European Commission

SESAME

SECURE AND SAFE MULTI-ROBOT SYSTEMS

The SESAME project has developed an open, modular, configurable, model-based approach for the systematic engineering of dependable multi-robot systems. The innovative technologies enable the development of multi-robot systems capable of dependable execution of tasks and missions in open configurations, and in operational conditions of uncertainty that include the potential of cyber-attacks. Project innovations have been validated in industrial multi-robot applications addressing Healthcare, Infrastructure Inspection & Maintenance, Agri-Food and Agile Production.

AT A GLANCE

Project Title
Secure and Safe Multi-Robot Systems

Project Coordinator
The Open Group (UK)

Partners
ATB (DE)
AVL (AT)
Bonn-Rhein-Sieg University (DE)
Cyprus Civil Defence (CY)
Domaine Kox (LU)
FORTH (GR)
Fraunhofer IESE (DE)
KIOS – University of Cyprus (CY)
KUKA Assembly & Test (DE)
Luxsense (UL)
PAL Robotics (ES)
Technology Transfer Systems (IT)
University of Hull (UK)
University of Luxembourg (LU)
University of York (UK)

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Total Cost
6.999.786 €

EU Contribution
6.999.786 €

Programme
H2020-ICT-2020-2 / Robotics in Application Areas

Further Information
www.SESAME-Project.org

Context and Motivation

Multi-Robot Systems (MRS) is a class of robotic systems in which distributed and interconnected robots are orchestrated to perform missions whose complexity and cost are too high for a single robot to accomplish on its own. Recent research highlights the strategic role of MRS in safety-critical and business-critical missions ranging from precision agriculture and fast delivery of medical samples to real-time road traffic monitoring and critical infrastructure inspection. The intrinsic characteristics of these missions involving teams of multiple robots, which include distributed sensing and action, uncertain operating environment, and the need for endurance and robust behaviour, necessitate the use of MRS instead of single robot solutions.

MRS bring additional benefits including improved scalability and performance since missions can be executed more efficiently through parallel activities, mission enablement through the use of collective intelligence to execute missions beyond the capabilities of individual robots, and increased robustness and reliability through redundancy in case of an individual robot failure or obstruction.

MRS brings also unique business opportunities that will have a significant impact on society and industry with the global MRS market expected to grow by more than 28% per year while reaching up to €120 billion annually by 2025. Paving the way for more widespread adoption of MRS requires new engineering-friendly development tools and dependability-driven development practices.

Challenge

Despite the MRS-driven societal and economic benefits, current engineering practices are mostly unsystematic and lacking explicit stakeholder involvement throughout the MRS lifecycle. The inherent complexity of MRS combined with increased connectivity between robotic team members and on-demand interaction with end-users leads to dynamic connections for information sharing, which make existing MRS vulnerable to cyber-attacks and accident-prone. MRS solutions deployed in critical missions incur increased risks to fail due to the following reasons:

- Multiple dimensions of uncertainty
- Complicated configuration tools
- Safety and Security interdependency
- Insufficient reliability and resilience

Wider adoption of MRS by society depends upon the perceived trust of stakeholders, including businesses, engineers, regulators and end users, with regard to the safety, security and ethical nature of these new systems.

Solution

At the heart of the SESAME project innovations is a model-based approach where models are automatically composable and also algorithmically analysable at both design time and runtime. SESAME further advances multi-robot systems engineering by providing:

- **Domain-specific languages** that hide the complexity and intricacies of robotic simulators and platforms
- **Machine Learning based libraries** of well-designed scenarios that are adaptable and reusable across applications
- **Design-time analysis of safety and security** via composition, reuse and automated analysis
- **Novel safety and security assurance** achieved by shifting part of the assurance to runtime
- **Seamless (re)configuration** at design and at runtime to easily adapt to changing needs and operating environments

SESAME builds on a novel and advanced synthesis of the state-of-the-art in model-based development, nature-inspired technologies, and AI data-driven techniques. Model-based techniques are used to capture pertinent engineering knowledge and assumptions about MRS operation, failures and their effects, in verifiable and executable at runtime models that can be used to assess, verify and ensure security and safety.

Two of the key technology advances that have been developed in the project are:

- **Executable Scenarios (ExSce)** are model-based narrative descriptions of robotic missions guiding the design, development, configuration and deployment of multi-robot systems.
- **Executable Digital Dependability Identities (EDDI)** are model-based artefacts spanning the multi-robot system lifecycle that carry verifiable dependability models of their reference robotic systems produced at design-time based on ExSce, capturing safety and security hazards, their causes, effects and possible corrective actions.

Expected Impact

SESAME will deliver to European industries substantial benefits for MRS in the following areas:

- **Accuracy** – improved robot self-localisation accuracy using sensor-fusion from multiple robots
- **Robustness** – collaborative intelligence enables robotic teams to cope with severe failures
- **Efficiency** – perception-aware trajectory planning reduces time for MRS task execution
- **Safety** – improved coverage of hazards related to emergent behaviour and uncertainty
- **Security** – increased coverage of cyber risks and extended robotics security assurance
- **Adaptability** – MRS automatically adapt to observed conditions providing substantial performance gains
- **Quality** – intelligent testing of operational designs quickly uncovers corner cases that could violate safety or security requirements

SESAME will lower the development costs and deliver greater assurance of the safety, security and dependability of multi-robot systems for wide range of European industries, which have been demonstrated and validated through five novel industrial applications from the Healthcare, Infrastructure Inspection & Maintenance, Smart Agri-Food and Agile Manufacturing sectors.

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