IC3 and IC4 trains at risk of blocking their wheels

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In November 2011, an IC4 train passed a stop-signal by 651 meters while trying to break. Investigations concluded it was “slippery tracks”. An investigation into risk factors for what causes a train to block the wheels while braking was initiated. This resulted in 30 monitored train rides from Copenhagen to Aarhus in the autumn of 2012. GPS position, speed, braking, and braking power were recorded. They were combined with a variety of both meteorological data and track characteristics. These explanatory variables were included in a risk factor study of the risk of a wheel-block resulting in a proof of concept.

Keywords: Data alignment, Data cleansing, Variable construction, Model building, Event prediction

Area: Industrial Applications / Domain knowledge & analytics (human in the loop)

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Introduction

On November 7th 2011, an IC4 train owned by the Danish state railroad company, DSB, passed a stop-signal by 651 meters while trying to break. Under normal conditions the train should come to a halt after about 1 km. However, the train spent approximately 2.8 km braking before coming to a halt, only 374 meters behind a freight train which was in front of it. The event caused a series of investigations on the efficiency of the IC4 braking systems. A few issues with the braking system were pointed out during the investigations. These have later been corrected. However, it is important to note, that none of these issues could explain such a large overshoot, neither by themselves, nor in combination. Indeed the main conclusion was that the brakes worked as specified.

It was therefore agreed to run an investigation on reasons and possible causes of what is known as “low adhesion” or more popularly “slippery tracks”. Hence an investigation into risk factors for what causes the train to block the wheels while braking was launched. Also, which differences might exist between the newer IC4 and the older IC3 train types?

Materials

This resulted in 30 monitored train rides from Copenhagen to Aarhus in the autumn period of 2012, where leaves tend to fall onto the tracks and cause slippery conditions under the influence of certain types of weather. Sensors recorded the train ride characteristics such as GPS position, speed, braking, and braking power. These data were combined with a variety of meteorological data from the Danish Meteorological Institute: temperature, dew point, wind speed, wind direction, turbulence, precipitation and solar radiation. Track characteristics were extracted from the track database over the Danish railroad system by the Danish infrastructure manager: Rail-net Denmark. This included variables such as size and kind of surrounding vegetation, information on slopes, curvature, elevations and recesses.

Methods

The first important task was to verify the quality of the data. The train logs and the meteorological data were indexed by time. The track data were indexed by distance to Copenhagen Central Station. The train logs turned out to have erroneous data and/or drop-outs in many cases. It was chosen to concentrate on those train logs which had more or less complete data. Even then the data could have errors most often as sudden “jumps” in the time stamps. These jumps – usually of an hour - were carefully checked and data was adjusted back to the expected to form by visual inspection. For the track data the variables above were entered into the analysis. For the meteorological data the data were supplemented with accumulated values over the previous 3, 4, 5, 6, 7, 8, and 24 hours. Finally a leaf index was constructed which took into account the amount of nearby vegetation and also the wind direction.

The final modelling of the wheel-block indicator in a risk factor study was done by means of a logistic regression with the possibility of including all the above mentioned explanatory variables. The model was reduced by means of the Akaike Information Criterion.

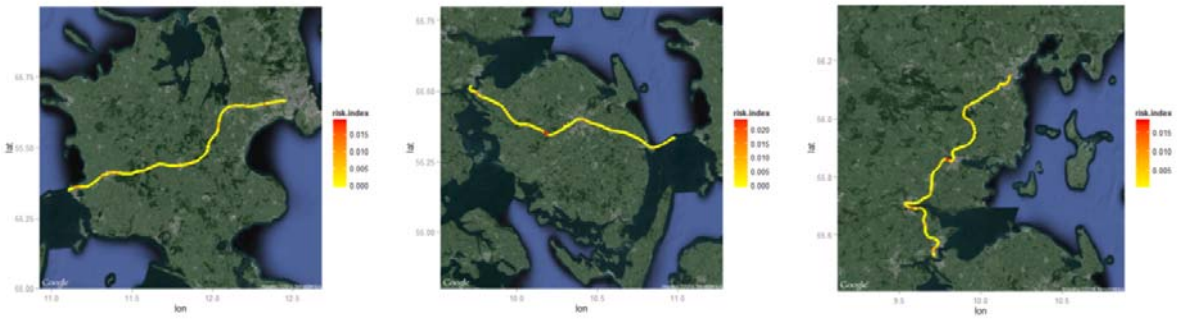

Figure: Smoothed risk-map for blocked wheel conditions. Left: Sealand, middle: Funen, right: Jutland.

Results, discussion and conclusion

Applications of the developed model included the construction of maps of blocking flag risks from Copenhagen to Aarhus, comparisons between IC3 and IC4 trains, and studies of the original Marslev incident.

In conclusion the probability of initiating a wheel-block was clearly affected by slippery tracks and showed it was possible to compute a risk index. One of the factors that contributed to track slipperiness in the trial period was leaf juice as indicated by the strong significance of the leaf fall index. Other variables such as weather variables and track and train characteristics and interactions between these were also of importance.

The investigation pointed towards problems with the quality of the data. The number of GPS positions relative to the number of data points was rather low and constituted a problem. Since position was based on GPS data, position, and thus track characteristics, vegetation and meteorological data were subject to uncertainty due to imprecise alignment. This lowered the validity of the study results. Furthermore, the speed profiles were faulty to some extent because of “jumps” in the time stamps. While we do not believe this plays a role, we cannot say for sure. A large amount of missing data or drop-outs also added to the picture of a deficient data base. Finally, data were collected on a rather limited number of days. In fact, the applied data were from only 11 different days thus limiting the possibility for generalizing the results – especially outside the leaf fall period.

We could not conclude that the IC3 and IC4 trains behaved differently, even though there was evidence that they had different probabilities of initiating wheel-blocks.

The model gave proof of concept. In principle it illustrated the possibility for further development, one of the perspectives being an early warning system for the train traffic. Of course this means resolving and streamlining problems with data issues.

CV – Professor Bjarne Kjær Ersbøll (April 2015)

Personal Details

Place and date of birth:	Hornsyld (Denmark), June 9, 1957
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Education

1990	PhD in Pattern Recognition and Image Analysis, DTU, Denmark
1983	MSc Eng degree in Applied Statistics, DTU, Denmark

Professional experience

2010-present	Full Professor at DTU Informatics/DTU Compute, DTU
2008-2009	Professor (Danish: Docent) at DTU Informatics, DTU
1992-2008	Associate Professor at IMSOR/DTU Informatics, DTU
1989-1992	Assistant Professor at IMSOR, DTU
1983-1989	Research Assistant at IMSOR, DTU

Publications - summary

ISI journal publications: 61; Citations: 1309; H.index: 13;
Google Scholar: 225 papers; Citations: 2491; H.index: 20;

Awards

2013 received the prize for research based consultancy at the annual celebration at DTU
2014 received an IBM Faculty Award for creating an educational profile in Data Science / Big Data

Teaching and supervision

Taught courses in statistics, pattern recognition, and image analysis at bachelor, master, and PhD level.
Supervised or co-supervised more than 100 MSc theses and 38 PhD theses (currently 2)

Research funding (2008 - present)

INTELLISWITCH: Intelligent railroad switches and crossings, Danish Research Council
BIOPRO2: BIO-based PROduction, Danish Research Council
NEXIM: Next Generation X-ray Imaging, Danish Research Council
CIFQ: Centre for Imaging Food Quality, Danish Research Council
Calculating Nutrients in Dairy Products, Danish Dairy Research Foundation
Nanolyse: NANOPARTICLES IN FOOD: Analytical methods for detection and characterisation, EU, FP7
ATIS4all: Assistive Technology and Inclusive Solutions for all, EU, Thematic Network

Management experience (most recent)

Big Data Value Association (BDVA.eu), Full Member representative for DTU
Lead professor for sector development project “BIG1”
Head of section “Statistics and Data Analysis”
Head of public and private sector consultancy unit “DTU Data Analysis”
Member of the administrative committee at DTU Compute
Member of the committee for dispensation and transfer of merit at DTU
Member of the management committee for FAIM: Farm Animal Imaging, EU-COST network
Member of the Danish Railroad authority
Member of the steering committee for 3D Lab at Panum Institute
Project manager of interdisciplinary DTU project: “Investigation of low adhesion” for Danish Ministry of Transport and DSB
Project leader and member of the steering committee for the public service sector consultancy project between DTU, Railroad Denmark and the Danish Transport Authority
Project leader and member of the steering committee to investigate of the braking ability of the IC4 train
Member of the Steering Committee of EU Network of Excellence: COGAIN
Task group leader of task 5 in EU Network of Excellence COGAIN
Co-founder and first chairman of “The COGAIN Association”.

Research interests

Work is mainly on applied statistics, data analysis, image analysis and data integration. Considerable experience in the application of these disciplines in industrial, medical, public sector and remote sensing projects. Research and teaching is largely inspired by finding solutions to actual problems in industry and other institutions - and often in collaboration with these.

Anders Stockmarr - biography

Anders Stockmarr completed his PhD in 1996 at the University of Copenhagen, Denmark. He has since worked with both theoretical and applied statistics, in particular, but not exclusively, in a biological setting, including human biology, plant biology and veterinary biology and epidemiology. He now serves as a senior researcher at the Technical University of Denmark in Lyngby, Denmark. He is the author of more than 40 scientific journal papers, published in a wide range of journals that covers a broad range of science disciplines.