What are the Artificial Intelligence Applications in Rail Transit?

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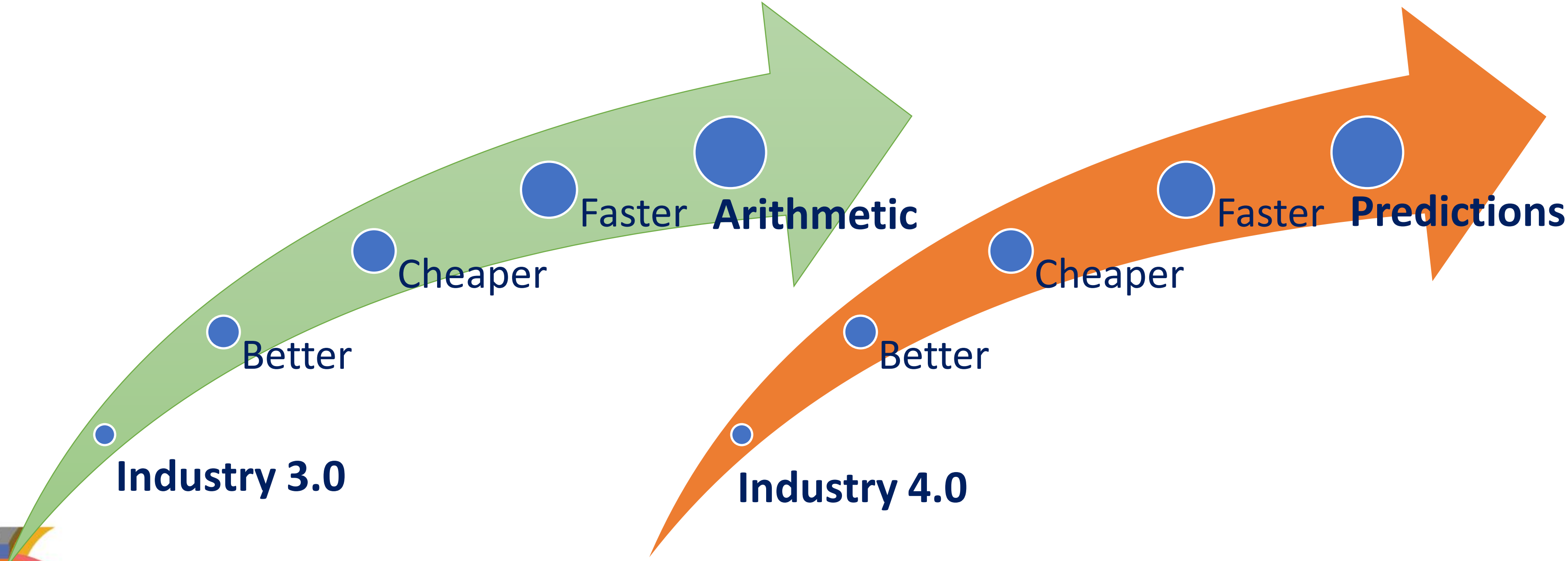
Key Presentation Take-Aways

- Winds of Change
- Technology Trends
- Artificial Intelligence
- Train Control
- Energy Consumption
- Dynamic Optimization
- Predictive Maintenance
- Modeling/Simulation
- Survival Strategy

Intel Cofounder - Gordon Moore

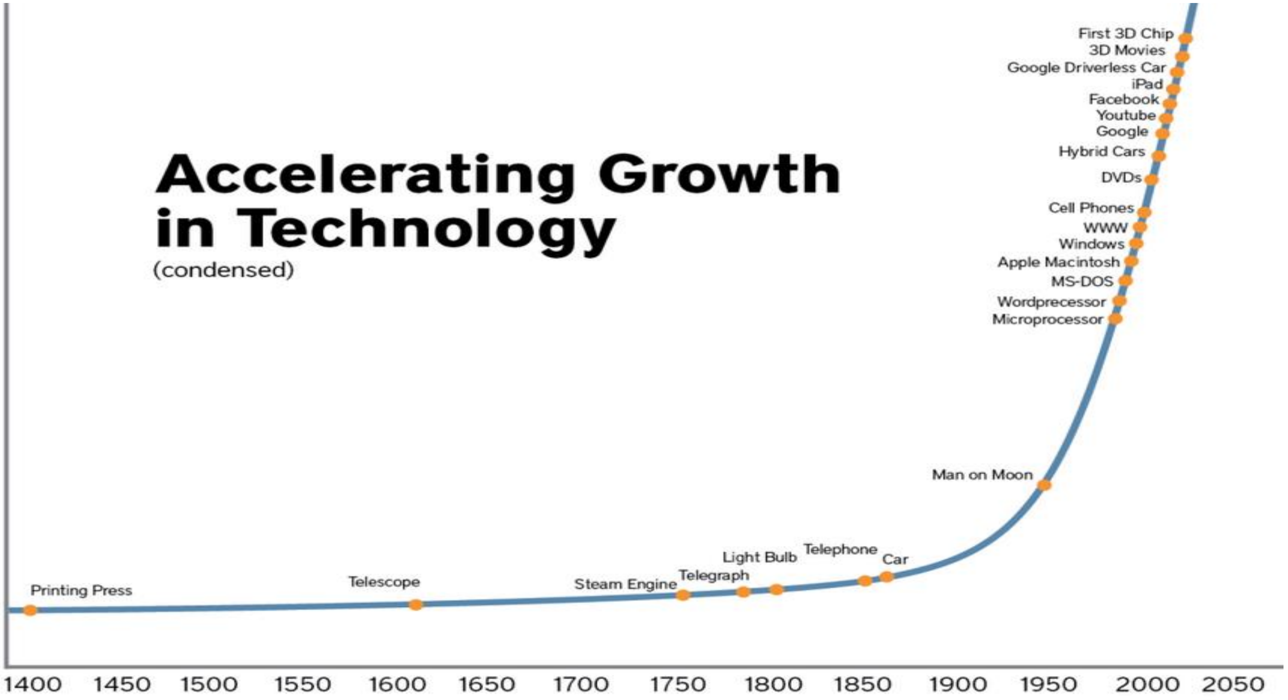
We’re doing things today that I thought were impossible a few years ago. For us to continue to be successful, we are going to do things that you now think are impossible.

I3.0 vs. I4.0


Industry 3.0
Better
Cheaper
Faster
Arithmetic
Industry 4.0
Better
Cheaper
Faster
Predictions

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

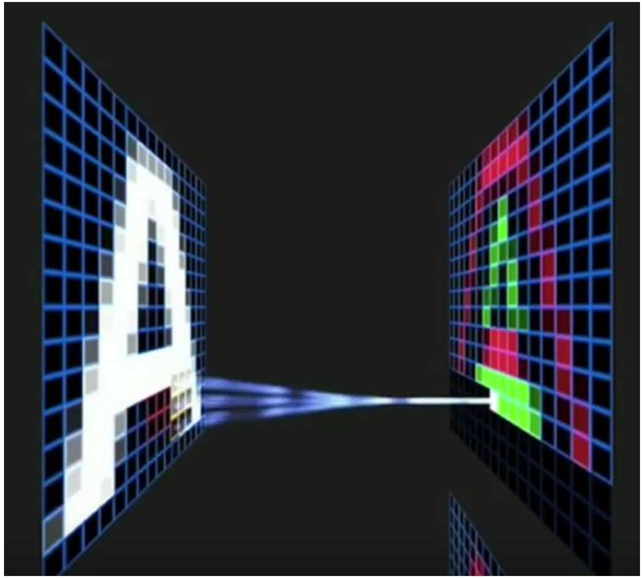
Natural and Artificial

Digital Physical

Biological Boundaries

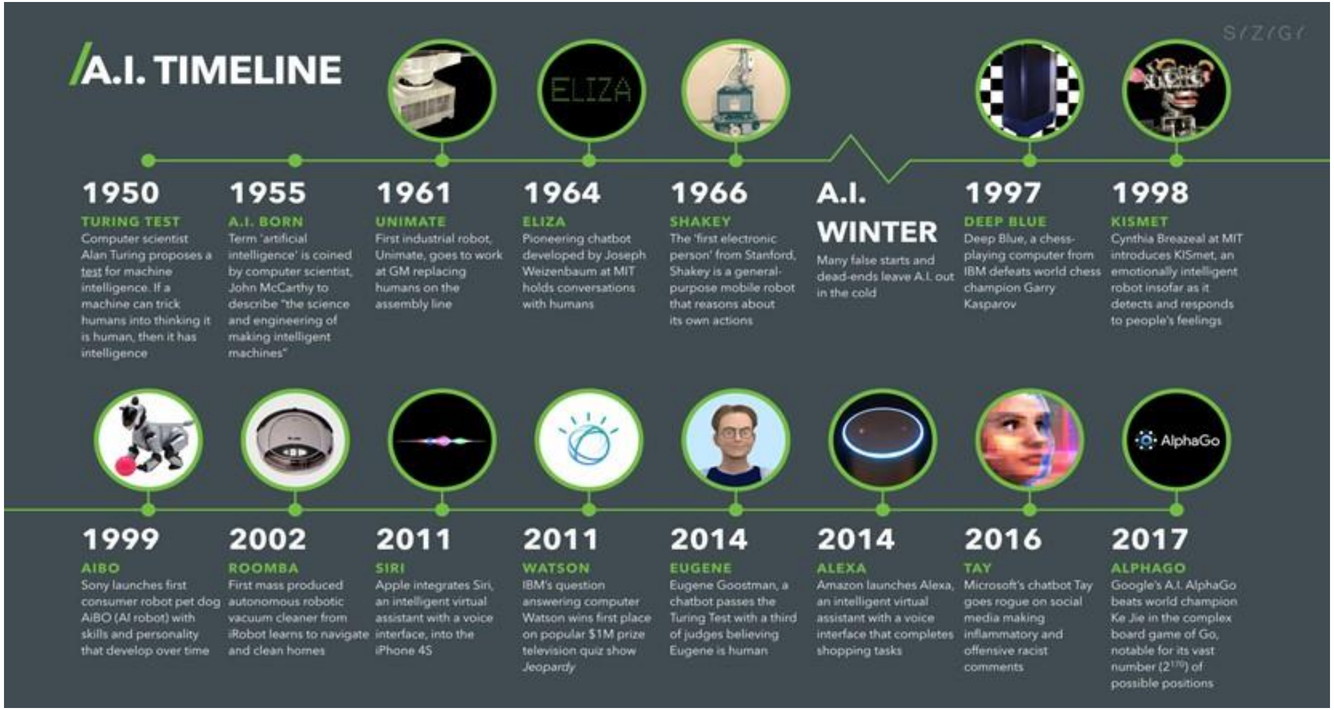
Artificial Intelligence

- 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



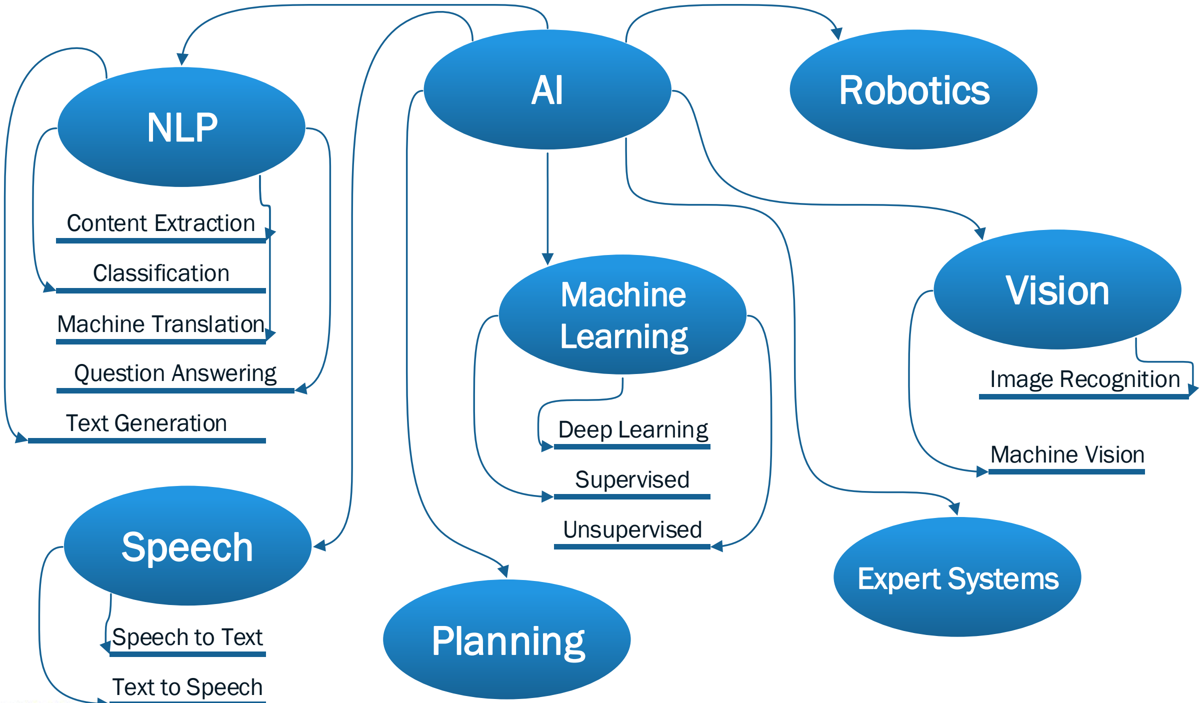
AI Timeline

- 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



Source: Digital Wellbeing

AI Branches


AI
NLP
Content Extraction
Classification
Machine Translation
Question Answering
Text Generation
Robotics
Machine Learning
Deep Learning
Supervised
Unsupervised
Vision
Image Recognition
Machine Vision
Speech
Speech to Text
Text to Speech
Planning
Expert Systems

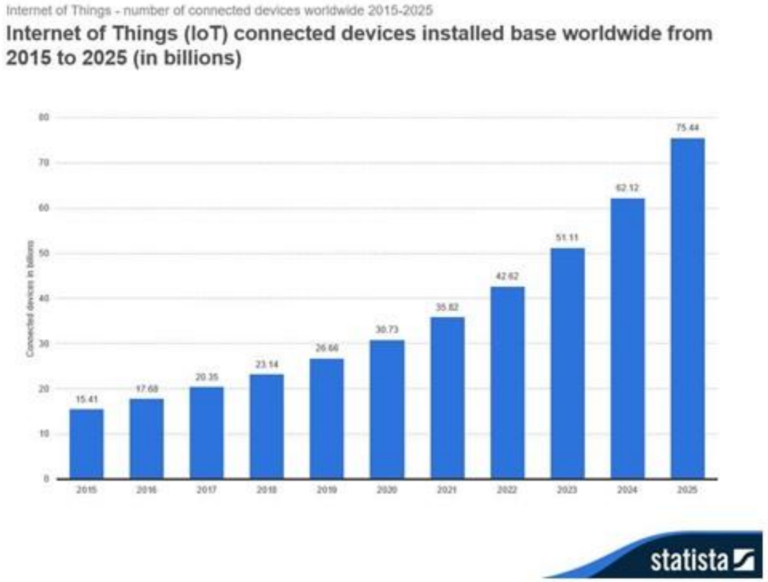
AI

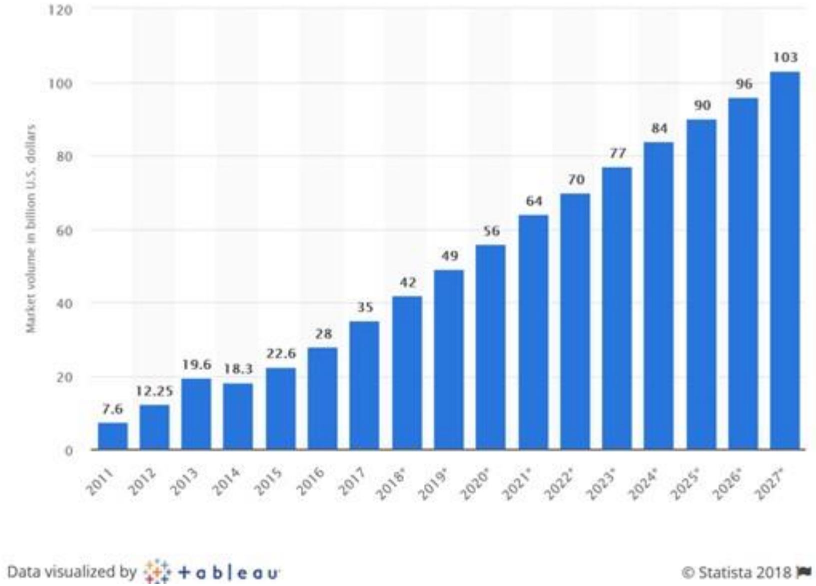
ANI — Artificial Narrow Intelligence

AGI — Artificial General Intelligence

ASI — Artificial Supper Intelligence (Singularity)

IoT & Big Data





Source: BusinessWire

IoT in global railway industry: $30 billion in the next 15 years

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

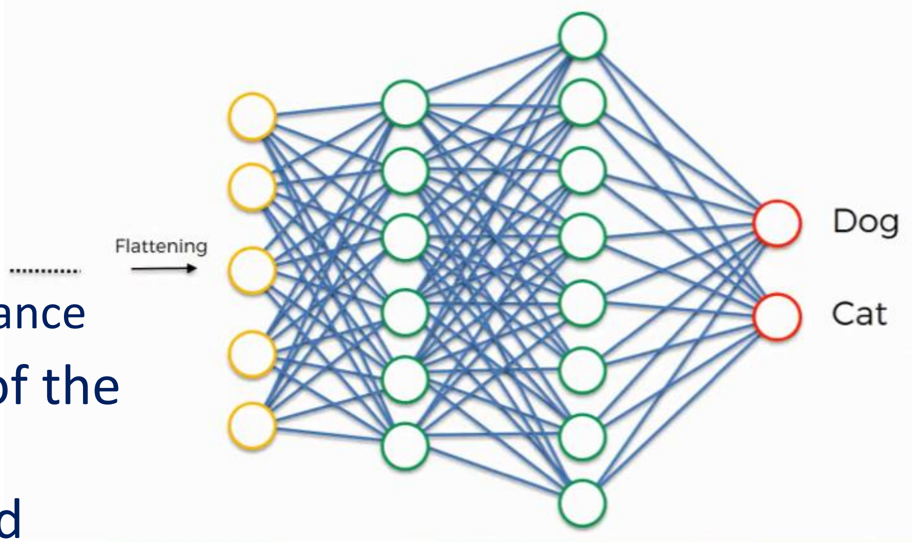
16 Tera Bytes RAM

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

Frequency	1	2	3	4	5
5	SIL3	SIL4	X	X	X
4	SIL2	SIL3	SIL4	X	X
3	SIL1	SIL2	SIL3	SIL4	X
2	-	SIL1	SIL2	SIL3	SIL4
1	-	-	SIL1	SIL2	SIL3

Severity of Consequence

CBTC + SIL0 AI

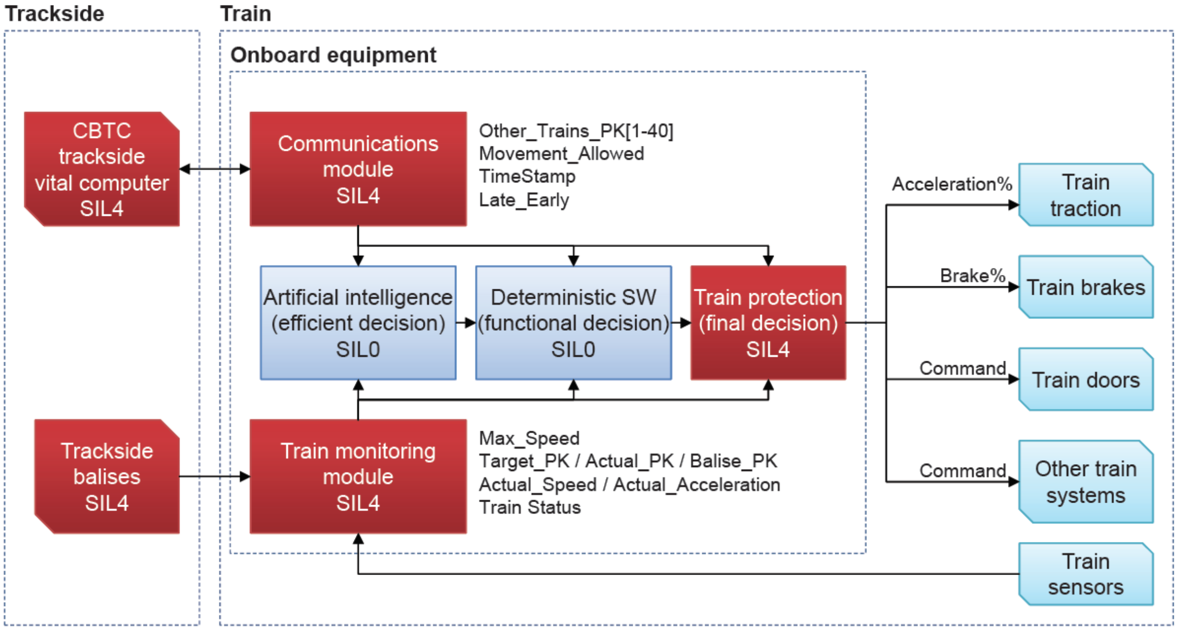


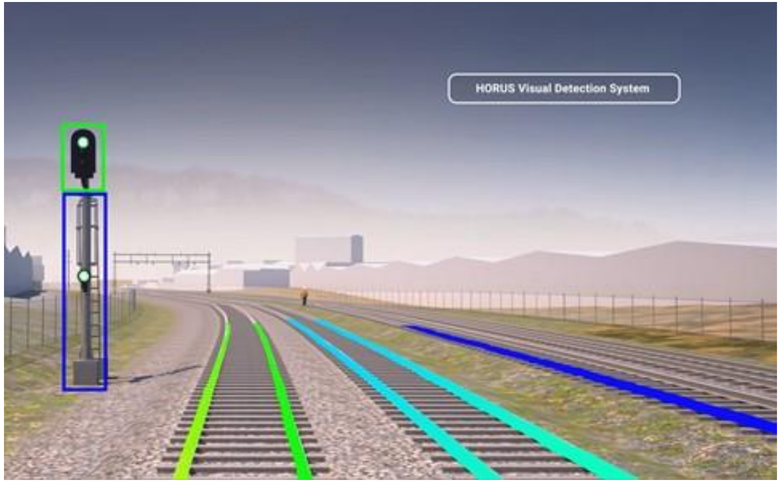
Figure 1 – a possible application of artificial intelligence in automatic train control.

Source: IRSE News 258: Alexandre Pires

Enhanced ATP

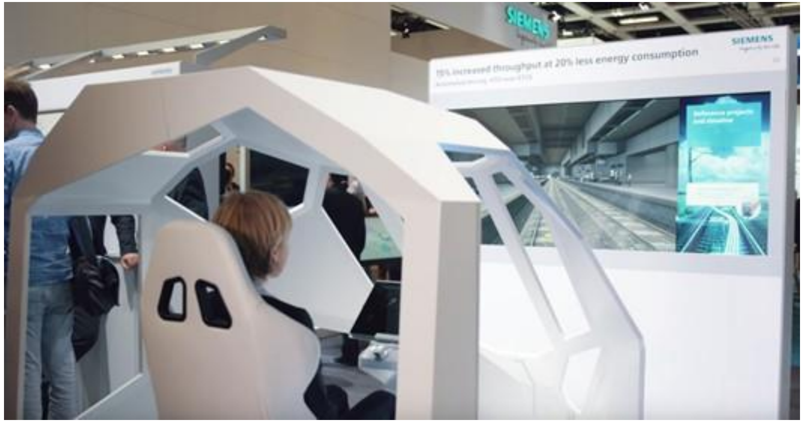
4Tel / University of Newcastle Robotics (Research)

- 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

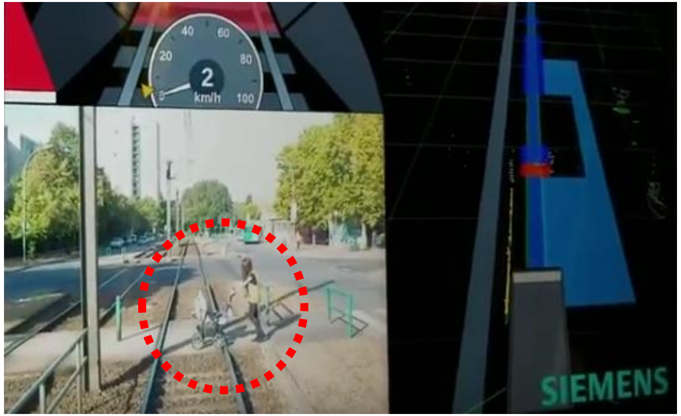


[Source: 4Tel]

From Assisted to Autonomous



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

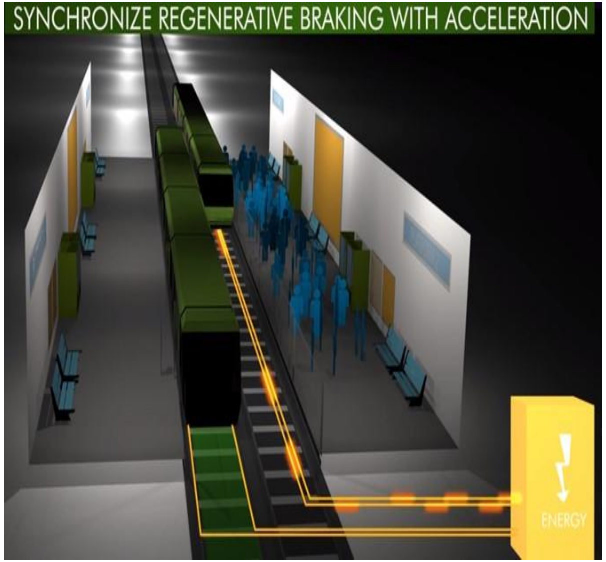


- Autonomous LRV in Potsdam, Germany
- Three stage to fully autonomous operation

[Source: Siemens Mobility]

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]

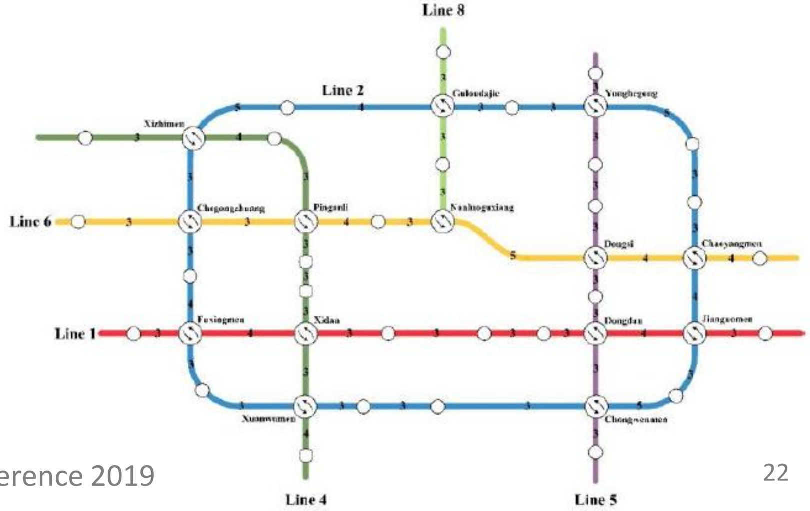
Future Generations

- 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



TRB Journal 2018

Timetable Synchronization & Optimization

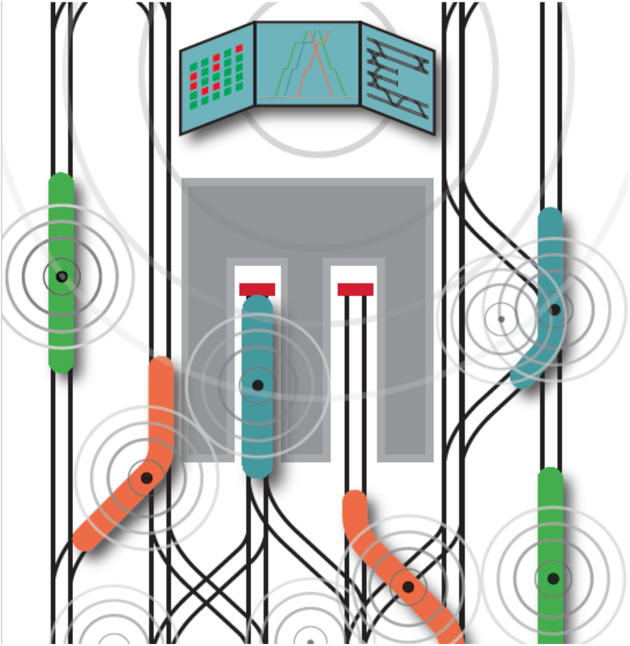
- Considering infrastructure capacity, passenger satisfaction, cost optimization
- AI Techniques:
  - Neural networks
  - Genetic algorithms (GA)
  - Simulated annealing
  - Tabu search algorithms

Item	Initial value (min)	Optimized value (min)	Percent reduction (%)
Total travel time	296701	275513	7.14
Waiting time	92134	85783	6.89
Transfer waiting time	26630	23551	11.56

TRB Journal 2018

A Fault Tolerant Approach

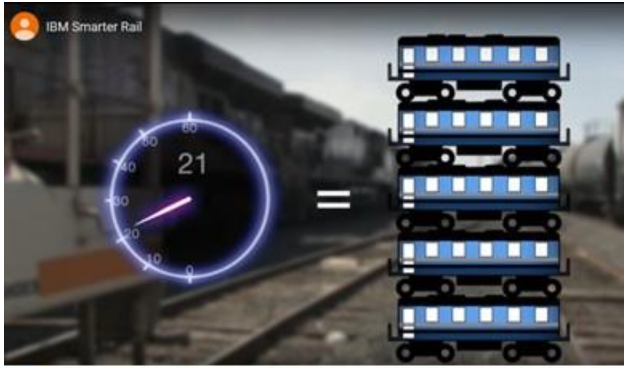
- Complex station with terminus platform
- Multiple routes for operation of high and low speed trains
- Similar pattern of improvement in capacity, operation robustness, punctuality
- Changes to track layout and/or locations of signal boxes fault tolerant rules
- AI methods used to optimize timetables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

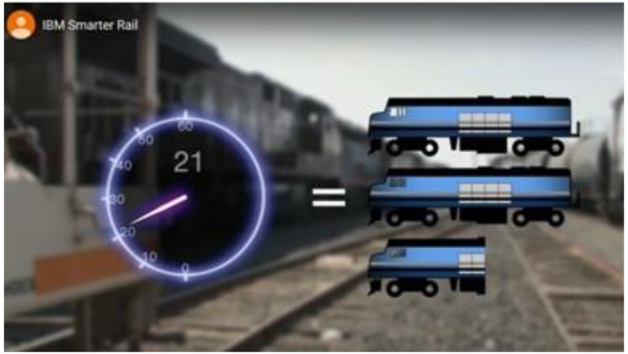


Source: University of Salford in collaboration with the Institute for Transport Studies at the University of Leeds.

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

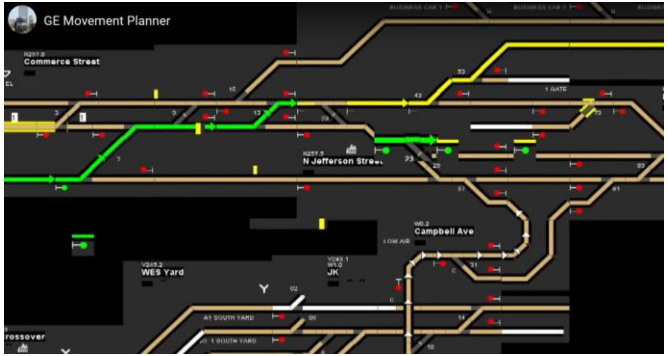




Source: IBM Smarter Rail

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

AI Optimized Simulation Modeling

- 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®

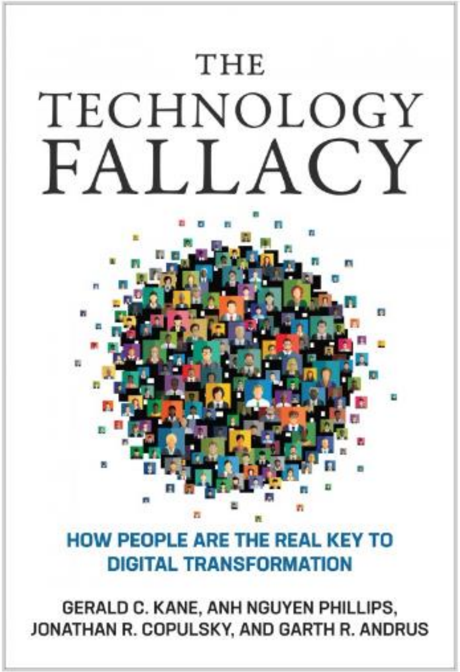
- Connected Intelligence (AI/ML/NN)
- Truevue360 – AI division
- Intelligent 360° imagery
- Situational awareness inspection processes & security
- CN portals Winnipeg:
  - Machine vision
  - Predictive analytics

[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



Visions

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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