

Value Added Strategy for Unplanned Rail Track Inspections [†]

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On-demand (or unplanned) track inspection could be due to a disruption in a track geometry recording car [1–5]. A proper selection of input- and output-memory order which is required for prediction of *missing* track measurement using a nonlinear autoregressive model with external series (NARX) is expected to create value added to the inspection decision.

For a M -meter length of unit track section, there could be sequence of track (measurement) points, denoted as $x_i; i = 1, \dots, m$ where $m = M/r$. Distance between two adjacent points is r meter and its value depends on the sampling rate employed by a track recording car during track measurement (inspection). Each x_i is assigned with amplitude of track irregularity e.g., longitudinal level. Here, it is expressed as $y(x_i)$. In the event of disruption, a predicted value of $y(x_i)$ is demanded as risk aversion towards unplanned train speed restrictions. The NARX model is formulated to predict track irregularity of a track section and is given as follows:

$$\tilde{y}(x_i) = f\left(y(x_{i-1}), \dots, y(x_{i-d_y}), u(x_{i-1}), \dots, u(x_{i-d_u})\right) \quad (1)$$

where $u(x), y(x) \in \mathbb{R}$ denote, respectively, the input and output of the model at discrete unit step i , while $d_y \geq 1$ and $d_u \geq 1$ are the input-memory and output-memory orders [6]. Performance of the NARX model is however sensitive to a selection of d_y and d_u . In the context of our study, the corresponding selection problem can be solved by determining a segment of size L denoted as $S = \{x_j, \dots, x_{j+L}\}; j, j + L \leq m$ which minimizes the weighted error function $wMSE$ given as follows [7].

$$wMSE(x_i) = (1 - \gamma) \sum_{t=j+L+1}^{j+L+n} (\tilde{y}(x_t) - y(x_t))^2 + \gamma \frac{1}{n} \sum_{r=1}^n w_r^2 \quad (2)$$

where γ is the performance ratio, w the network weights and biases and n the number of hidden nodes in the network. The function $wMSE$ represents the performance of NARX model in Equation (1) to predict track irregularity for a unit track section $[x_{j+L+1}, x_{j+L+n}]$.

An example is prepared to demonstrate benefits of analyzing the effect of proper selection of segment S . Here, the NARX model takes measurement of track gauge, alignment (left and right) and the value of recent change in the longitudinal level calculated from two consecutive track inspections as external variables. An output of the model is longitudinal track irregularity over a $M = 100$ m unit track section. Related data series in the example is plotted in Figure 1. In this example, the value of L was 10 (is equivalent to 5 m track). Thirteen values of x_j were selected as candidates for the segment S and their model performance is displayed in Figure 2. Results show the existence of variation in the performance of prediction model due to a different choice of position of S .

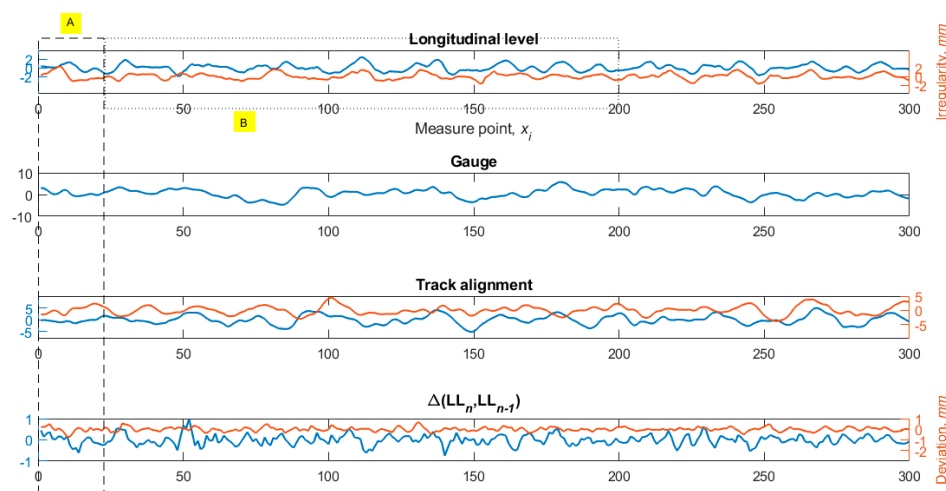


Figure 1. Collection of data series used in the example. The bottom three plots associate with $u(x)$ in the Equation (1).

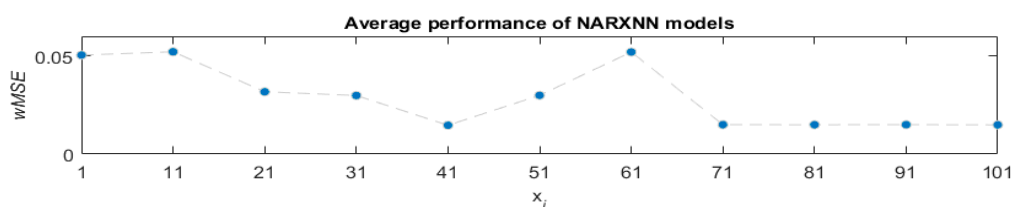


Figure 2. Model performance averaged over 30 simulation runs for 11 choices of S_i .

Disruptions in track geometry inspection create an opportunity to deliver value added to track inspections program. This goal can be achieved through an effective decision in assigning on-demand (manual) inspection to an affected track area. A case of *missing* longitudinal track irregularity where the missed values can be predicted by NARX is presented. The simulation results demonstrate that the segment selection step in NARX is beneficial to obtain rich information from unplanned track inspection. More simulation works are however required in future to strengthen the claim/suggestion.

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