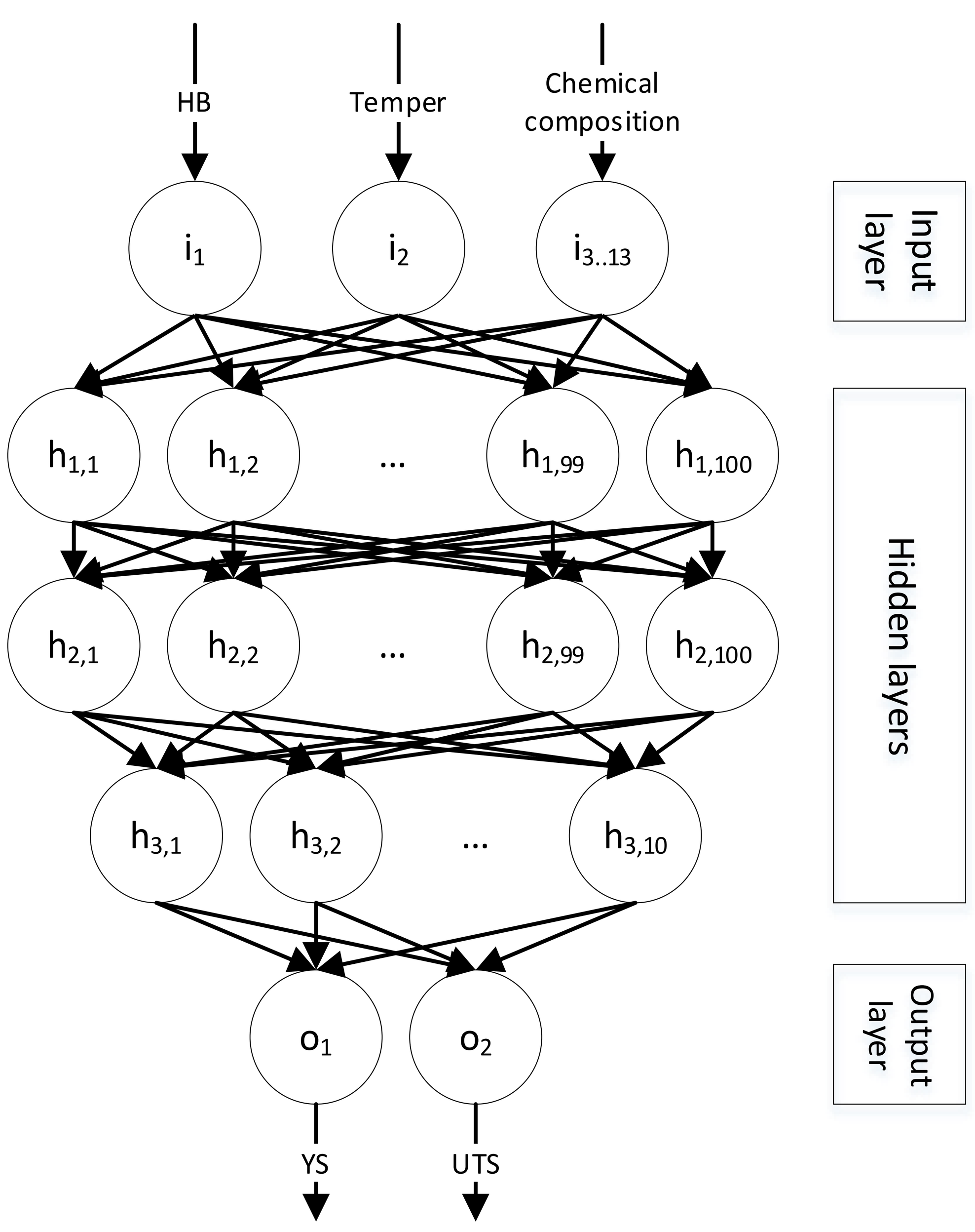
Prediction of the Yield Stress of Aluminum Alloys using Big Data and Artificial Neural Networks

David Merayo, Alvaro Rodríguez-Prieto, Ana María Camacho
Department of Manufacturing Engineering, UNED, Juan del Rosal 12, Madrid 28040, Spain

In this work, a computer-aided tool is developed to predict the yield stress of aluminium alloys. The system is based on the use of artificial neural networks supported by a large dataset containing the most relevant chemical and mechanical properties of thousands of aluminium alloys. The volume of considered data exceeds *5k* registries. The information is retrieved from an open online material library, filtered, organized and prepared to train the artificial neural network (ANN), which takes as input the alloy chemical composition, its temper and its Brinell hardness. After the training, the ANN is able to predict the yield stress of aluminium alloys with an average confidence greater than 95% .

Introduction

Aluminum is one of the most common elements on earth and its alloys are one of the most widely used structural materials for their excellent properties. On the other hand, hardness is one of the most relevant properties of materials and the decision to select a material to produce an industrial component critically affects its ability to fulfill the work for which it was designed.



Nondestructive approaches to approximate the yield strength (YS) have been of interest to engineers because mechanical data can be collected quickly without requiring samples for testing.

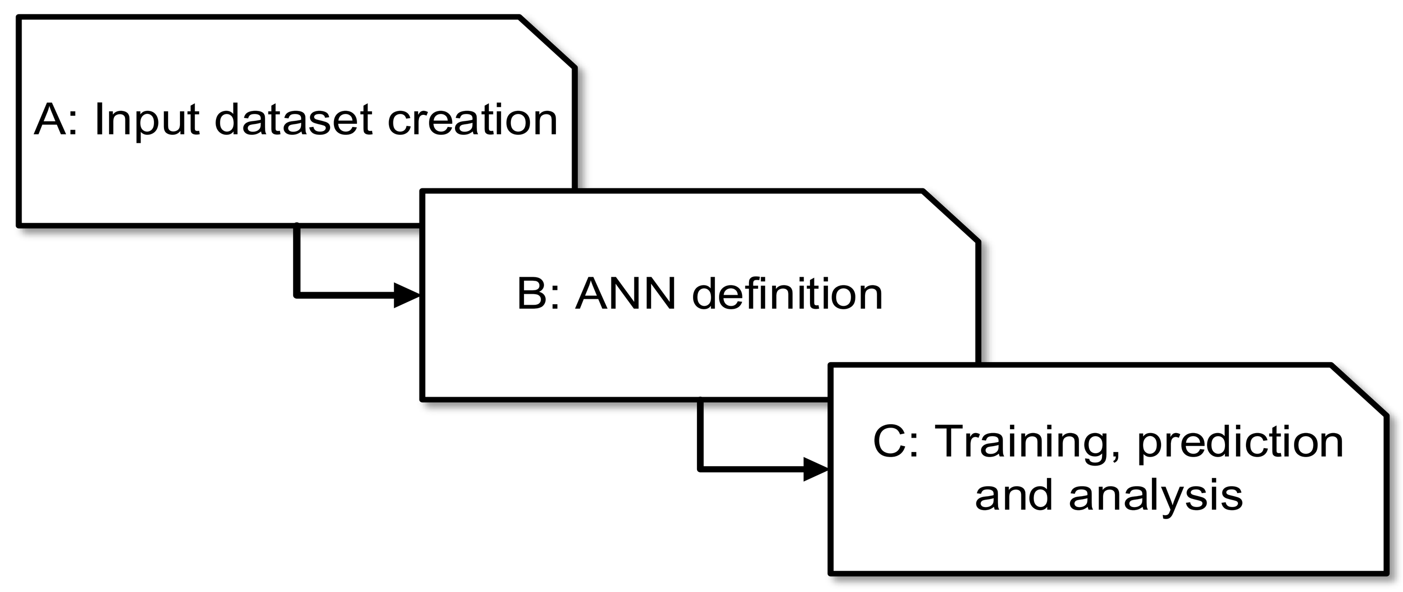
The methodological approach presented in this article allows to use artificial neural networks to estimate the yield strength based on known values (chemical requirements specified by standards and tempers, both typically accessible in databases) and an almost non-destructive test (hardness test) .

A multilayer artificial neural network is a supervised learning algorithm capable of learning a non-linear function by training on a set of labeled input data that can be used to perform classifications and regressions.

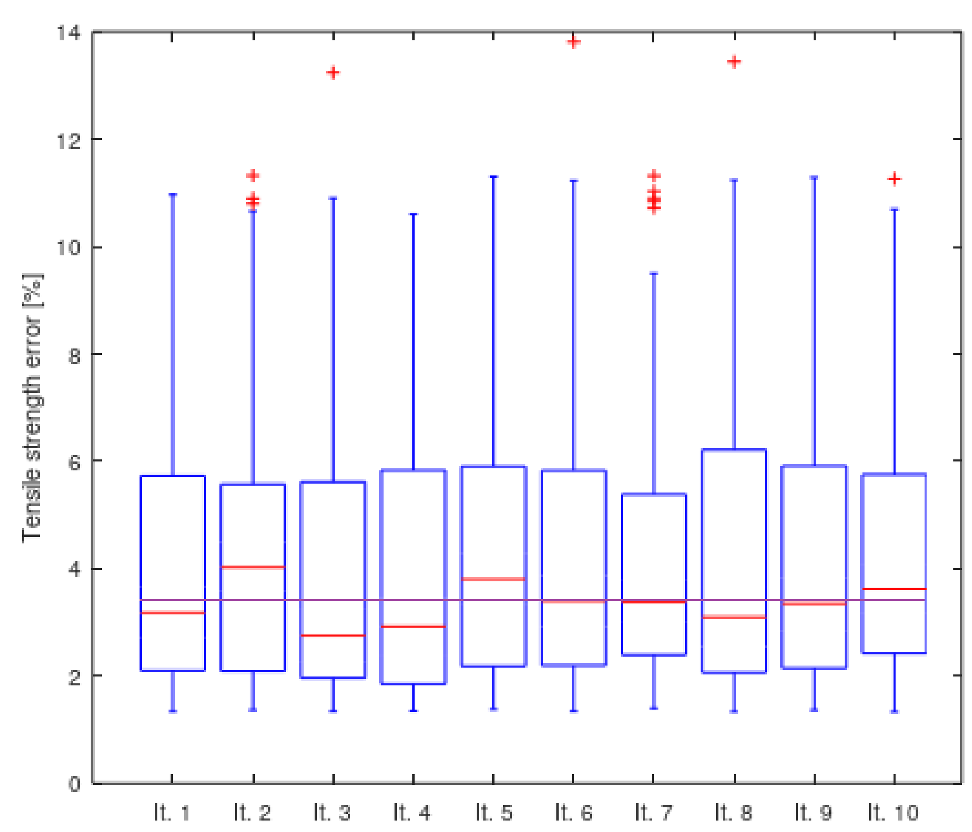
Methodology

The methodology is based on three stages:

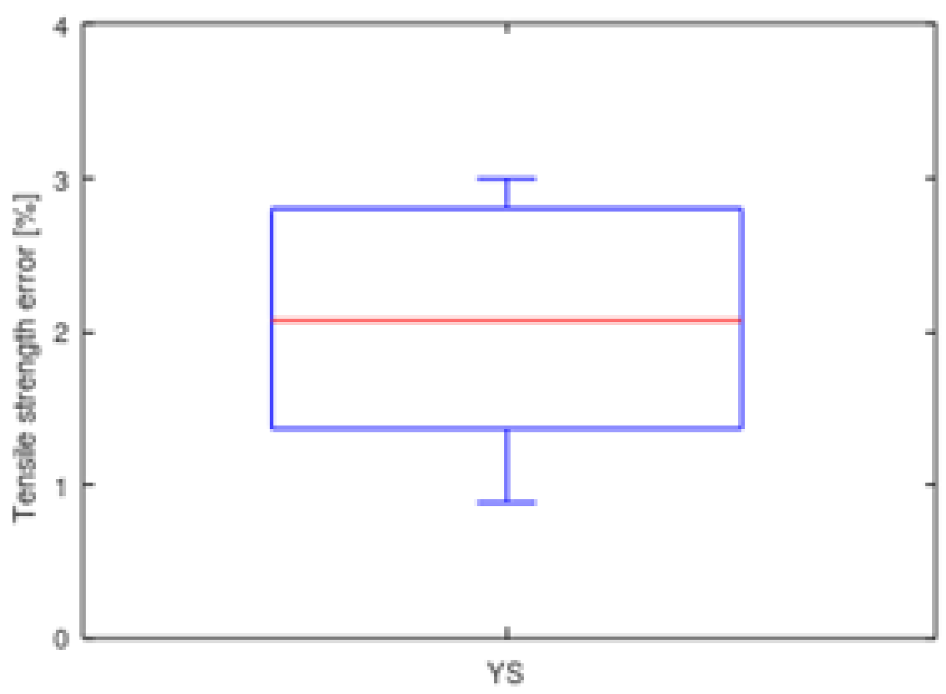
- Input dataset creation: records on aluminum alloys are filtered and organized. Only data on Yield Strength, Brinell hardness, 11 alloying elements and 35 tempers are considered.
- Definition of the Artificial Neural Network: a multilayer neural network is defined with 3 hidden layers and more than 200 perceptrons.
- Training, prediction and analysis: 10 fully-independent iterations of training and prediction are performed. For each iteration, the input dataset is randomly split into two subsets which comprise, respectively, 80% (training subset) and 20% (testing subset) of the records. Finally, the information is analyzed.



Results



Predictive error for all iterations



Predictive error for Al 7010-T6

After performing 10 training-prediction iterations, the following results are obtained: the average relative error for the yield strength prediction is 3.67%, with a standard deviation of 2.61% and a median of 3.19%. Furthermore, the results of the 10 iterations are very homogeneous, which indicates that the method is stable and converges.

With a confidence greater than 98%, the predictive relative error remains limited below 11% although some outliers appear (relative error less than 14%).

The performance of this methodology has been compared with an empirical equation [1] developed expressly for the Al 7010-T6 alloy, obtaining that the relative predictive error of the neural network is only 2% higher.

[1] Tiryakioğlu, M. *et al. (2015).* Hardness-strength relationships in the aluminum alloy 7010. Materials Science and Engineering: A, 631, 196-200.

Conclusions

In this work, the yield strength of aluminum alloys is predicted using artificial neural networks, taking as input their chemical composition, their temper and the results of a hardness test. Since it allows knowing the mechanical behavior of a component based on an almost non-destructive test (hardness test) and parameters specified in standards and scientific databases, it is a contribution of industrial interest. The main conclusions of this work are presented below:

- Artificial neural networks can be used to predict the yield strength of aluminum alloys based on their chemical composition, temper and hardness with an average relative error of 3.67%.
- A methodology based on artificial intelligence can achieve a similar performance to that obtained using empirical equations. This methodology provides greater generality although its predictive performance is slightly lower than that of the empirical equations.
- A multilayer ANN can be trained to make predictions about the mechanical behavior of an in-service industrial component on which a hardness test can be performed.