Bayerisches Staatsministerium für Wohnen, Bau und Verkehr

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Predictive Maintenance – Forecasting the road condition of the highway A70 using ArcGIS and Neural Networks

Project Goal

For a road builder it is essential to plan measures for the maintenance of the infrastructure on the basis of the respective roadway and building condition as well as their development. Accurate prediction results can help to improve the cost efficiency of maintenance. On the other hand, the overall development of public infrastructure can be better monitored.

The project goal was to develop an artificial intelligence solution to forecast highway conditions using neural networks on 4 characteristic variables: general road roughness, lengthwise roughness index, grip of the road at 80 km/h driving speed and the damage level of the highway due to cracks. The forecast will support the Bavarian State Building Administration in its future maintenance planning and was visualized in ArcGIS.

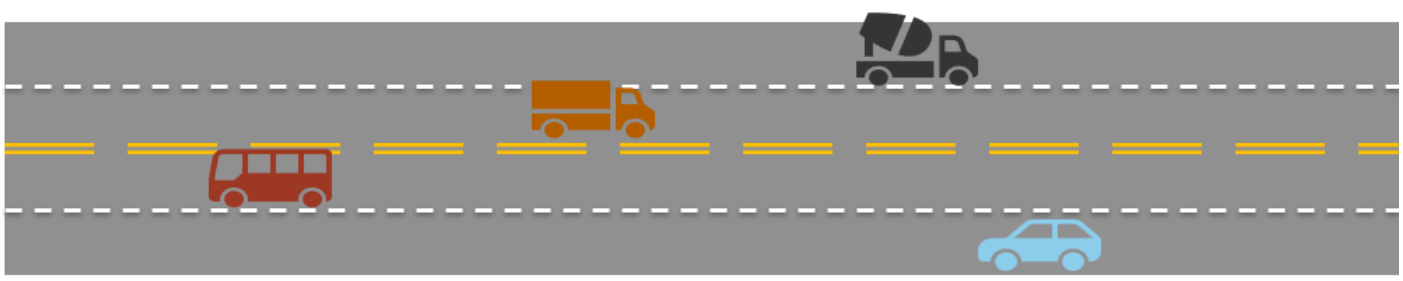
Provided Data

The Bavarian State Ministry of Housing, Building and Transport has provided historical A70 highway (Schweinfurt, Bamberg, Bayreuth) condition assessment data from the years 2009, 2013 and 2017. This assessment data from each year contained 4839 road sections (100m length per section) with 1-3 lanes in two driving directions. Each road part has 134 different road quality measurements and geographic information.

In addition, the traffic density data of the A70 highway was also provided for the years 2005, 2010 and 2015, which includes overall traffic, the average number of daily heavy motor vehicles (HMV) and the average number of daily light motor vehicles (LMV).

Challenges

The data provided were collected at three different points in time, which resulted in a significant proportion of missing values in the aggregation. First of all, a reasonable and accurate imputation method was to be applied before the actual modeling. Additionally, the correlation between the measurements and the geographic information was very strong. This correlation was important to be taken into account while building the model. Traditional neural network models don’t meet this need so the sophisticate time-dependent multivariate neural network models were tested and selected.

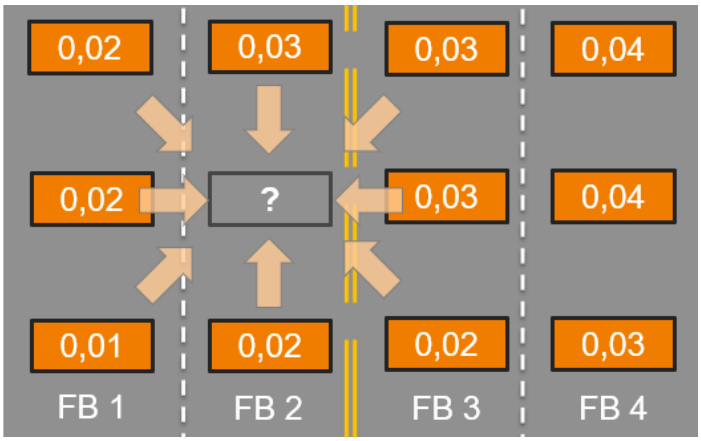


Applied Methods

Data Wrangling

First of all the traffic density data was merged with the high way condition data. Then the variables which had too many missing values (> 50%) were excluded from the downstream modeling process.

In order to meet the requirement of neural networks, that missing values should be imputed before the modeling, a weighted neighborhood imputation was employed, because it uses the geographic information to fill the gap in the missing data.

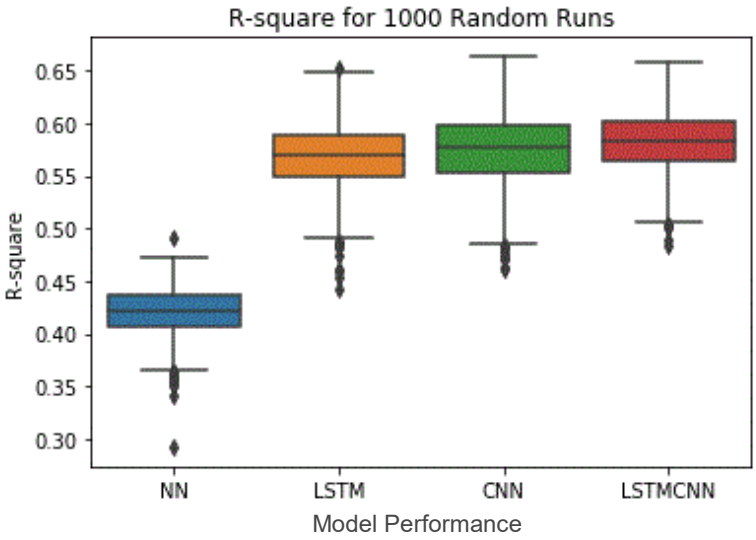


Weighted Neighborhood Imputation

Time dependence neural network modeling

We compared the predictive performance of four models: A general Neural Network (no time information included), LSTM (Long term short memory), CNN (Convolutional Neural Network) and the stacking model of LSTM + CNN.

R-square was used to assess the models performance. The higher the R-square, the better the model. Using the general Neural Network as a baseline with an R-square that is visibly lower than the other time–dependent models, the R-square of the stacked LSTM+CNN model was the highest and shows the best model performance.



Project outcome

The combination of LSTM + CNN model was successfully used to predict the road condition variables. The accuracy of the forecasting level reached an R-square around 60%. This means the model is structured correctly and can be further employed to forecast road conditions. The results were visualized in ArcGIS.