Leveraging Digital Twins for Condition Monitoring in Railway Infrastructure

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Lucas Rocha

• Received a Master’s Degree in Multimedia from the University of Porto in 2022.

• Currently a student in the Doctoral Program in Informatics Engineering at the Faculty of Engineering of the University of Porto (FEUP).

• Researcher at the Digital and Intelligent Industry Lab (DIGI2), at the Faculty of Engineering of the University of Porto.

• Areas of research include digital twins, computer graphics, augmented reality and mixed reality.
Contextualization

First Industrial Revolution
- Mechanical manufacturing powered by water and steam

Second Industrial Revolution
- Mass production powered by electricity; division of labor

Third Industrial Revolution
- Information technology and electronics; greater automation

Industry 4.0 (Fourth Industrial Revolution)
- Internet of Things (IoT)
- VR & AR
- Cyber-physical systems
- Artificial Intelligence
- Big Data analysis
- Digital Twins
- ...

Motivations

- Optimization of service and maintenance
- Increase sustainability
- Increase rail transport competitiveness
Related Work

Approximated number of digital twin-related scientific publications per year

Adapted from Tao et al., (2019) and Lim et al. (2020)
Related Work

- Digital Twin: Manufacturing Excellence through Virtual Factory Replication (Grieves, 2015)
- Reengineering Aircraft Structural Life Prediction Using a Digital Twin (Tuegel et al., 2011)
- The digital twin of an industrial production line within the industry 4.0 concept (Vachalek et al., 2017)
- Digital Twin Shop-Floor: A New Shop-Floor Paradigm Towards Smart Manufacturing (Tao & Zhang, 2017)
- Development of a Generic Implementation Strategy of Digital Twins in Logistics Systems under Consideration of the German Rail Transport (Jeschke & Grassmann, 2021)
- Alstom Develops a Rail Network Digital Twin for Railway Yard Design and Predictive Fleet Maintenance (The AnyLogic Company)
Materials and Methods

Structure of the Digital Twin System Environment
Implementation – Railway Vehicle Digital Twin

- Mobile Dashboard – Main View
- Mobile Dashboard – History Graph View
Implementation – Railroad Infrastructure Digital Twin

Mobile Dashboard – Main View

A velocidade máxima neste trecho é de 120 km/h
Evaluation Method

- Online survey based on five-value Likert scale method
- Five Likert statements + text field for feedback
- Survey sent to project partners

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<thead>
<tr>
<th>#</th>
<th>Statement</th>
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<tbody>
<tr>
<td>S1</td>
<td>The user interface of the prototype is, in general, intuitive and easy to interact with.</td>
</tr>
<tr>
<td>S2</td>
<td>The data on the damage indicators is presented in a clear and understandable way.</td>
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<tr>
<td>S3</td>
<td>The data shown by the history graph of the damage indicators is presented in a clear and comprehensible manner.</td>
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<tr>
<td>S4</td>
<td>If employed in a real-world context, the proposed prototype would be useful for supporting the monitoring of the conditions of rail transport vehicles.</td>
</tr>
<tr>
<td>S5</td>
<td>If employed in a real-world context, the proposed prototype would be useful for supporting preventive maintenance.</td>
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Results

<table>
<thead>
<tr>
<th></th>
<th>Respondent 1</th>
<th>Respondent 2</th>
<th>Respondent 3</th>
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<tbody>
<tr>
<td>S1</td>
<td>5</td>
<td>4</td>
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Main issues raised by feedback:

• Confusing placeholder text on launch
• Touch selection not clear enough
• Navigation along the history graph not clear enough
• Use of continuous lines instead of broken lines in the history graph
Conclusion and Future Work

- Greater understanding of the potential of digital twins for rail transport operations
- Improvement: User-generated alert notices
- Improvement: Real-time display of data on vehicle location
- Future Work: Explore the potential of other Industry 4.0 technologies for rail transport operations
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