Major themes within inspection and maintenance (I&M) robotics

Contact person for this document: Aksel.A.Transeth@sintef.no, coordinator for the euRobotics topic group on inspection and maintenance robotics.

Introduction

In this short memo we describe major themes of inspection and maintenance (I&M) robotics through specifying:

1) Main use case categories for I&M robotics
2) Main challenges which cut across the various use cases and need to be solved in order to enable more commercial and full-scale use of I&M robotics.

The use cases and challenges are identified from a range of application areas and markets for I&M robotics including water supply and sanitation, energy generation and distribution, oil and gas, chemical industry, aquaculture, maritime, nuclear, transportation, cargo, mobility, as well as civil infrastructure such as that associated with cities.

The content of this document is based on input from the member of the euRobotics topic group on I&M robotics.

Note: The words “robot” and “robotics” refer to all types of physical robots, i.e., robot manipulators, unmanned vehicles (land, underwater, air, ..), …. “Software robots” such as chatbots etc. are not included.

Use case categories

Robot operations within the below-mentioned use case categories include close-up and general inspection, monitoring, cleaning, surface treatment (painting, sand-blasting, etc.), and other intervention operations (such as valve-turning, subsea hot-stab operations). The complexity significantly increases when moving from non-contact to contact-based operations. Operations in confined spaces also impose challenges. To this end, most commercial I&M robotics today concerns inspections. However, some intervention operations such as cleaning and surface treatment are also starting to become more commonplace.

Use Case category 1: I&M of industrial assets & equipment

Scope: Inspection and maintenance of industrial assets & equipment. Such assets include, e.g., pressure vessels, tanks, ship hulls, hydro production turbines, wind turbines, gas-/ steamturbines, flare-stacks, aquaculture infrastructure (e.g., net cages), generators and specific components on assets e.g., pipe bends etc. This category also includes I&M of trains and other assets. Robots are currently typically deployed and retrieved by humans (as opposed to being “resident”).

Use Case category 2: I&M of plants and infrastructure areas

Scope: Inspection and maintenance including plant surveillance and remote operation with robots at industrial plants, larger unstructured areas with assets and general infrastructure on-shore and offshore such as electrical substations, offshore O&G platforms, onshore O&G facilities, harbors, subsea facilities, nuclear facilities, power stations, buildings, airports, quay walls, etc. “Resident” robots for I&M are in some cases also highly relevant for emergency handling operations as first responders.

Use Case category 3: I&M of long-distance infrastructure

Scope: Inspection and maintenance of long-distance infrastructure such as rail infrastructures, tunnels, bridges, dams, waterways, drinking water networks and installations, power lines etc. Emergency handling such as identifying trees fallen over power lines or providing an overview of areas close to roads and rail in connection with avalanches is also relevant for robot solutions for I&M of long-distance infrastructure.

Cross-use case challenges

Challenge 1: More sustainable deployments

Description
The overall challenge is to move from one-off tests, demonstrations and deployments and thus increase both the number of and sustainability of long-term deployments of I&M robotics with the introduction of new technology and new operational models.

Why is addressing this challenge important?
The industry needs deployments of I&M robotics for suppliers to sell their products and services, and end -users to benefit from robotics. Moreover, increased deployments can lead to increased need for R&D and education on I&M robotics through identification of R&D challenges, etc..

Challenge 2: Standards, verification and validation (V&V)

Description
How can we ensure that a robot will operate safely, reliably and efficiently? And how can we do this even if the robot has some degree of autonomy? What standards should a robot system adhere to - both in terms of the robot as a sensor and actuation platform, and as a tool for analysis of robot-enabled data.

Why is addressing this challenge important?
End-users need to be convinced that the new robotic system will operate safely and reliably, and that the robots carry out tasks as expected. Suppliers need to know which standards to adhere to. Also, suppliers can benefit commercially from proving (through V&V) that their robots operate according to end-user specifications.

Challenge 3: Robustness and reliability

Description
Robustness and reliability of several aspects of robotics:

- Robots that can operate for long periods of time (months) without being attended by humans
- Robots that can operate in harsh environments (corrosive, warm, freezing, humid, snow, rain, explosive, …)
- Robots that can take the rugged treatment of human operators in the field.
- Robots that are robust and reliable when delivered as products to end-users.
- Robots that can operate with partial use of their navigation & control sensors (GPS denied environments, ..)
- Robots that can safely operate or shut down upon physical or cyber attacks (incl. spoofing, jamming, etc.)

Why is addressing this challenge important?

- Long-duration operations / “resident robots”: Allow for robots to be deployed at sites for long-duration time-periods (e.g., up to 6 months and more). Some facilities may have very difficult access (e.g., due to ice in the northerns areas, etc.). Resident robots could then ensure remote access to such facilities. Other considerations include; maintenance, potential biological growth (e.g. in underwater robots), ensuring same performance across seasons.
- Harsh-environment robots: Infrastructure in need of inspection and maintenance are placed in “all” types of environments from desert-like areas to freezing mountain areas, in corrosive facility atmospheres, in explosive environments, etc. Robots thus need to be able to operate there to provide I&M services.
- Rugged treatment: Infrastructure/plant operators are not researchers, they do not treat robots with care as a lab researcher would. They expect equipment to be rugged and take knocks and bumps without damage or electronics failing.
- Robust and reliable robots upon commercial deployment: Robots that do not meet end-user expectations in terms of robustness and reliability may lead to end-users trial, fail and lose confidence in robot technology.

Challenge 4: Integration

Description

This challenge encompasses integration of I&M robotics into both systems and operations, including, e.g., digital twins, plant management systems, work procedures, etc. Such integration is concerning both the physical operations with robots in terms of monitoring and controlling their movements, as well as integration of the data the robots gather.

Why is addressing this challenge important?

To fully realize the potential with I&M robotics the robots need to be an integrated part of operations and systems, and not an “extra” or “one-off” tool used in special circumstances.

Challenge 5: Mission-specific automatic data collection and analysis of robot-enabled data

Description

Mission-specific automatic data analysis of robot-enabled data in order to automatically detect, e.g., faults such as corrosion, pittings, cracks, etc. in the data gathered during inspection operations. A key challenge within this area is to achieve sufficiently high quality of the data analysis output such that the industry can accept this new approach as a full-fledged alternative to manual inspections. Moreover, ensuring that the quality of the data itself is high is also important.

Why is addressing this challenge important?

Robots collect a vast amount of data. Manual processing of all this data is both tedious and tiring for human inspection personnel. To this end, we need systems that can analyze the data automatically.

Other challenges relating to I&M robotics

- Intuitive human-robot interaction: Tele-/remote operation, keeping the operator in the loop, ...
- Robust autonomy: In terms of fault-detection, localization, collision avoidance, manipulation, and mobility. Robust perception (i.e. robust interpretation of sensor data) has been highlighted as a key challenge for enabling robust autonomy.