Workshop summary: "Generative AI in inspection and maintenance (I&M): Learnings across sectors, low-hanging industry use cases, and future challenges and opportunities"

1 Introduction

In the following we summarize the main findings from a workshop titled "Generative AI in inspection and maintenance (I&M): Learnings across sectors, low-hanging industry use cases, and future challenges and opportunities". The workshop was held in connection with ADRA Forum 2024 on 5 Nov., in Eindhoven, the Netherlands. The summary is written by Aksel A. Transeth and Ahmed Mohammed, SINTEF.

Presentations from the workshop can be found via this link:
https://drive.google.com/drive/folders/15ugqSyeI3ql1X22I5LFMjtE0gLWHRDWF?usp=sharing

The workshop was organized by the topic groups on inspection and maintenance (I&M) in ADRA and euRobotics, the RIMA Alliance, as well as other organizations and projects[1]. Further information about the workshop can be found here: https://www.sintef.no/en/events/generative-ai-in-inspection-and-maintenance-im-learnings-across-sectors-low-hanging-industry-use-cases-and-future-challenges-and-opportunities/

2 Demonstrated Capabilities and Limitations of GenAI for I&M, and high-impact use cases

Three **main types of infrastructure** in the industry and public sector, and there is a large variety in terms of form factor etc:

1. Assets and equipment: Pressure vessels, ship hulls, hydro turbines, flare stacks, aquaculture net cages, generators, pipe bends, storage tanks, …
2. Plants and areas: Electrical substations, offshore/onshore O&G platforms, harbors, nuclear facilities, power stations, buildings, airports, quay walls, …
3. Long-distance / linear: Rail infrastructures, tunnels, bridges, dams, waterways, drinking water networks and installations, power lines, …

Which problems needs to be solved in the industry which GenAI can assist in? **High-impact use cases.**

- **Change management is a key challenging in introducing new technologies such as AI and robotics in organizations.** Easy and intuitive use of new technologies is crucial to facilitate integrating the new technologies and establishing the new work processes possibly needed by such technologies. Natural language interaction with the new technologies (e.g., field robots for inspection) through LLMs and voice commands can be key to enable the easy and intuitive interfaces needed to facilitate change management. Interaction via voice (between

[1] The workshop program is organized as collaboration between the ADRA topic group on inspection and maintenance, the GenAI4EU initiative, the RIMA Alliance, the euRobotics topic group on Inspection and Maintenance, the JARVIS EU project (GA no. 101135708), Nemonoor, and the NAINE and RINVE network.
The workshop organizers are Aksel A. Transeth (SINTEF – coordinator of ADRA topic group on I&M, chair of the RIMA Alliance, coordinator of the euRobotics topic group on I&M and the RINVE network), Thomas Vögele (DFKI – co-chair of the RIMA Alliance), Ebert van Vonderen (TUKE – secretary of the RIMA Alliance), Kirill Safronov (KUKA), and Ahmed Mohammed and Magnus Bjerkeng (SINTEF).

human personal) is an important part of today's I&M operations and such interaction with robotics, data and AI can therefore ease change management.

- **Coding and simulator development takes time**, and GenAI is already speeding up these processes. Current industry use of GenAI include assistance in code generation and simulation / visualization generation – i.e., making such tasks easier for engineers.
- There is **a lack of data for training** machine learning models. E.g., to have data from different conditions (weather-specific, fog, night/day, turbidity under water, etc.). Foundation models are typically trained on everyday objects, and training data for industry-specific objects and phenomena (e.g., defects such as corrosion, cracks, etc.) is lacking. There is a need to produce training data for I&M-specific task (defect detection, predictive maintenance, etc.). The industry is starting to look into using GenAI for generating training data for machine learning models (e.g., for object detection and localization). E.g., Using ControlNet to maintain annotation labels, reducing labeling costs. Some has explored unsupervised learning with foundational models like Generative AI.
- **Labelling of data** for training machine learning models is time consuming and thus costly. GenAI can support by auto-labelling data, and simulated data can be automatically labelled.
- **High impact use cases include, e.**g.,
    - **Go beyond the capabilities of current (manual) inspections and other operations** through robotics and **automatic analysis of data** from, e.g., infrared cameras, visual/lidar, directional microphones, etc.
    - There are stronger **regulatory requirements**: E.g., all fugitive gas leakages in the industry i the EU may need to be reported.
    - **Predictive maintenance:** Predict the "health" of infrastructure to, e.g., assess expected lifetime and need for maintenance.
    - Germany needs to rebuild 4,000 bridges due to insufficient inspections during life span. They are considering using drones and ground-penetrating radar to improve inspection processes.
    - Two robots are permanently installed at a bridge in Genova, Italy, for inspection and cleaning. While they proved effective, civil engineers are reluctant to rely on them fully.
    - There are lots of other use cases. E.g., a use case for Canon printers was discussed, where the system can suggest fault causes based on the hardware design and incorporate user feedback to improve diagnostics.

It is important to highlight **value generation** (e.g., reduced costs, improved safety, improved uptime of assets, etc.) in connection with use cases and technology development.

3 Research, Development, and Innovation Challenges to Boost European Competitiveness for GenAI in I&M

Main relevant research areas going forward in I&M

- **Defect and anomaly detection**: Automatic data analysis for anomaly/defect detection, possible multi-modal when needed. Anomaly detection in changing environments (e.g., different weather conditions)
- **Provide more high-quality data**: Automatic generation of training data to produce simulated/modified data with, e.g., diffusion models. Current challenges also includes that, e.g., GenAI can generate non-existent patterns, especially with recurring words or elements in input data.
- **Ease of use**: Intuitive user interaction to facilitate easy use of robots and AI for personnel not trained in robotics (e.g., inspection, maintenance, operations personnel). Provide textual descriptions to operators. Conversational user interfaces.

- **Ease of adoption**: Similar to “ease of use”, but also includes simplifying deployments, thus avoiding costly and time-consuming changes and adaption to robots between use cases.
- **Increased autonomy**: Agentic AI. Automated planning of operations. Combine data-driven and model-based approaches. Handle “edge cases” (e.g., different weather, abnormal situations at the facilities that the robot operate, etc.). Context-aware (better understand the environment and how to carry out operations). Eventually a full autonomy stack.
- **Understand the health of infrastructure and provide actionable information**: Methods for predictive maintenance to predict problems in advance. GenAI and Foundation models give, e.g., the possibility to process a very large amount of data and extract trends and knowledge.
- **Validation and verification of autonomous functionalities** (e.g., automatic defect detection). Build trust in results from automated analysis of inspection data.

Overall challenges

- Address robustness issues in GenAI applications.
- Be better: increase efficiency, capabilities, etc. to go far beyond capabilities of human operators.
- Reduce costs associated with data labeling and improving adaptability to varying conditions.
- Enhance trust and acceptance of AI and robotic systems in inspection and maintenance. Trust and acceptance of robots remain too low despite their ability to detect issues more accurately than humans.