What are the Artificial Intelligence Applications in Rail Transit?

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Key Presentation Take-Aways

• Winds of Change
• Technology Trends
• Artificial Intelligence
• Train Control
• Energy Consumption
• Dynamic Optimization
• Predictive Maintenance
• Modeling/Simulation
• Survival Strategy
We’re doing things today that I thought were impossible a few years ago. For us to continue to be successful, we are going to do things that you now think are impossible.
I3.0 vs. I4.0

Industry 3.0
- Better
- Cheaper
- Faster

Industry 4.0
- Better
- Cheaper
- Faster
- Predictions

Arithmetic
Technology Trend

- Microprocessors
- Word processors
- MS-DOS
- Apple Mac
- Windows
- Internet
- Cell phones
- DVDs
- Hybrid cars
- Google
- Youtube
- Facebook
- iPad
- Driverless cars
- 3D chips

Source: miovision
I4.0 – New Ecosystem

Altering the Way We Live - Work - Interact

Scale, Scope, Complexity of Transformation is Unprecedented

Changing us not what we do!

Exponential Rate

Digital Physical

Natural and Artificial

Biological Boundaries
Artificial Intelligence

• Simulation of human intelligence in machines
• Designed to address a specific problem
  • Deep blue, Alpha Go, Jeopardy, etc.
• Deluge of data (Zeta Bytes): $10^{21}$
• Massive processing power
• AI will transform many industries
  • but it’s not magic
AI Timeline

- Over 60 years history
- Alan Turing - 1950
- John McCarthy - 1955
- Deep Blue - 1977
- Roomba - 2002
- Siri – 2011
- Watson -2011
- Alexa - 2014
- Alpha Go (2^{170}) - 2017
AI Branches

NLP
- Content Extraction
- Classification
- Machine Translation
- Question Answering
- Text Generation

AI
- Machine Learning
  - Deep Learning
    - Supervised
    - Unsupervised

Robotics

Vision
- Image Recognition
  - Machine Vision

Speech
- Speech to Text
- Text to Speech

Planning

Expert Systems

Content Extraction
Classification
Machine Translation
Question Answering
Text Generation
Deep Learning
Supervised
Unsupervised
Speech to Text
Text to Speech
Planning
Expert Systems

APTA Rail Conference 2019
AI

ANI • Artificial Narrow Intelligence

AGI • Artificial General Intelligence

ASI • Artificial Supper Intelligence (Singularity)
IoT in global railway industry: $30 billion in the next 15 years

Source: BusinessWire
Breakthroughs

**Hardware**
- Moore’s Law: Transistors in a chip doubling/2 years
- 10 nm pushing the limits
- 3D chips

**Processing Speed**
- Processing speed
  - MHz to GHz

**Analytics**
- AI
IBM Watson Cloud Based Platform

- Thousands of Processors
- 500 Gb/Sec
- 16 Tera Bytes RAM
Railway Digitalization

- Smarter / More Sustainable Trains
- Faster and More Flexible Manufacturing/Testing
- Extended Factory Boundaries
- Condition Monitoring - Predictive Maintenance Reduced Time / Cost
- Predicting Delays and Service Disruptions
- Creating Integrated Ecosystem
- Cognitive Technologies – Responsive - Agile
Deterministic - Probabilistic

- **AI:**
  - Algorithm, mathematical model or software
  - Can learn what to do to improve performance
  - Time based on its own past performance
- **Deterministic:** Full understanding of the desired software behavior
- **Probabilistic:** Basic neural math and huge processing power
Train Control

SIL0: non-safety
• Could be Probabilistic
• AI Based:
  • Arrival time
  • Timetable
  • Ride comfort
  • Train regulation

SIL4: safety critical (max hazard $10^{-9}$)
• Must be Deterministic
• AI Assisted:
  • No direct control
  • Advisory role to SIL4
    • Position
    • Acceleration
    • Safe braking
    • Interlocking
CBTC + SIL0 AI

Figure 1 – a possible application of artificial intelligence in automatic train control.

Source: IRSE News 258: Alexandre Pires
Enhanced ATP

4Tel / University of Newcastle Robotics (Research)

- Driverless Car Technologies
  - Artificial Intelligence
  - Deep Machine Learning
- Safety Enhancement
  - Hazards Detection
  - Signal Aspect Detection
  - Level Crossing
- Driver Advisory Systems
  - Ontrack obstacle detection
  - Optimize human intervention for sensitive decisions impacting operation

Source: 4Tel
From Assisted to Autonomous

- Simulator & real environment testing
- Obstacle detection
- Improve safety - increase capacity
- Improve energy consumption

- Autonomous LRV in Potsdam, Germany
- Three stage to fully autonomous operation
Green CBTC

- Intelligent scheduling
- Speed optimization
- Maximize coasting
- Align trains for maximizing regenerative braking efficiency
- Create driving profiles & computerized instructions
- Efficiency gains – 15% reduction in energy consumption
- Smoother operations – reduced wear on track and trains
- Energy control – adjust peak energy demand spikes

Source: Thales
Future Generations

- Thales 2033 Intelligent Railway Network
- Data and information processed in the cloud
- Cloud based automatic train control system
- Optimized reliability and availability
- Sensory data collection
- Predictive maintenance

Source: Thales
Timetable Synchronization & Optimization

- Beijing subway network case study
- Time-dependent passenger demand-driven timetable synchronization & optimization
- Optimize travel time in a network
- Adjusting departure times, running times, stopping times, and headways of all trains on each line
- Multi-objective - Pareto optimum schedules
**Timetable Synchronization & Optimization**

- Considering infrastructure capacity, passenger satisfaction, cost optimization
- AI Techniques:
  - Neural networks
  - Genetic algorithms (GA)
  - Simulated annealing
  - Tabu search algorithms

<table>
<thead>
<tr>
<th>Item</th>
<th>Initial value (min)</th>
<th>Optimized value (min)</th>
<th>Percent reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total travel time</td>
<td>296701</td>
<td>275513</td>
<td>7.14</td>
</tr>
<tr>
<td>Waiting time</td>
<td>92134</td>
<td>85783</td>
<td>6.89</td>
</tr>
<tr>
<td>Transfer waiting time</td>
<td>26630</td>
<td>23551</td>
<td>11.56</td>
</tr>
</tbody>
</table>
A Fault Tolerant Approach

- Complex station with terminus platform
- Multiple routes for operation of high and low speed trains
- Similar pattern of improvement in capacity, operation robustness, punctuality
- Changes to track layout and/or locations of signal boxes fault tolerant rules
- AI methods used to optimize timetables in the implementation of the fault tolerant rules

Source: University of Salford in collaboration with the Institute for Transport Studies at the University of Leeds.
IBM Smarter Rail

- One mile speed increase saves
  - 5,000 freight cars
  - 250 locomotives
- Dynamic scheduling
- Surveillance of track and infrastructure
- Predictive maintenance
- Integration with road, sea, and air travel

Source: IBM Smarter Rail
GE Movement Planner

• GE’s RailEdge® Movement Planner breakthrough
• Predicts patterns in train traffic
• Reduces environmental impact (1t/486mi/1g)
• Increases railroad capacity, velocity and efficiency
• Increases average network speed of trains 10-20%

US freight doubles in 25 years
Every mile speed increase
$200m CapEx savings

Source: Norfolk Southern
• Machines can learn more than a radiologist lifetime experience in one day
• Machine can be trained to learn from thousands of transit simulations
• Construct models using algorithms that learn from data and update in real time
• Learn from past predictions, outcomes and errors
• Optimization and calibration in virtual world

Source: AnyLogic
Prediction & Prevention

- Records locomotive and video data, takes inputs from different sources/devices, and makes it immediately available
- Real time locomotive status
- Advanced analytics
- Artificial intelligence
- Machine learning
- Live visual intelligence
- Real time status
- Early identification health issues
- Increased safety
- Decreased maintenance costs

Source: Wi-Tronix
SNCF – Condition Based Asset Management

- Network of 30,000 kilometers railway
- 15,000 daily train runs
- Ridership increased 50% in the last 10 years
- Started more than a decade ago:
  - IBM Watson AI
  - Remote sensors: vibration, temperature, pressure, etc.
  - Field and onboard equipment
  - Automatic alerts
  - Datapred algorithms
  - Sequential machine learning
  - Real time data processing

Source: OSIsoft
Machine Vision/Learning

- Since 2002 (Nebraska, Iowa and Arkansas)
- Thousands of Sensors
- Cameras, LIDARs, Laser
- 50,000 Images/Sec
- 360 Laser View
- Machine vision
- Machine learning
- Maintenance schedule
- Increased safety
- Reduced costs

Source: UP
Railcar Inspection Portal - rip®

- Connected Intelligence (AI/ML/NN)
- Truevue360 – AI division
- Intelligent 360° imagery
- Situational awareness inspection processes & security
- CN portals Winnipeg:
  - Machine vision
  - Predictive analytics

Source1: duostech
Source2: duostech
Strategy to Survive the Digital Disruption

• People are the Real Key to Digital Transformation
• Digital disruption is primarily about people
• Effective digital transformation involves changes to organizational dynamics
• Cultural shift to more agile, risk tolerant, and experimental
• Digital maturity with ability to take advantage of opportunities offered by the new technology
• Cultivating a digital environment, enabling intentional collaboration, fostering experimental mindset

Source: MIT Research
Technology is no longer the constraint to achieving goals, we are constrained by our imagination and a supporting business case.

Smarter and more sustainable trains will be designed, tested, and calibrated in a virtual environment, and factory boundaries will extend to customer sites.

“Status quo is more dangerous than the unknown”

John Kotter - Harvard Business School

Interconnectedness, collaboration and partnership is creating an ecosystem of values sharing industry knowledge and innovation.

Technology typically is rarely inherently sustaining or disruptive; it depends upon how you deploy it in the market place that determines its disruptiveness.” Clayton Christensen - Harvard Business School
THANK YOU

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