Consecutively numbered slides:

1. Show Task for assignment and introduce group:

Hello everyone, today us, group 30, are going to show you what RMSE is and how it is used on a concrete example.

Furthermore, we are going to introduce you to a research paper that uses RMSE as well as present how and why RMSE is used in that context.

1. Show short agenda

We will start with the definition of RMSE

Go over to a simple example to explain the effect and usage

Show you the concrete formula

And finally go to the research paper in that RMSE is used.

1. What is RMSE?

Root Mean Square Error (RMSE) is the standard deviation of the residuals (prediction errors).

Residuals are a measure of how far from the regression line data points are.

RMSE is a measure of how spread out these residuals are.

In other words, it tells you how concentrated the data is around the line of best fit.

[https://www.statisticshowto.com/probability-and-statistics/regression-analysis/rmse-root-mean-square-error}

We got two examples here to give you a natural feeling for this:

The blue points are our observed data points while the red line is the hypothesis for our correlation. The RMSE now gives information in a single value on how big the spread between actual observed and forecasted data pairs is, averaged over all pairs.

The observed data points are fixed now, but we could easily change our hypothesis. On our concrete example we could check if a polynomial approach of a third degree would result in better RMSE:

We see, that the RMSE got a bit better. This may advance with the degree of our polynomial, until we hit the polynomial degree of the number of datapoints (which is 46 in this case) At that point we will reach an RMSE of 0 as there will be no deviation between observed and predicted values. At this point the meaning of RMSE is exposed. Used like this the RMSE is a quality index on how good your prediction is in comparison to observed data.

1. How is RMSE used?

As you now hopefully understood what RMSE is about we could talk about the appropriate formulas and suitable notations. A pretty easy and straight forward notation would be the following:

Short notation:

This leads to the underlying basic formula:

Classic way:

… forecasted data point i

… observed data point i

number of data pairs

One hint: It doesn’t matter if you substract forecast from observed or the other way around as the result is squared anyway.

This is how RMSE is used.

1. Concrete example

Our concrete example paper goes by the name:

Hybrid Artificial Intelligence Approaches for Predicting Buckling Damage of Steel Columns Under Axial Compression.

The main purpose of this paper is to investigate the ability to predict the buckling load of steel columns using two hybrid AI models such as Genetic Algorithm combined with Adaptive Neuro-Fuzzy Inference System (ANFIS-GA) and Particle Swarm Optimization combined with Adaptive Neuro-Fuzzy Inference System (ANFIS-PSO).

We will start with the motivation on predicting buckling damage on steel columns superficially and will miss out completely on the explanation for the two Hybrid Artificial Intelligence Approaches, as this would miss our original subject by a mile. Just keep in mind, that both algorithms are trying to predict the buckling load and that those estimators performance is validated by coefficient of determination (R²), Mean Absolute Error (MAE), and most important for our task Root Mean Squared Error (RMSE).

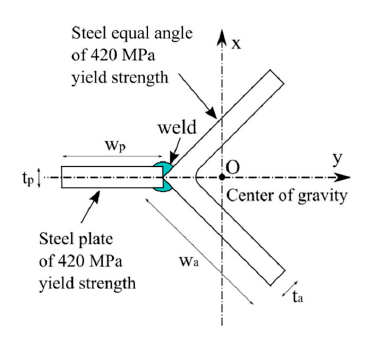
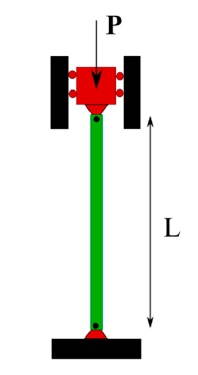
1. Predicting Buckling Damage of Steel Columns Under Axial Compression

For a lot of technical applications, the sturdiness of a construction element is very important. Imagine steel columns of a house that is loaded with the weight of the above floors:



As a structural engineer it is your job to choose the right amount and size of the steel columns, so that each single element isn´t going to buckle due to overload. The problem with buckling now is that it´s highly nonlinear, which means that the breakdown of such a column is not noticeable until the critical force is reached and the column breaks down without a warning. Slight changes in the geometry (like a small curvature of the column) have a strong effect on the critical breakdown force. Luckily this problem is solved for our structural engineer, as he can simply use standard approximation formulars on columns that are standardized in shape and materials as well as great safety coefficients. Problem solved.

Now there are companies, that would like to improve those standard columns -> less weight, easier to use, competitive price. One shape from the paper could look like this (top view):

Things are not easier now, as there are even more geometrical parameters that need to be considered in the calculation process and they definitely need to guarantee that their new construction element is showing the same performance, so that our construction engineer is willing to use them. According to the authors of our paper there are two ways to do so in the state of the art. One way is brute force testing, but “all of these laboratory experiments are generally complex, costly and time consuming”. Furthermore, they note, that it is not always possible to investigate a large number of variables such as length of columns, geometry of cross-section and mechanical properties of materials, as well as boundary conditions. The second basic approach is to use finite element method as it´s well suited to solve nonlinear problems. The authors state two problems there. Firstly, the available commercial software mostly only applies to specific cases with limited variations of input parameters, secondly the nonlinear finite element method remains too challenging for researchers, particularly in terms of nonlinear algorithm implementation to solve the first problem with a self-developed software.

1. Hybrid Artificial Intelligence Approaches

This is where the authors suggest to use two AI methods to solve this problem more convenient then done nowadays through usage of Genetic Algorithm combined with Adaptive Neuro-Fuzzy Inference System (ANFIS-GA) and/or Particle Swarm Optimization combined with Adaptive Neuro-Fuzzy Inference System (ANFIS-PSO). The workflow to do so reads as follows:



To sum things up, the paper uses results of 57 buckling force trials, in which the above mentioned input variables of the steel columns are variated. The output of each trial is the buckling capacity of a column with the chosen input parameters. This dataset, split in training and test data, is used to train both AI models whose performance is validated by coefficient of determination (R²), Mean Absolute Error (MAE), and Root Mean Squared Error (RMSE).

In a last step the monte carlo method is used to propagate variability of input variables to the output results by repeating randomly input sampling. This means that input parameters are changed up to a certain amount randomly throughout different iterations of the algorithm to enhance variability without blowing up the whole simulation effort unnecessarily. We won´t dive deeper into details now, but we recommend the following video for everyone who is interested:

<https://www.youtube.com/watch?v=7ESK5SaP-bc>

We will concentrate from here on to step three: “Validation of model” and the use of RMSE in this paper. If you are interested in the other steps, we recommend to read the whole paper.

1. Validation of model and use of RMSE:

Training dataset

|  |  |
| --- | --- |
| Genetic Algorithm    RMSE: 68.711 kN | Particle Swarm Optimization    RMSE: 54.437 kN |

Test dataset:

|  |  |
| --- | --- |
| Genetic Algorithm    RMSE: 65.371 kN | Particle Swarm Optimization    RMSE: 60.522 kN |

As you can see, from a perspective of RMSE the results look better for the particle swarm optimization, as this algorithm simply is showing better prediction results of over 14kN for the training dataset and nearly 5kN for the test dataset. Just to give a feeling for those values an average car weights around 1400 kg nowadays [1] which also equals nearly 14kN. So, the particle swarm algorithm is literally preforming a carload better than the genetic algorithm.

That’s all from us today. We hope you enjoyed the video …. ->

[1] <https://www.automobil-produktion.de/technik-produktion/forschung-entwicklung/durchschnittsgewicht-von-fahrzeugen-nimmt-zu-336.html#:~:text=Im%20Schnitt%20wiegen%20die%20in,d%C3%BCrfte%20sich%20das%20Gewicht%20erh%C3%B6hen.&text=Nach%20Einsch%C3%A4tzung%20von%20ANP%20Management,in%20Europa%20immer%20weiter%20zu>.