AI, IoT in Railroads

Sanjay P Samuel
Corridor Design Manager
Sound Transit – Seattle, WA

IEEE Internet of Things (IoT) Vertical and Topical Summit at RWW2021, January 16th 2021
Railroad History

- Rail in USA

IEEE Internet of Things (IoT) Vertical and Topical Summit at RWW2021, January 16th 2021
What is Artificial Intelligence (AI)?

• According to the father of Artificial Intelligence John McCarthy, it is “The science and engineering of making intelligent machines, especially intelligent computer programs”.

• Artificial Intelligence is a way of making a computer, a computer-controlled robot, or a software think intelligently, in the similar manner the intelligent humans think.

• AI is accomplished by studying how human brain thinks, and how humans learn, decide, and work while trying to solve a problem, and then using the outcomes of this study as a basis of developing intelligent software and systems.
Time Line of Artificial Intelligence

1950
Turing Test
Computer scientist Alan Turing proposes a test for machine intelligence. If a machine can trick humans into thinking it is human, then it has intelligence.

1955
A.I. Born
Term “artificial intelligence” is coined by computer scientist John McCarthy to describe “the science and engineering of making intelligent machines.”

1961
UNIMATE
First industrial robot, Unimate, goes to work at GM replacing humans on the assembly line.

1964
ELIZA
Pioneering chatbot developed by Joseph Weizenbaum at MIT holds conversations with humans.

1966
SHAKEY
“First electronic person” from Stanford. Shakey is a general-purpose mobile robot that reasons about its own actions.

1977
WINTER
Many first startups and new ideas leave A.I. out in the cold.

1997
DEEP BLUE
Deep Blue, a chess-playing computer from IBM defeats world chess champion Garry Kasparov.

1998
KISMET
Cynthia Breazeal at MIT introduces Kismet, an emotionally intelligent robot mimics as it detects and responds to people’s feelings.

1999
AIBO
Sony launches first consumer robot pet dog AIBO (All robot) with skills and personality that develop over time.

2002
ROOMBA
First mass produced autonomous robotic vacuum cleaner from iRobot learns to navigate and clean homes.

2011
SIRI
Apple integrates Siri, an intelligent virtual assistant with a voice interface, into the iPhone 4S.

2011
WATSON
IBM’s question answering computer Watson wins first place on popular $1M prize television quiz show Jeopardy!

2014
EUGENE
Eugene Goostman, a chatbot passes the Turing Test with a third of judges believing Eugene is human.

2014
ALEXA
Alexa launches Alexa, an intelligent virtual assistant with a voice interface that completes shopping tasks.

2016
TAY
Microsoft’s chatbot Tay goes rogue on social media making inflammatory and offensive racist comments.

2017
ALPHAGO
Google’s A.I. AlphaGo beats world champion Ke Jie in the complex board game of Go, notable for its vast number (2^{172}) of possible positions.

IEEE Internet of Things (IoT) Vertical and Topical Summit at RWW2021, January 16th 2021
Branches of Artificial Intelligence
What is The Internet of Things (IoT)

- The Internet of Things (IoT) describes the network of physical objects—“things”—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet.

- Recently, industries have used machine-to-machine communication (M2M) to achieve wireless automation and control. But with the emergence of cloud and allied technologies (such as analytics and machine learning), industries can achieve a new automation layer and with it create new revenue and business models.

- IIoT is sometimes called the fourth wave of the industrial revolution, or Industry 4.0.
IIoT in Railroad

- Information Systems
- Train Control Systems
- Energy efficiency Systems
- Smart Infrastructure Systems
- Predictive Maintenance Systems
IIoT in Railways

IEEE Internet of Things (IoT) Vertical and Topical Summit at RWW2021, January 16th 2021
Internet of Smart Trains

IEEE Internet of Things (IoT) Vertical and Topical Summit at RWW2021, January 16th 2021
Systems monitored in a train
Where are we today with our technology?
AI & IIoT in Railways:

- Smarter / More Sustainable Trains
  - Trip Optimizer
  - Locotrol Distributed Power
  - Railyard Planner
    https://youtu.be/3J6pec_AEmA
  - PTC & CBTC
  - Digital Twin

- Predicting Delays and Service Disruptions
  - Movement Planner
    - Predicts patterns in train traffic
    - Increases railroad capacity, velocity and efficiency
    - Condition Monitoring - Predictive Maintenance Reduced Time / Cost

- Faster and More Flexible Manufacturing/Testing
- Cognitive Technologies – Responsive - Agile
Positive Train control- PTC

- Positive Train control (PTC) is advanced technology designed to prevent accidents by errors such as over speed conditions or running red-light.

- Three Components of PTC Systems:
  - Wayside/Track Systems
  - Onboard Equipment
  - Office Servers
  - Wireless and ground-based communication systems tie each together
Two-way communications-based PTC system
Communications Based Train Control- CBTC

- Communications-based train control is more expansive variant of an overlay-type system. It is a sophisticated computer-aided dispatching framework which requires train information to be sent to a central location, which then disseminates the information to all entities in the network through:
  - Speed optimization
  - Intelligent scheduling
  - 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
Communications Based Train Control - CBTC
CBTC Control Room

IEEE Internet of Things (IoT) Vertical and Topical Summit at RWW2021, January 16th 2021
Digital Twin is most commonly defined as a software representation of a physical asset, system or process designed to detect, prevent, predict and optimize through real time analytics to deliver business value.

Digital Twin can help across three core areas:
- Network
- Process
- Asset
Digital Twin

- General Electric, offered rail companies a suite of software applications to create, maintain and leverage digital twins both for trains (engines and carriages) and for the infrastructure.

- Adoption of Digital Twins can lead to decreasing maintenance cost moving to proactive maintenance, that is not just cheaper since it can be planned, it also avoids downtime and recovery cost.

- Possibly even more important, coupling trains digital twins with the infrastructure digital twins it becomes possible to detect wear in the rails, loose ballast and track gouge deformation.

- It is not just detection! Once a problem is detected, the infrastructure digital twin(s) (the application controlling it, based on machine learning and artificial intelligence) can communicate the problem to the train digital twin that in turns send the instruction to activate the breaks, reduce speed or even stop.
Digital Twin of a Locomotive

- Why “Twin” a Locomotive when I have a working one.
  - ‘Twin’ a locomotive to ensure reliability, resale, and efficiency.
  - A good digital twin can tell us valuable information of the locomotive inside as well as outside.
  - Twins will offer real-time moments of use and inform us of speed, brake temperature, vibration, heat, precipitation, track incline, fuel consumption per mile/per ton, tractive effort, and more.
Actual and “Digital twin” Train’s view in software:
The process involved in developing a digital twin train

- Mathematical model of the locomotive.
- Mathematical model of the Train and its Trip
- To predict the characteristics of the Train and its car
- Predicts the desired route, travel time, weight of the train, speed limits, construction zones
How to design digital twin for existing rail network?
Digital Twin for Network

- ROUTE
- HEALTH INDEX

- TRACK
- HEALTH INDEX

- RAILS
- HEALTH INDEX

- BALLAST
- HEALTH INDEX

- GEOMETRY
- HEALTH INDEX

- WAYSIDE ASSETS
- HEALTH INDEX

- BRIDGES
- HEALTH INDEX

- CROSSINGS
- HEALTH INDEX

- SIGNALS
- HEALTH INDEX

---

- Hierarchy of the Railway network
- Health index roll-up for the whole Route
- Daily reports for Maintenance planning

---

https://trackinspection-dattaraj.run.aws-usw02-pr.ice.predix.io

IEEE Internet of Things (IoT) Vertical and Topical Summit at RWW2021, January 16th 2021
How to maintain and retire, these multi million-dollar infrastructure units including railroad tracks, locomotives, and rail cars
IIoT to monitor and control the electronics, heating, pneumatics, and power and tracking of systems
Prevent catastrophic train derailments with monitoring controlling devices
Sources:

- IHHA%20otts2011_Aronian.pdf
- Meteorcomm LLC, ETMS Wireless Network, 2011
- https://www.ge.com/research/sectors/transportation
- https://www.youtube.com/watch?v=3J6pec_AEmA&feature=youtu.be
Questions?

Thank you