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Abstract

Conveyor belts operating in harsh mining environments are susceptible to damage during material transport, and the failure of a belt section in a loop can disrupt conveyor operation, potentially leading to significant financial losses. The extent of these losses is directly dependent on the scale of mining operations and their production capacity. The scientific objective of this dissertation is to develop an artificial intelligence (AI)-based method for predicting parameters associated with conveyor belt failures, including damage size and occurrence metrics, by utilizing operational characteristics and historical maintenance records obtained from mining environments. The utilitarian goal of the thesis is to improve the operational efficiency of mines by developing an AI-based predictive maintenance system for conveyor belts. Preventive repairs based on predicted condition can prevent advanced damage and emergency downtime in conveyor belts, while also enabling more efficient resource allocation, extending belt service life, and improving safety to ensure smooth operations in mining environments.

Previous studies [1-6] have identified combinations of dependent (output) and independent (input) parameters affecting the severity of conveyor belt failures, such as the type of material being conveyed, the conveyor length, and the belt speed. However, the less frequently studied parameters and additional elements considered in this thesis—identified through an Ishikawa diagram within a root cause analysis—include the conveyor slope and the route configuration (fixed or sliding), as well as the type of conveyed material (overburden, lignite and its mixtures, and limestone).

This dissertation develops and validates a predictive method based on long short-term memory (LSTM) neural networks for forecasting the size and characteristics of conveyor-belt damage in surface mining. Two independent empirical datasets were used: (i) a visual-inspection database from one of the lignite mines (927 records, 11 input variables describing belt geometry, transported material, age and repair history; 5 damage-related outputs) and (ii) a DiagBelt+ magnetic scan database from one of the limestone mines (≈929 records, 6 inputs, 5 outputs). The method was developed and verified using subjective historical data from visual inspections (from the lignite mine, which uses straight conveyors) and objective data from the assessment of the belt core condition generated by the DiagBelt+ magnetic diagnostic system during subsequent scans (in the limestone mine which uses a very long curved conveyor).

Dependent parameters considered in this dissertation include the number of cut cords in the core, the cumulative number of repairs, the total number of damages for sections, the damage density (number of damages per meter of belt in the section), the damage area and dimensions (length and width of the recorded damage signals), and the timing of these events. The models specifically predicted belt condition indicators including number of repairs, number of cut steel cords, and damage geometry (length, width, area).

The method was implemented in Python/TensorFlow and tested with alternative hyperparameters (e.g., 3 hidden layers with 36 neurons, batch size 16, optimizers Adam/Nadam/RMSprop, ReLU or Swish activation). The rationale for selecting the LSTM neural network algorithm over other prominent modeling approaches is discussed, along with hyperparameter choices for network training. Evaluation used three relative error indicators and multiple training/testing splits. For DiagBelt+ data, median relative errors were ≈55% for damage length and ≈60% for width; for visual-inspection data, the best models achieved median errors of ≈33% for age- and repair-related targets. Furthermore, the models were extended to future forecasting through a recursive modeling framework, demonstrating their capability to provide reliable insights that can inform proactive repair and maintenance planning.

The study demonstrates that the proposed LSTM approach can support predictive maintenance of conveyor belts, while highlighting the influence of data quality and belt segment length on accuracy. All issues discussed in this dissertation—including the importance of belt conveyors in mining operations, their structural characteristics, the occurrence of damage during material transport, and the selection of appropriate machine learning algorithms—are situated in the context of international literature, taking into account both the historical perspective and the latest achievements in scientific research.

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