution. Thanks to AI rules (*Hypotheses*), combined with certain *External Principles*, the ANN will be used only on a limited number of simulated records, expected to be of superior quality.

An example of a set of *hypotheses* - the conditions for the *outstanding* records (in plain text):

> the fibrous reinforcement content (V_f) between 0.13 and 2.40 % vol.,
> the length of fibres (l) between 10 and 40 mm
> the equivalent diameter of the fibres (d) between 0.40 and 0.89 mm

As a side effect it is also possible, by applying ***aq18***, to identify combinations of factors that accompany certain classes of results. For example, to find out which details of the test conditions are not important, and should not be included in the report. Such regularities are sometimes quite difficult to pinpoint, especially in case of various accidental correlations in the experimental results.

Still open remains the important problem of merging the databases of diverse composition and/or structure, but there are certain expectations here, thanks to possibility of using the wild cards descriptions in ML programs.

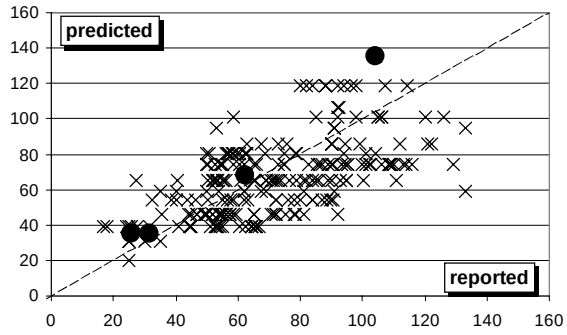

Figure 1. Predictions of the strength of HPC mixes, obtained by ***Fuzzy ARTMAP***, for 303 tests records from recent investigations, after training on 346 learning records from years 1985-1993.

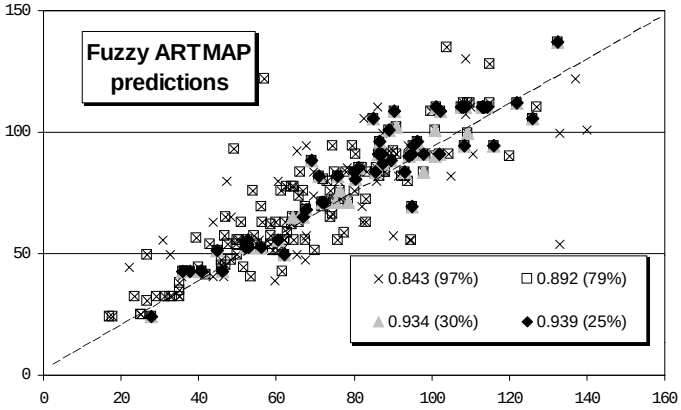

Figure 2. Predictions on 217 test records according to ***Fuzzy ARTMAP***. The numbers in the legend show coefficients of correlation between actual data and predictions. In the parentheses given are percentages of the records recognized by the system. Four different settings of the control parameters.

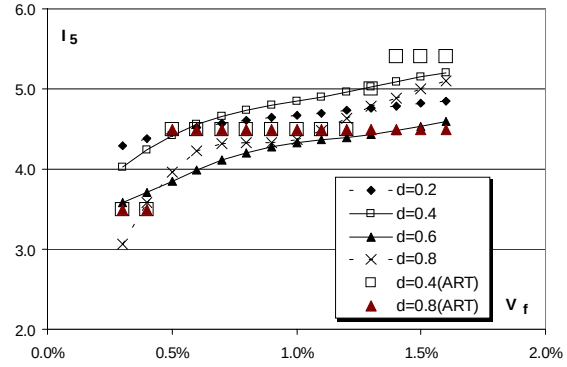

Figure 3. Example of virtual-reality type models: dependence of flexural toughness index I_5 on fibrous reinforcement content (V_f) and on fibre diameter (d), in [mm], according to predictions from ***aiNet*** (the lines) and from ***Fuzzy ARTMAP*** (the points).