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Prediction of wheel wear in light rail trains using an improved grey GM(1,1) model

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Background





- Accurately prediction of wheel wear of light rail trains in the future is crucial to reduce vehicle operation costs and ensure operation quality.
- The wheel wear is difficult to be predicted due to poor information and small data samples.
- The amount of wheel wear gradually increases with the running mileage.
- The grey future prediction model is supposed to deal with the wheel wear prediction problem effectively.

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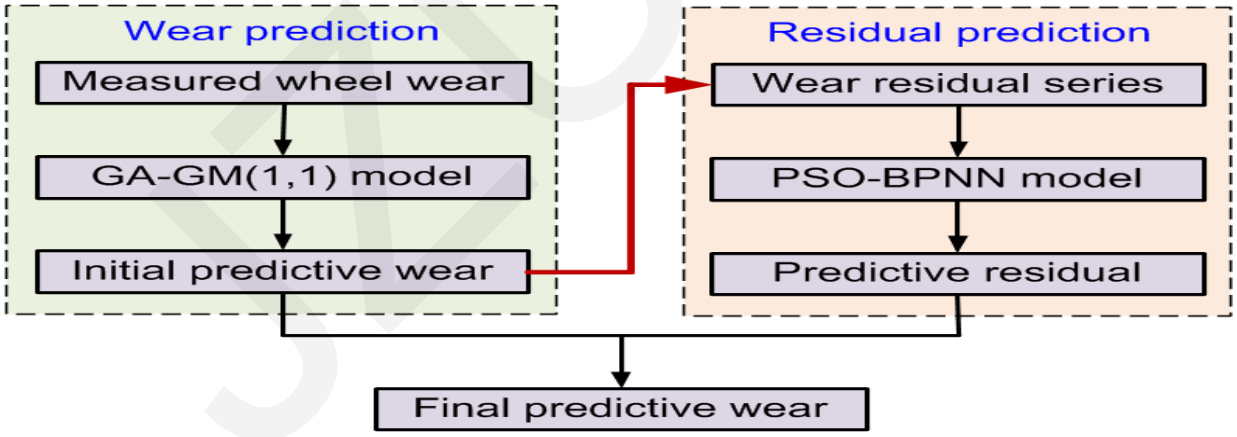
Method

Background values are optimized by genetic algorithm (GA)

Residual error series of the GA-GM(1,1) model is corrected through back propagation neural network (BPNN)

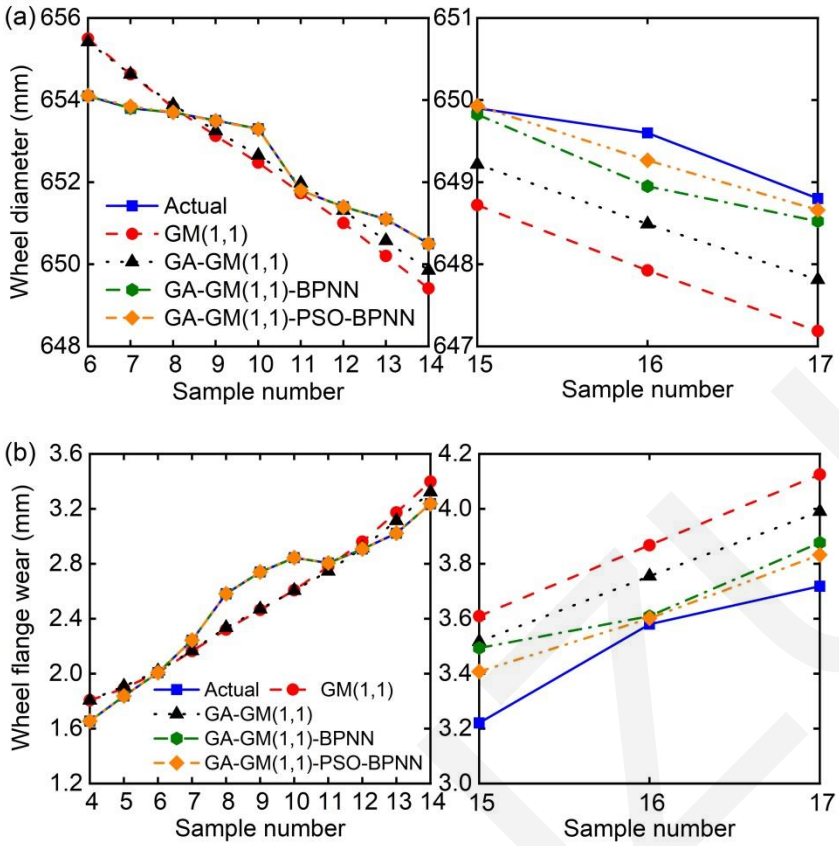
Weight and bias in BPNN are optimized by particle swarm optimization (PSO) algorithm

GM(1,1) → GA-GM(1,1) → GA-GM(1,1)-BPNN → GA-GM(1,1)-PSO-BPNN



Flow chart of the GA-GM(1,1)-PSO-BPNN model for wheel wear prediction

Results



Actual and predictive data curves using different models of wheel diameter (a) and wheel flange wear (b)

- The traditional GM(1,1) model reflected the overall changing trend of the measured wear data series, but could not well track the local variation.
- By correcting the initial predicted residual error series of the GA-GM(1,1) model using the BPNN, the forecasted data were closer to the actual values in each period.
- The GA and PSO algorithms can bring a strong approximation ability to GM(1,1) and BPNN models.
- From highest to lowest, the fitting and prediction performance ranking of the four methods was GA-GM(1,1)-PSO-BPNN > GA-GM(1,1)-BPNN > GA-GM(1,1) > GM(1,1).

Conclusions

- The improved GA-GM(1,1) model lowered both the fitting and prediction errors of the classic GM(1,1) model.
- Combining the advantages of the GA-GM(1,1) model in linear prediction and the BPNN model in stochastic data prediction, the GA-GM(1,1)-BPNN model further upgraded the fitting and prediction performances.
- Benefitting from the contribution of PSO algorithm, the GA-GM(1,1)-PSO-BPNN model showed the most reliable performance with the least errors of the four models.
- The GA-GM(1,1)-PSO-BPNN model overcame the impacts of the nonlinear and random characteristics of the measured data in the case of small samples.

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