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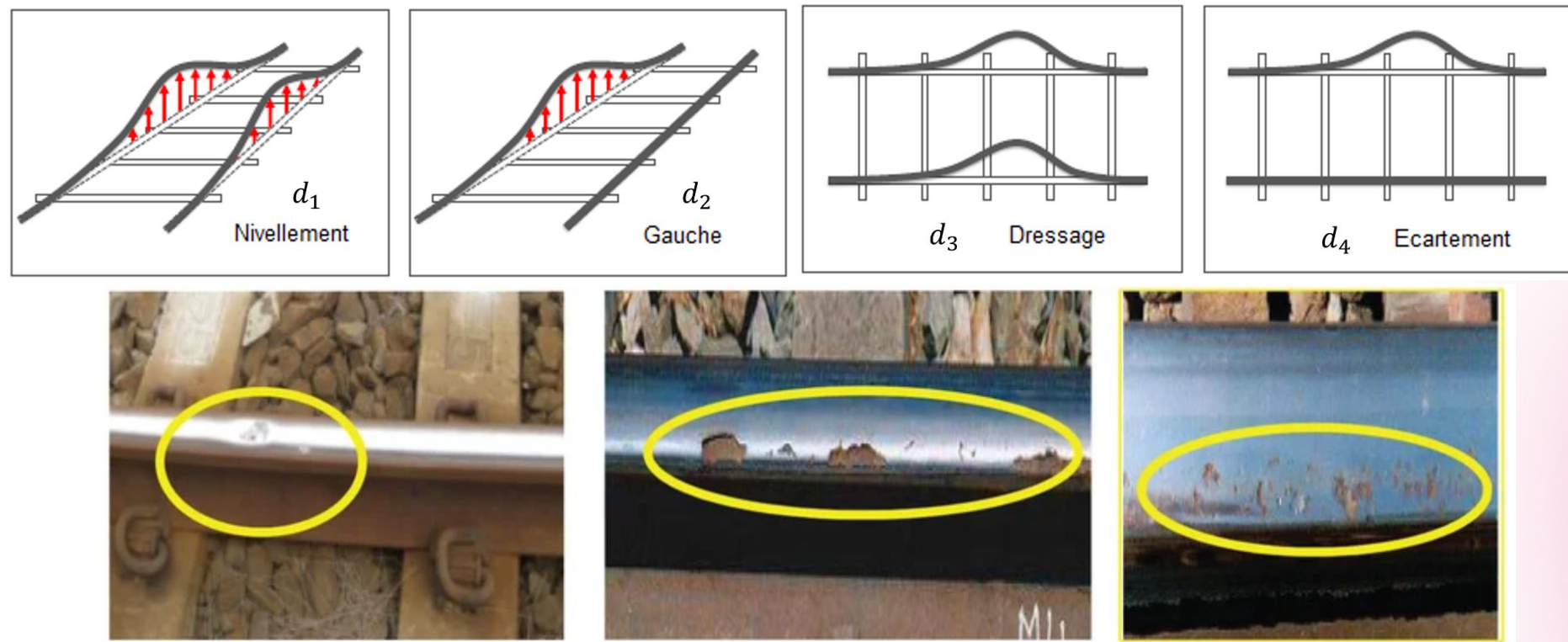


**Open Synthetic Simulation for Railway Defect Detection:  
Parametric Modeling and Texture Extraction from Real Imagery**

Project n° 10

# 01

## Context – Background Information



- **Track Sentry Vision (TSV):** Developing a low-cost, autonomous system for detecting railway defects.
- **Data Requirements:** Reliable detection algorithms need large, annotated datasets, which are costly to obtain (if available).
- **Missing Defect Data:** Surface faults are well documented, but critical track geometry deviations are missing from public datasets.
- **Closed Ecosystems:** Inspection data kept private, existing simulation tools are proprietary and closed.

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## **Context – Proposed Solution & Implementation**

- **Open Digital Twin:** Building an open-access 3D simulation of railway infrastructure using open-source data.
- **Two-Part Methodology:** Combining parametric 3D track modeling with texture extraction from real photographs.
- **Physical Accuracy:** Simulating realistic material properties instead of using generic textures.
- **Synthetic Output:** Generating varied, fully annotated video sequences of defective tracks to train diagnostic systems.

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## Founding Team

- **Augustin Crespin** ([augustin.crespin@uclouvain.be](mailto:augustin.crespin@uclouvain.be))
  - *Institution:* UCLouvain
  - *Expertise:* Constraint Programming, Neurosymbolic AI
- **Ioannis Kostis** ([ioannis.kostis@uclouvain.be](mailto:ioannis.kostis@uclouvain.be))
  - *Institution:* UCLouvain
  - *Expertise:* Computer Vision, Generative AI, Multimodal Learning
- **Tanguy Vansnick** ([tanguy.vansnick@umons.ac.be](mailto:tanguy.vansnick@umons.ac.be))
  - *Institution:* UMONS
  - *Expertise:* Visual Data Processing, Deep Learning-based Feature Extraction, Large-Scale Data Management

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## Work Plan

- WP1: Parametric 3D Modeling (WD 1-5)
  - **Define Specs:** *Establish standard track geometry.*
  - **Build Assets:** *Create parametric track models in Blender.*
  - **Add Geometry Defects:** *Inject track alignment and sleeper deviations.*
- WP2: Texture Extraction (WD 6-7)
  - **Segment Images:** *Isolate materials from real photos using Foundation Models.*
  - **Extract Textures:** *Generate tileable PBR maps.*
  - **Establish Baseline:** *Compile a baseline material database.*
- WP 3: Integration & Packaging (WD 8-10)
  - **Apply Materials & Defects:** *Map PBR textures to 3D geometry and simulate surface flaws in the shader*
  - **Render & Annotate:** *Generate validation scenes with automatic ground-truth labels.*
  - **Package Library:** *Deliver the open-source Python tool.*
  - **Dataset Preparation:** *Organize rendered data for downstream model training.*

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## Expertise Sought

- **Parametric 3D Modeling:** *Build procedural track geometry and inject structural defects.*
  - Procedural 3D Modeling: *Building adjustable, script-driven track components in 3d modeling software like Blender.*
  - Precision Modeling: *Accurately translating real-world technical (railway) specs into exact digital geometry.*
- **Texture Extraction:** *Segment real photos to extract PBR texture maps.*
  - Applied Computer Vision: *Using AI foundation models (e.g. SAM) to automatically isolate specific materials from field photos.*
  - Physically-Based Material Synthesis: *Modeling light interaction with complex materials (e.g., oxidized steel, weathered concrete) to generate physically accurate surface textures.*
- **Integration & Packaging:** *Automate annotated renders and package an open-source library.*
  - Python Automation: *Writing scripts to automatically generate varied defect scenes and extract ground-truth labels.*
  - Software Engineering: *Structuring the final workflow into a documented, reusable open-source Python library.*

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