Towards validation and verification of an autonomous railway inspection and repair system

I. Durazo-Cardenas[1], A. Starr, T. Tomiyama

Cranfield University, School of Aerospace, Transport and Manufacturing

Cranfield, Bedfordshire. MK430HT

Abstract

A new concept for railway autonomous inspection and repair is being developed for the UK's national railway. The new system aims at reducing human interventions at highly hazardous locations such as tunnels; while simultaneously inspecting and repairing rail components autonomously. It is envisioned that the new system will be deployed using a robotic arm mounted on a road-rail vehicle.

Different routes for verification and validation at different levels are being evaluated. In the first level, the new system concept design will be validated by breaking it down into sublevel components and individually assessing integration, interfacing and structure. A second level will use a "digital twin" approach to simulate appropriate outputs for the tests, e.g. simple I/O for sub-systems and if appropriate, extended work into three-dimensional views. Finally a third lower level will validate and verify the inspection capability and its robotic arm interfacing, using a combination of modelled data and part inspection measurements.

1. Introduction

The term "rail robot" or "tunnel robot" has been used to summarise a new concept of a device which investigates faults with a high degree of autonomy, and uses its own tools and materials to effect repair. The Railway Inspection and Repair System (RIRS) concept proposes an autonomous vehicle which can perform inspection and maintenance tasks in the UK national railway. It is envisioned that the new system will use a robotic arm mounted on a road-rail vehicle.

This new tunnel robot will reduce human interventions at highly hazardous locations, potentially saving lives. Additionally, higher network availability is expected by virtue of its autonomous inspection and repair capability. Due to its national importance, the system's validation and verification (V&V) (Durst et al., 2017) must be formally conducted.

1.1. Aims & Objectives

Aim: Formal verification and validation of the RIRS system architecture, operating system and inspection subcomponents. The objectives are:

- Define customer's operational need and design specification, and tailor work programme.
- Verification and validation: ensure that the system meets design specifications and operational needs.
- Create platform for simulation and laboratory trials for V&V.

2. Method

2.1. Definitions: Stakeholder workshops will be conducted to discuss and agree the following.

a) Needs: the customers' requirements for a working system.
b) Specification: design details, software interfaces, standards and regulations.
c) Tasks: iteration and revision of the detailed work activities for the V&V.

2.2 Laboratory based testing

Methods for simulation and laboratory testing will be prepared in detail, to assess the behaviour of the sub-systems themselves.

[1] Corresponding author: i.s.durazocardenas@cranfield.ac.uk, Tel: 01234750111

- Interfaces: Operator, Ellipse system, Rail defect management system, Signalling, Command & control link, Railway system and Maintenance system.
- Structure Vehicle system: Payload, Vehicle system platform, Vehicle system manager.
- Structure Command and control system: Support & maintenance, Task planning and management, Communications and Operator workstation.
- Inspection method: capability, probability of detection.

Later, the behaviours of the interaction of the sub-systems together will be assessed.

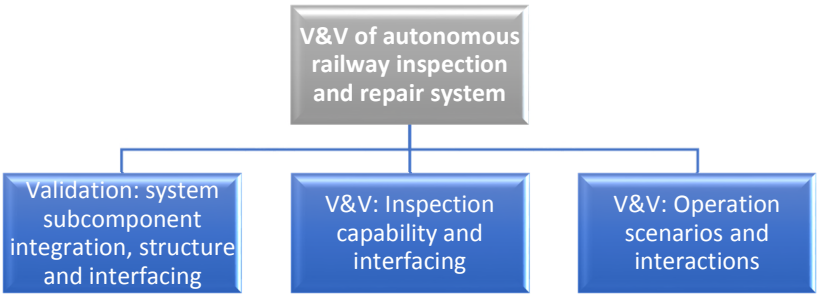

Figure 1 Validation and verification outline for autonomous railway inspection and repair system

3 Validation and verification

Outputs from stages 2.1 and 2.2 will be systematically compared with the requirements definitions and specifications from 1.1 to test each sub-system, and then the integration functions, for critical review of system effectiveness.

3.1 Simulations

A “digital twin”(Bradley and Hehenberger, 2016) will be used in a low-cost environment, based on an open-source platform to ensure future maintainability and portability, and also to benefit where possible from the open-source support community. The digital twin will be built in a hierarchical modular structure to meet the requirements of the selected sub-systems, offering flexibility and scenario development for study and planning of systems, and interaction between systems. The user interaction with the simulation is critical. Simulations will display appropriate outputs for the tests, e.g. simple i/o for sub-systems and if appropriate, extended work into three-dimensional views for whole vehicle behaviour with an option for an immersive environment to improve the effectiveness of:

- understanding how autonomous inspection and repair vehicles interact with their environment;
- training designers, developers and users to use a virtual reality simulation of the inspection and repair technologies

4 Conclusions

A new concept for railway autonomous inspection and repair is being developed for the UK’s national railway. Several routes to validation and verification are being proposed, from concept design and subcomponent integration, as well as interfacing to the modelling of scenarios and system response. At a lower level, V&V is also conducted for the robot detection capability and uncertainty characterisation.

References:

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