NM-RS

DIEHL BGT Defence

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Executive Summary

Networked Multi-Robot Systems

1 SUMMARY

The project Networked Multi-Robot System (NM-RS) was the first Category B project contracted under the supervision and the coordination of the European Defence Agency. The participating member states (pMS) were Germany (as lead nation), Italy, Spain and Belgium.

The NM-RS project started in June 2007 and was successfully terminated in July 2010. In these 36 months the NM-RS project team – consisting of industrial partners from four European Nations – realised within a simulation system a networked multi-robot system to evaluate the performance and the benefits of such a networked system performing autonomously coordinated operations.

The industrial group consisted of:

- **Diehl BGT Defence** (main contractor) and **Fraunhofer FKIE** from Germany,
- **OTO Melara** together with **Celin Avio** and **Scuola Superiore Sant'Anna** from Italy
- **SENER** and **Universidad Politécnica de Madrid** from Spain
- **Patrimony of the Royal Military School** (PRMS) from Belgium

The main objective of the project was to

1. Focus on robots to reduce the risk of personal damage or loss of life
2. Increase the efficiency for military operations i.e. reconnaissance, inspection and security

To reach the objectives within the given time and the financial volume the project NM-RS was realised in a simulation system. The lessons learned in realising NM-RS were thought to gain knowledge in the field of networked robot systems and to improve the initial knowledge for a possible hardware realisation.
The requirement of a realistic performance in a simulation environment determined the simulation of all parts – i.e. the complete environment (including static and moving objects, enemy forces, civilians, etc.), the various robot platforms (including their realistic physics), all sensors (including all gathered sensor data and a learning system) and the communication itself (including a realistic communication model).
The algorithms for the guidance, navigation and control of the robot platforms and the coordination of the multi-robot system (centralised as well as decentralised) are on the other hand real algorithms which are designed to use simulated as well as real sensor data. This allows the transfer of the NM-RS results into the real world and the implementation of the NM-RS algorithms in existing hardware.

For the realisation of NM-RS a thorough reporting was contracted. Every six month the actual project status has been reported to the Technical Arrangement Management Group (TAMG). At the end of the project the software of NM-RS was demonstrated in a Final Presentation.

Given the success of NM-RS the pMS accepted the proposed idea of a second project phase. In NM-RS 2 a networked multi-robot will be realised by transferring the results from NM-RS on existing hardware/ real robots. One of the main objectives of NM-RS 2 is to verify the results gained of NM-RS project.

2 OVERVIEW

2.1 Project Identity

Project titel	**Networked Multi-Robot System**	
Project acronym	**NM-RS**	
Contract number	B-0004-ESM2-ERG	
Starting date	T0	June 4th, 2007
Date of termination	T0 + 36	July 13th, 2010
Contracting authority	The European Defence Agency Brussels, Belgium	
Main Contractor	Diehl BGT Defence GmbH & Co. KG Ueberlingen, Germany	

2.2 Project Organisation

A Technical Arrangement Management Group (TAMG) has been formed by the government officials appointed by the Contributing Members to manage the project on the basis of the Technical Arrangement (TA) B-0004-ESM2-ERG.
The main contractor reported on a six month basis the progress within NM-RS project in a progress review meeting to the members of the TAMG. These reviews gave the background for approval and payment of the contracted milestones.

The main contractor coordinated the realisation of the NM-RS project. Each Approved Sub-Contractors as well as the Main Contractor were responsible for the realisation of at least one workpackage and coordinated the work within their workpackage respectively. Together all partners formed the Industrial Group (IG).

2.3 Project Objectives and Scope of Work

Concerning the famous 3D's of a robotic task or mission (dirty-dull-dangerous), the vision for the future use in military operations is wide. In the case of unmanned ground vehicles (UGVs) various nations push the development of autonomous capabilities for single robots – the employed autonomous behaviour ranges from teleoperated to (semi-)autonomous and is steadily increasing.

An alternative approach to the constant improvement of the autonomous performance of single robots is in the deployment of a networked multi-robot system. In a multi-robot system a group or swarm of mobile and autonomous (re-)acting vehicles, e.g. land vehicles, fulfil pre-planned tasks by themselves and report the results to the operator in an effective manner.

The operator will be a mission pre-planner and supervisor. Underlying architectures have to consist of high-level commands, not time-critical, deliberative levels and of time-critical, real-time low-level commands to deliver flexible and robust, scalable (or adjustable) autonomous functionalities.

Following an efficient way of research and development, NM-RS addressed first the simulation framework for such an autonomous behaving group of unmanned ground vehicle systems to understand the necessary modules (sensors, navigation, coordination, Man-Machine-Interface etc.) design and interactions for emerging autonomous functionalities under the control of an operator. In a second step, this will lead to a more effective hardware design without the necessity to test technological implementations only in real hardware.

NM-RS demonstrated via simulation the benefits of networked multi-robot systems performing autonomously coordinated operations. On top of guidance, navigation, control and multi-robot coordination, sensor systems, communication and human-machine-interface as well as command & control machine interface aspects were considered.

Additionally the following factors were evaluated in the realisation of NM-RS project:

- Interoperable simulation environment with open architecture
- Possibilities to plan specific missions and command a group of UGVs with one control station
- Tactics and procedures of multi-robot systems in military applications
- Definition of a sensor set for multi-robot systems
- Centralised and decentralised multi-robot coordination

2.4 Project structure and WP responsibilities

The following paragraphs list the contribution to the project/ responsibilities of the main contractor and each approved sub-contractor:

DBD:
DBD lead the WP 2000 complex “Simulation Environment for Multi-Robot Systems” as well as WP 8000 “Performance Assessment”.

Next to the realisation of the simulation system itself, DBD as main contractor has been responsible for the definition and fixture of the overall simulation environment with the underlying service architecture and the interfaces between all the modules developed by the partners.

SENER:
SENER lead the work packages of the WP 3000 complex “Guidance, Navigation and Control”.

Closing WP 3100 up to WP 3500, requirements and suitable models for the robot classes dynamics, the appropriate set of navigation sensors in relation to and combination with the developed virtual sensor suite as well as the intelligent sensor fusion simulation have been worked out, coded and tested.

Oto Melara:
Oto Melara lead the work package complex WP 4000 “Surveillance sensor and signal processing” as well as WP 6000 “Human-Machine-Interface”.

WP 4000 included the selection, definition and development of the sensor suite for surveillance and reconnaissance to perform obstacle avoidance and intruder detection as well as robot reactions comprising the near-sensor signal-processing to be interfaced to the navigational sensor suite. Multimodal sensor fusion algorithms have been implemented and tested for environmental observing and for control of navigational vehicles behaviour.

Within the WP 6000 (“Human-Machine-Interface”) complex the set-up and integration of a human-machine-interface capable to deal with multi-robot systems has been realised. The developed graphical user interface for the simulation control also includes a virtual reality player, which will be able to visualize and store the data of defined functions – e.g. sensors, errors etc. – in the MSRS software framework.

FhG-FKIE:
FhG-FKIE lead the work package complex WP 5000 ”Communications”.

The realised communication module runs on a linux system and simulates a realistic communication between the robots itself as well as the communication between the robots and the control station.

PRMS:
PRMS leads the WP 7000 complex “Multi robot coordination”.

The multi-robot coordination has been a central aspect in NM-RS project. The main focus was concerning the global planning of appropriate, scenario relevant missions and tasks. Different planning algorithms have been developed and evaluated. The goal has been to limit the amount of interactivity and synchronization between the robots, therefore reducing the demand on high quality and availability communication services to enhance autonomous behavioural inter-robot coordination.