Miniaturised Robotic systems for holistic in-situ Repair and maintenance works in restrained and hazardous environments (MiRoR)

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Project Background

Current Repair/ Maintenance Technology
Since the layout and construction of many working environments is very complex (e.g. gas turbine engines and nuclear reactors), the conventional approach to maintenance requires disassembly of the system to allow end-effectors (e.g. inspection and/or cutting tools) to reach the target positions for inspection or repair, which can lead to large additional expenditure:
1. For repairing a gas turbine engine, about 10% of the total cost is spent to take it off the wing; the loss in revenue when grounding an aircraft is ca. $100,000/day.
2. In the energy industry, the cost of removal and reassembly of a generator is ca. $250,000 for fossil fuelled plants and ca. $400,000 for nuclear plants; the loss in revenue for a non-operational plant can amount to €500,000/day.

Project Aims
MiRoR is an EU funded project that aims to develop the novel concept of a Miniaturised Robotic Machine (Mini-RoboMach) system that will be demonstrated for holistic in-situ repair and maintenance of large and intricate installations. The system is comprised of two robots, a walking hexapod and a semi-rigid continuum robot:
1. A novel “free-leg hexapod” for providing both “walking” and 6-axis processing capability;
2. An original stiffness-controlled continuum robot for enabling “snaking” and 6-axis light processing ability;

The complementarily of these robots leads to a hybrid configuration of Mini-RoboMach, i.e. “walk & snake-in” can both be utilised. The system is commanded by an intelligent controller with the following key abilities:
1. Self-positioning: enabling walking and/or snake navigations to/from work and calibration of end-effectors on required features;
2. Reasoning: deciding on methods for accessing the working area while learning from these experiences;
3. Planning: scheduling task successions and optimising Mini-RoboMach path in reference to intervention in different locations;
4. Adaptation: modifying the parameters of treatment procedures for developing a self-protection ability of Mini-ReboMach.

Walking Hexapod Robot (WalkingHex)

System overview
The Walking Hexapod was developed for in-situ inspection and repair of nuclear facilities and other scenarios where human intervention is undesirable. The robot can self-position in a complex environment and automatically reference and calibrate itself, allowing for operations that utilise its precisely controlled platform, such as 5-axis high speed milling and Non-Destructive Testing.

Specifications of the Walking Hexapod:
• 6 legs with 3 DoF each;
• Dimensions: 525 x 525 x 380 mm (depending on configuration)
• Gait (walking) Accuracy: ±1mm
• Machining Accuracy: <0.1mm
• Payload Capacity: 12kg

Gaits the Walking Hexapod is capable of executing:
• Straight and rotational
• Step climbing (>20mm)
• Slope climbing (>10°)

Semi-Rigid Continuum Robot (SeRCR)

System overview
The semi-rigid continuum robot was developed for in-situ inspection and repair of gas turbine engines. The slender arm can weave between the blades to reach desired positions in the engine and the stiffness of the arm can be selectively controlled.

Specifications of the continuum robot:
• 12 sections with 24 DoF;
• Dimensions: min. 12mm in diameter with a 7.5mm delivery channel; 1256 mm in length;
• Position Accuracy: ±1 mm for sweeping in any ±5° operation area;
• Position Repeatability: ±0.5 mm;
• Payload Capacity: 200g;

The SeCR has two states of stiffness that can be actively switched between: soft and rigid. In the rigid state, the stiffness can be enhanced by approximately 70%, compared with that of the soft state. Preliminary experiments have proved that the robot can provide an appropriate stiffness and control accuracy to allow for stable blending of metallic materials, including those widely employed in the aerospace industry, e.g. aluminium and titanium.