ESMERA CONSTRUCTION CHALLENGES

Maintenance of transport infrastructures (roads, railways) has a big impact on the quality of the service provided by transport operators, cost of operation and the safety of people and goods transported.

The robots that can support this activity can be operated/supervised by trained personnel and may be operating in hazardous, or extreme environments where people may be at risk. Therefore, certification and validation of operation will be important elements in the deployment of this type of robot system.

The current market size is not so high like in other sectors as reported in the 2018 IFR World Robotics report '*Annual sales units of all other categories of professional service robots are below 1,000 units: professional cleaning, demolition and construction robots,* ***inspection and maintenance*** *systems, rescue and security applications, underwater systems and mobile platforms in general use'*.

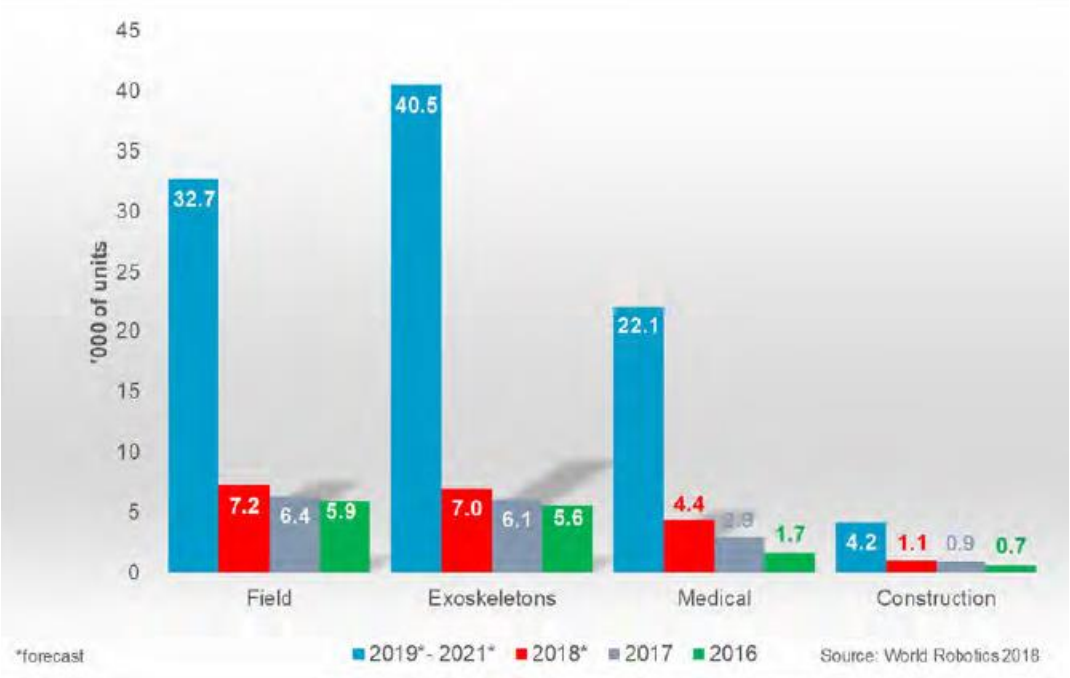

Figure 1. The distribution of service robots in different areas[1]

However, the impact on working conditions, environment (with more and more restricted regulations) and the above-mentioned safety, quality of service and operational cost, may open big opportunities for this kind of robotic solutions.

Some of this domain needs are:

- Availability of demonstrations of higher technological maturity. In particular; all-terrain motion and sensing; all-weather performance; and autonomous navigation
- Progressively lower system costs through increased use of commercial-off-the-shelf components rather than custom development of systems, while providing increased robustness and dependability;
- Ease integration with human operators, mainly when they are used to complement and act as an aid to a human mission expert. For this reason, the system has to be easily deployable, able to provide

[1] This graph was taken from
https://ifr.org/downloads/press2018/Executive_Summary_WR_Service_Robots_2018 .pdf

the relevant information to the mission expert, while seamlessly and autonomously performing the tasks that do not require operator input in the background.
Proposals answering to this challenge are expected to contribute to overcoming some of the technical and non-technical barriers for this kind of applications: (1) to show real-world deployment of robotics technology, firstly to prove compliance and secondly to show capability by means of large scale demonstrators; (2) safe operation certified to predefined levels in order to maintain a positive public perception of robotic deployment; (3) technology barriers related to operation time due to power autonomy, correct interpretation of scenes in order to make the correct autonomous decisions.

ESMERA has identified the following challenges as potential scenarios that proposals can use to develop and test their innovative ideas. All of them have been defined by relevant Industrial Companies that are willing to support experiments by facilitating the validation scenarios. Nonetheless, proposals are open to proposing their own application in this domain as long as they demonstrate advances in any of the requested abilities.

Construction Challenge 1: Vegetation Management

Millions of trees of different kinds together with smaller plants are growing along the railway and managing vegetation is hugely important for the safe running operation of railways. If it is not managed well, the encroachment of vegetation and even fallen leaves may pose a risk to the safe running of the railway and cause delays or accidents.

As defined in the Robotics 2020 Multi-Annual Roadmap, the key abilities that are paramount for this challenge are:

- **Dependability:** The robots will have to operate reliably for significant periods of time to meet the requirements of the challenge providers such as working at all-weather missions and long-term deployment.
- **Perception ability:** The scene classification is required and the operation of the solution must be possible in most weather and environmental conditions.
- **Motion ability:** A key attribute of the robots needed for this challenge is that they have to be able to move around difficult environments. Autonomous robots also have to locate themselves accurately.
- **Manipulation:** Mobile manipulation on uneven terrain is also expected from the developed solution.
- **Decisional Autonomy:** The robots will have to operate autonomously for significant periods of time during a working day. The solution should be capable to achieve pre-planned missions in medium complexity tasks with limited human supervision.

It is expecting from the system to fulfill the following metrics:

- **Operation environment:** The system would need to operate on all pre-defined areas. The system should be able to work in all weather conditions including the possibility of working at any time of ~~a~~ the day.
- **Mobility:** The system should be easy to deploy and to use and carried to the deployment site by road.
- **Accuracy:** The system should be able to correctly identify vegetation and remove the unwanted plant in its working environment.

Under the above challenge ESMERA, project proposes two options. The proposer must address at least one of these challenges although addressing more than one or highlighting where elements of the proposed system could be used for the benefit of more than one system would be beneficial.

A) ESMERA proposed challenges: this challenge is extracted from *three* industrial use cases which are:

CONSTRUCTION CHALLENGE 1. A1 (C1.A1)

Vegetation management between railway tracks. Currently, herbicides are used to prevent plant growth between the railway tracks.

For environmental and health reasons (due to changes in legislation, the herbicide glyphosate will be prohibited from end 2022), it is necessary to find a non-chemical solution to remove or cut back vegetation.

The robot needs to be able to navigate in between the tracks. This path is tread-proof and consists of sleepers (spacing of 80 cm) and ballast.

Furthermore, there are railway systems (e.g. axle counters or continuous train control) between the tracks. The components work with a magnetic field.

Some requirements for the robot are the following:

- The robot needs to mow or pull out plants growing between the railway tracks.
- If possible, it should collect the removed plants.
- Suggested dimensions: height of up to max. 40 cm, width up to approx. 100 cm so that it can move in between the train tracks with a **train passing overhead**.

This challenge is provided by the company Deutsche Bahn.

Figure 1: Detection and management of vegetation between railway tracks

CONSTRUCTION CHALLENGE 1.A2 (C1.A2)

Vegetation management next to railway tracks. The path next to railway tracks is tread-proof. The ground is either grass or pebble stones.

There are some drainage pipes next to the tracks which the robot would need to circumnavigate as well as masts for overhead lines or lighting standing alongside the tracks.

Furthermore, there are axle counters standing next to the tracks. The axle counters work with a magnetic field.

Some requirements for the robot are the following:

- The robot needs to mow or pull out plants growing next to the railway tracks.
- The cuttings can be dropped along the path
- The robot has to move along uneven pathways, circumnavigating obstacles
- Width of up to approx. 80 cm in order to be able to move alongside the tracks.

This challenge is provided by the company Deutsche Bahn.

Figure 2: Detection and management of vegetation next to railway tracks

CONSTRUCTION CHALLENGE 1.A3 (C1.A3)
Vegetation management in railways, common requirements.

- Withstanding the suction effect of fast-moving trains
  - There are fast-moving trains at up to 300 kmph so that the robot would need to withstand the suction from these passing trains.
  - Along most tracks, trains only travel at up to 160 kmph.
- Ability to locate robot anytime, anywhere.
- The robot should move along the tracks autonomously ensuring that all plants kept short or removed but without damaging any of the railway systems

To guarantee the safety of the trains circulating in the area in which the robot is operating.
This challenge is provided by the company Deutsche Bahn.

Figure 2: Detection and management of vegetation between and next to railway tracks

B) Open challenge (CONSTRUCTION CHALLENGE 1.B (C1.B))

Any other proposal for similar technologies is eligible for funding, provided that a thorough explanation of the industrial needs is presented. The proposals will also have to clearly identify the state of the art in commercially available solutions and highlight the differences/advances over it. More specific each proposal in order to be in line with the ESMERA requirements has to provide:

- Clear indication of the company, institution or other that are in need of the proposed solution (no funding is allocated to challenge providers)
- Description of the problem that the company or companies need to be solved.
- Proof that currently there is no comparable solution (concept or approach, performance, cost…) in the market.

Construction Challenge 2: Inspection and maintenance

Inspection and maintenance of the tunnels which includes the tunnels over 100 years are key functions in maintaining safe and effective facilities in the construction sector in which a rise in passenger and freight traffic means reduced access time for inspection and repair. R The requirement in Construction Challenge 2 is for a robotic system that can inspect current rail tunnels, identify areas that need repair and perform such repairs in a faster time than current manual methods allow.

As defined in the Robotics 2020 Multi-Annual Roadmap, the key abilities that are paramount for this challenge are:

- **Dependability:** The robots will have to operate reliably for significant periods of time to meet the requirements of the challenge providers such as working at all requested environment.

- **Perception ability:** Inspection is a key feature of the tasks and the ability to perceive features in the environment and interpret sensor data correctly will be a key determinant of success in this challenge.
- **Motion ability:** A key attribute of the robots needed for this challenge is that they have to be able to move around difficult environments (such as tunnels). Autonomous robots also have to locate themselves accurately.
- **Decisional Autonomy:** The robots will have to operate autonomously for significant periods of time during a working day. The solution should be capable to achieve pre-planned missions in medium complexity tasks with limited human supervision.

It is expecting from the system to fulfill the following metrics:

- **Operation environment:** The system would need to operate on all pre-defined areas at any time of a day.
- **Maneuverability:** The solution should be able to maneuver in tight spaces increasing flexibility and cost-efficiency.
- **Safety:** It is expected from the robot to be safe for itself and other elements and workers in the surroundings.
- **Accuracy:** The system should identify any structural problems with the highest possible accuracy.
- **Autonomy:** The robot will only need limited human time, as when moving from one place to the other, identifying the problems and maintaining them if it is necessary.

Under the above challenge, ESMERA project proposes two options. The proposer must address at least one of these challenges although addressing one or highlighting where elements of the proposed system could be used for the benefit of more than one system would be beneficial.

A) ESMERA proposed challenge: this challenge is extracted from an industrial ESMERA use case~~s~~ which is:

CONSTRUCTION CHALLENGE 2. A1 (C2.A1)

Tunnel inspection. Interventions of maintenance people inside tunnels of subways and raw inspections after infrastructure incidents are time-consuming operations.

- The access to these deep tunnels (35m below ground level on average) are inside the urban space and offer serious problems for maintenance people: parking difficulties, tools supply difficulties.
- Once inside the tunnel, walking is hard, walking between the sleepers is risky, limited space between the tracks, low lighting and hard work conditions (humidity, dust, etc.)

The key task for the robot is to automatically travel to the Point of Intervention from the docking station and, once there, to inspect (visual) the complete volume of the tunnel with many possible viewpoints.

The robot should be able to work without any traffic interruption.

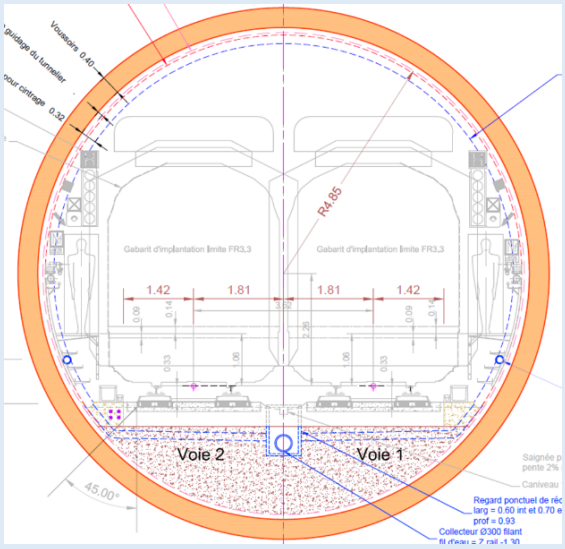

Figure 4: Section of tunnel

- Some additional actions would be appreciated: rail conductivity measurement
- small rubbish handling or
- rail brushing.

For root cause analysis, teleoperation is acceptable. In this case, communication between the robot and the control center should be properly addressed.
Other functions the robot could implement are welcome as well: intruder tracking, lighting, help in evacuation tasks, etc.
This challenge is provided by the company SNCF.

B) Open challenge (CONSTRUCTION CHALLENGE 2.B (C2.B))

Any other proposal for similar technologies is eligible for funding, provided that a thorough explanation of the industrial needs is presented. The proposals will also have to clearly identify the state of the art in commercially available solutions and highlight the differences/advances over it. More specific each proposal in order to be in line with the ESMERA requirements has to provide:

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