CONET Newsletter

INFSO-ICT-224053 www.cooperating-objects.eu **Issue nr.5, September 2009**

Contents

Editorial

Welcome to the fifth issue of the CONET newsletter. CONET is the EU FP7 network of excellence on Cooperating Objects, merging the fields of embedded systems for robotics and control, pervasive computing and wireless sensor networks. CONET focuses on establishing the field of Cooperating Objects within the research and industrial community, thus strengthening the position of Europe in the research landscape.

This issue presents a guest column from John L. Vian, Boeing Research & Technology, about Autonomous system-of-systems technology development. In the "member profile" section, AICIA partner is introduced and some of their activities on cooperative robotics are presented. Next, an interesting article deals with Networked UAVs for Mapping and Tracking; this article has been prepared by Salah Sukkareih. And finally, this issue proposes an overview on a related project: PECES: PErvasive Computing in Embedded Systems, section written by UBONN.

If you are interested in obtaining up-to-date information about the CONET project please visit our website at: http://www.cooperating-objects.eu/

We hope you will enjoy this issue. ■

Autonomous System-of-Systems Technology Development

By John L. Vian, Boeing Research & Technology

Heterogeneous networked cooperating objects are increasingly seen as a means to reduce the cost of completing complex tasks while also enhancing the functional capability and reliability of the overall system. Cooperative autonomous vehicles will eventually exhibit the user-friendly, intelligent, and adaptive characteristics envisioned in many future transportation concepts. These systems stand to offer unprecedented levels of top-level functional performance when compared to today's generally single-platform solutions, whether it is in terms of goods moved, area searched, MANET coverage, surveillance persistence, or environmental parameters monitored.

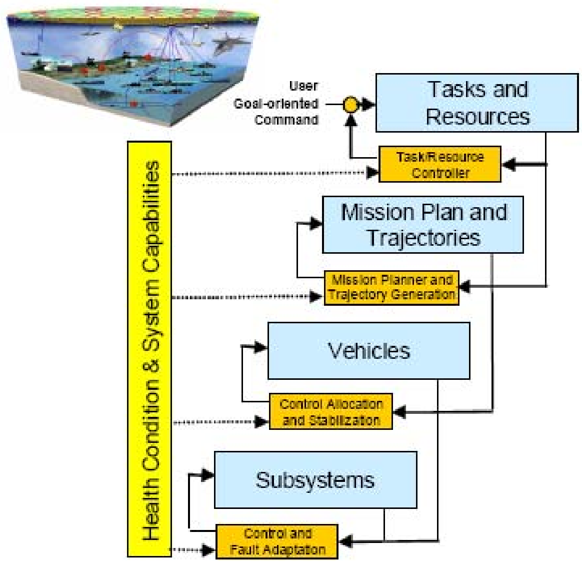

Figure 1 – Health-based adaptive control architecture for hybrid system of systems.

Technical advancements will be needed in several areas to enable the high degree of multi-vehicle collaboration and autonomy that is essential to realize these visions. While impressive work has been accomplished the areas of mission planning, trajectory de-confliction, and robust control, the formalized methods needed to control a hybrid system-of-system in a safety-critical environment are still under development. Additionally, it is suggested that new hierarchical health-adaptive approaches will be needed to make these complex-coupled systems reliable, and to guarantee achievement of their top-level system-of-systems performance metrics as illustrated in Figure 1.

Finally, new cost-effective means to rapidly prototyping these system concepts will greatly enhance the transition the latest academic research into useful products. Universities and industry players alike are investing in indoor testbeds in order to quickly understand the benefits and challenges of multi-vehicle coordination. A Vehicle Swarm Technology Laboratory (VSTL) was recently established at Boeing Research & Technology (BR&T) in Seattle WA with ongoing efforts to promote platform commonality and collaborative research with BR&T Europe and BR&T Australia.

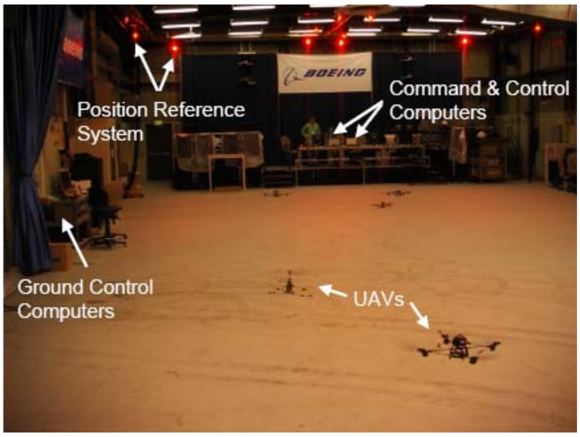

Figure 2 – Boeing VSTL in new 100’x50’x20’ facility.

The VSTL, shown in Figure 2, is designed to use real hardware to examine autonomous system frameworks that include multi-vehicle systems health management, as well as issues related to centralized versus decentralized control. The testbed uses aerial and ground vehicles that operate autonomously in a large, indoor volume to execute various mission scenarios and evaluate different collaborative vehicle concepts of operation. Researchers can rapidly execute multiple mission scenarios in a short period of time with minimal setup and organization between tests. The VSTL has been pivotal in the engagement on intelligent adaptive systems research with a number of universities, suppliers, and customers [1-9].

The ability to control a swarm with a minimal number of operators has been enabled by implementing health-adaptive behaviours. This behaviour includes vehicle and navigation state-based adaptation which increases mission reliability. Safety bound monitoring commands in controlled actions, including normal landing, open-loop position graceful landing or thrust termination when things go wrong with a vehicle. These protections are essential when demonstrating concepts of operation involving large numbers of vehicles as shown in Figure 3.

Figure 3 – Twelve-vehicle autonomous flight in original 30’x50’x30’ VSTL.

The VSTL platform includes a swarm command and control operator interface and real-time virtual environment as illustrated in Figure 4.

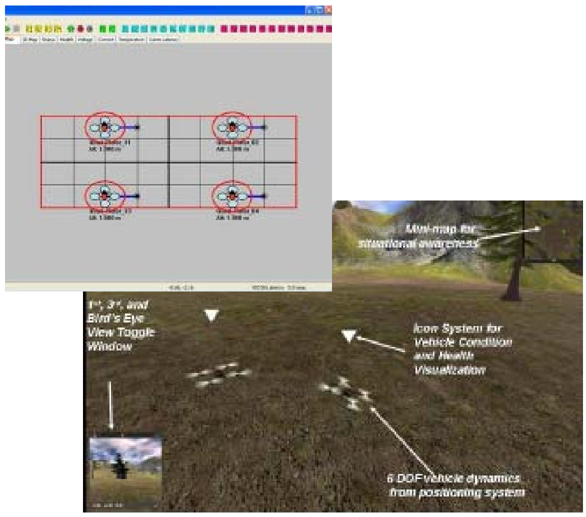

Figure 4 – SwarmView and swarms virtual environment

The command and control interface, called SwarmView, allows a single operator to supervise multiple vehicles and provides detailed real-time monitoring vehicle state and health information. The integrated virtual environment provides a three-dimensional visualization of the swarm to enhance the value of concept of operation demonstrations.

In summary, the Boeing VSTL has been an effective platform for rapid prototyping of multi-vehicle task & mission planning, health-adaptive control, and vehicle and communication hardware systems. Many advanced algorithms have been integrated and demonstrated with multiple real vehicles including:

- Heterogeneous Hierarchical Area Search
- Mixed Integer Linear Programming Auto-Tasking
- Persistent Surveillance
- Trajectory Deconfliction and Collision Avoidance
- Autonomous Heterogeneous Inspection

Furthermore, this intermediate activity between pure simulation-based testing and real operational-system field testing provides valuable risk reduction as advanced technology is transitioned into marketable products.

References

1. Meuth, R, Saad, E., Wunsch, D., and Vian, J. (2009). "Adaptive Task Allocation for Search Area Coverage," IEEE International Conference on Technologies for Practical Robot Applications, Woodburn MA, November 9-10, 2009.
2. Nigam, N., Bieniawski, S., Kroo, I., Vian, J., (2009). "Control of Multiple UAVs for Persistent Surveillance: Algorithm Description and Hardware Demonstration," InfoTech@Aerospace Conference, Seattle WA, April 6-9, 2009.
3. Halaas, D. J., Bieniawski, S. R., Pigg, P. E., and Vian J. L., (2009). "Control and Management of an Indoor, Health Enabled, Heterogenous Fleet," InfoTech@Aerospace Conference, Seattle WA, April 6-9, 2009.
4. Saad, E. W, Vian, J. L., Clark, G. J., Bieniawski, S. R., (2009). "Vehicle Swarm Rapid Prototyping Testbed," AIAA InfoTech@Aerospace Conference, Seattle WA, April 6-9, 2009.
5. Valicka, C. G., Stipanovic, D. M., Bieniawski, S. R., Vian, J. L., (2008). "Cooperative Avoidance Control for UAVs," 10th International Conference on Control, Automation, Robotics, and Vision, Hanoi, Vietnam, December, 17-20, 2008.
6. Bieniawski, S. R., Halaas, D., and Vian, J., (2008). Micro-Aerial Vehicle Flight in Turbulent Environments: Use of an Indoor Flight Facility, for Rapid Design and Evaluation, AIAA GNC Conference, Honolulu HI, August 18-21, 2008.
7. Bethke, B., How, J. P., Vian, J. L., (2008). "Group Health Management of UAV Teams With Applications to Persistent Surveillance, American Control Conference, Seattle WA, June 11-13, 2008.
8. How, J. P., Bethke, B., Frank, A., Dale, D., and Vian, J., (2008). "Real-Time Indoor Autonomous Vehicle Test Environment," IEEE Control Systems Magazine, April 2008, pp 51-64.
9. Valenti, M., How, J., Vian, J., (2007) "Multi-Vehicle Flight Testbed for Extended Mission Analysis and Fault Isolation, Detection and Recovery," NATO Research and Technology Organization Joint Symposium on Platform Innovations and System Integration for Unmanned Air, Land and Sea Vehicles, Florence, Italy, May 14-17, 2007. ■

Member Profile: AICIA

Prepared by AICIA, GRVC-US.

AICIA: *Asociación para la Investigación y Cooperación Industrial de Andalucía*.

http://www.aicia.es

The Association of Research and Industrial Co-operation of Andalusia (AICIA) is a public interest non-profit Association. AICIA has 43 industrial companies as associated partners. Its objectives are to foster, guide and promote industrial research. AICIA has an agreement with the University of Seville to use the human and material resources of the School of Engineering to accomplish the goals provided in the Association rules. The activities of AICIA are set out in a long list of research and development projects, engineering works, tests, evaluations, reports, analysis and consultations. In the last years, AICIA increased very significantly its involvement in international projects including projects of the European Framework Programmes.

The GRVC group is led by Prof. Aníbal Ollero and includes 45 researchers and engineers with strong expertise on autonomous robotics systems, cooperative perception and distributed systems including sensor networks. The group participated in 45 projects in the last 5 years, and has a long tradition of participation in the Framework Programmes including 4 projects of the FP4 (DEDICS, INFLAME, FAMIMO, ROSPIR), 3 of the FP5 (SPREAD, EUFIRELAB, COMETS), 3 of the FP6 (AWARE, URUS, EMBEDDED WISENTS) and one NoE of FP7 (CONET).

The group was the Scientific and Technical Coordinator of the Consortium in the **COMETS** IST project on Real-time coordination and control of multiple heterogeneous unmanned aerial vehicles (UAV). COMETS was the first project in Europe demonstrating experimentally the cooperation of multiple UAVs and its application to forest fire applications. COMETS designed and implemented a distributed control system for cooperative detection and monitoring using heterogeneous UAVs. Particularly, both helicopters (see Figure 5) and airships were integrated in the COMETS system. COMETS designed and implemented new control architecture, new UAV control techniques, and distributed sensing techniques and real-time image processing capabilities.

In **Embedded Wisents** on Cooperating Embedded Systems for Exploration and Control featuring Wireless Sensor Networks, the group coordinated the Work package on Road mapping and led the research studies

From June 2006 until August 31, 2009 the group has been the coordinator of the consortium of the successful **AWARE** IST project. The AWARE project has designed, developed and validated in field experiments a platform providing the middleware and the functionalities required for the cooperation of unmanned aerial vehicles with ground sensor-actuator wireless networks, including static and mobile nodes carried by people and vehicles. The project has demonstrated the self-deployment of the network by using autonomous helicopters that transported and deployed sensor nodes and loads. The AWARE platform includes a publish/subscribe middleware supporting mobility, a gateway application to enable the cooperation between high bandwidth and low bandwidth networks, and an autonomous decision framework for the distributed cooperation of multiple UAVs in surveillance and tracking missions. AWARE has demonstrated for the world-wide first time, in December 2007, the transportation of a load by using multiple coupled unmanned helicopters. Then, three small helicopters with moderate hardware requirements cooperate in the transportation of a load that a single helicopter cannot transport due to payload constraints. The last demonstration has been carried out in very hard constraints with wind gust of more than 30 Km/h. The project has developed a scalable, energy-efficient and self-organizing ground sensor network that has been validated in fire detection. The AWARE project also developed network-centric functionalities based on the distributed cooperation of autonomous helicopters, ground cameras and wireless sensor networks with nodes that can be transported by people. The functionalities have been demonstrated in surveillance, fire detection and localisation, fire monitoring, fire extinguishing, and firemen tracking. The technologies developed in the project can be applied to disaster management and civil security and are also useful in the filming of dynamic events. More information of AWARE is in http://www.aware-project.net.

In the **URUS** (Ubiquitous Networking Robotics in Urban Settings) project, the objective is to analyze and test the idea of incorporating a network of robots (robots, intelligent sensors, devices and communications) in order to improve life quality in urban areas. URUS is focused in designing a network of robots that in a cooperative way interact with human beings and the environment for tasks of assistance, transportation of goods, and surveillance in urban areas. Specifically, our objective is to design and develop a cognitive network robot architecture that integrates cooperating urban robots, intelligent sensors, intelligent devices and communications. More information on URUS is in http://urus.upc.es

The group is also the Associated Coordinator of CONET FP7 NoE.

Figure 5: Some of the autonomous systems developed by the GRVC AICIA-University of Seville group

Other recent projects related to Cooperating Objects and Wireless Senor Networks have been the Spanish Projects **AEROSENS,** on the integration of aerial fixed wing UAVs and Unmanned Ground Vehicles (UGVs) (see Figure 5) with WSNs, **CROMAT** on the cooperation of aerial and ground robots, **PROTEC-SENS** on fire fighters protection based on Wireless Sensor Networks with mobile nodes, **ATLANTIDA** on air traffic management with demonstrations by using UAVs, **SADCON** on the application of UAVs and WSNs to environment protection, and **SIRE** on network robot systems.

The group also developed, in cooperation with EADS-CASA, **distributed systems for aircraft testing** that are being used in the manufacturing of the aircrafts CN235, CN295 and A400M.

The researchers of the GRVC group are authors of 120 publications in the last 5 years, including 6 books, and received several research and technology transfer awards

More information about the research activities by this group can be found in:

ⓘ **http://grvc.us.es/** ■

Networked UAVs for Mapping and Tracking

By Salah Sukkareih, Australian Centre for Field Robotics, The University of Sydney, NSW, 2006, Australia

Introduction

In September 2007 the Australian Centre for Field Robotics conducted a number of flight trials which comprised of 2 networked unmanned aerial vehicles (UAVs) demonstrating the benefits of decentralized data fusion and cooperative control.

Figure 1 – Brumby MkIII FVs 2 and 3 on the runway at Marulan – the flight test facility for the ACFR

Figure 2 – The nose on the Brumby UAV houses the vision and IR sensors

The pair of UAVs where performing an information-gathering mission, where the objective was to utilize the UAV team to estimate the position and velocity of a number of ground-based features. The UAVs were given prior knowledge of the feature states and were required to increase the amount information of these states to a predefined threshold.

This demonstration was the culmination of almost a decade of activity in cooperative UAV systems and the benefits of decentralised data fusion.

Decentralised Data Fusion and Feature Observations

A Decentralised Data Fusion (DDF) system is a network of sensor nodes where each node has its own processing capability and where collectively they do not require any central fusion facility or central communication system.

In a DDF system the data fusion occurs locally at each node based on the information it received from its own sensor and from information that has been communicated from neighbouring nodes.

If each sensor and its node are placed on a moving robotic platform then the overall system becomes a decentralised robotic network, and in this particular system implementation present here we have a decentralised UAV network.

In our application we were interested in mapping and tracking ground based features. The features used in these demonstrations were stationary 1 square metre white targets placed around the area of operation.

The vision detector that we used was based on a SVM classifier that was trained on data obtained from previous flight trials. The detection thresholds were based on reported probabilities from the SVM classifier and we chose to minimize false alarms at the expense of missed detections. This was accomplished by requiring the probability of a feature being a white target to exceed 80%.

An inverse covariance form of the EKF was implemented to map and track the features using a moving target model. The feature states estimated were the positions in x, y, and z, and the velocity in x and y.

We used a tree network topology between the two UAVs and a ground node. The ground node was used for monitoring. All feature detection and state estimation was done in real-time onboard the UAVs.

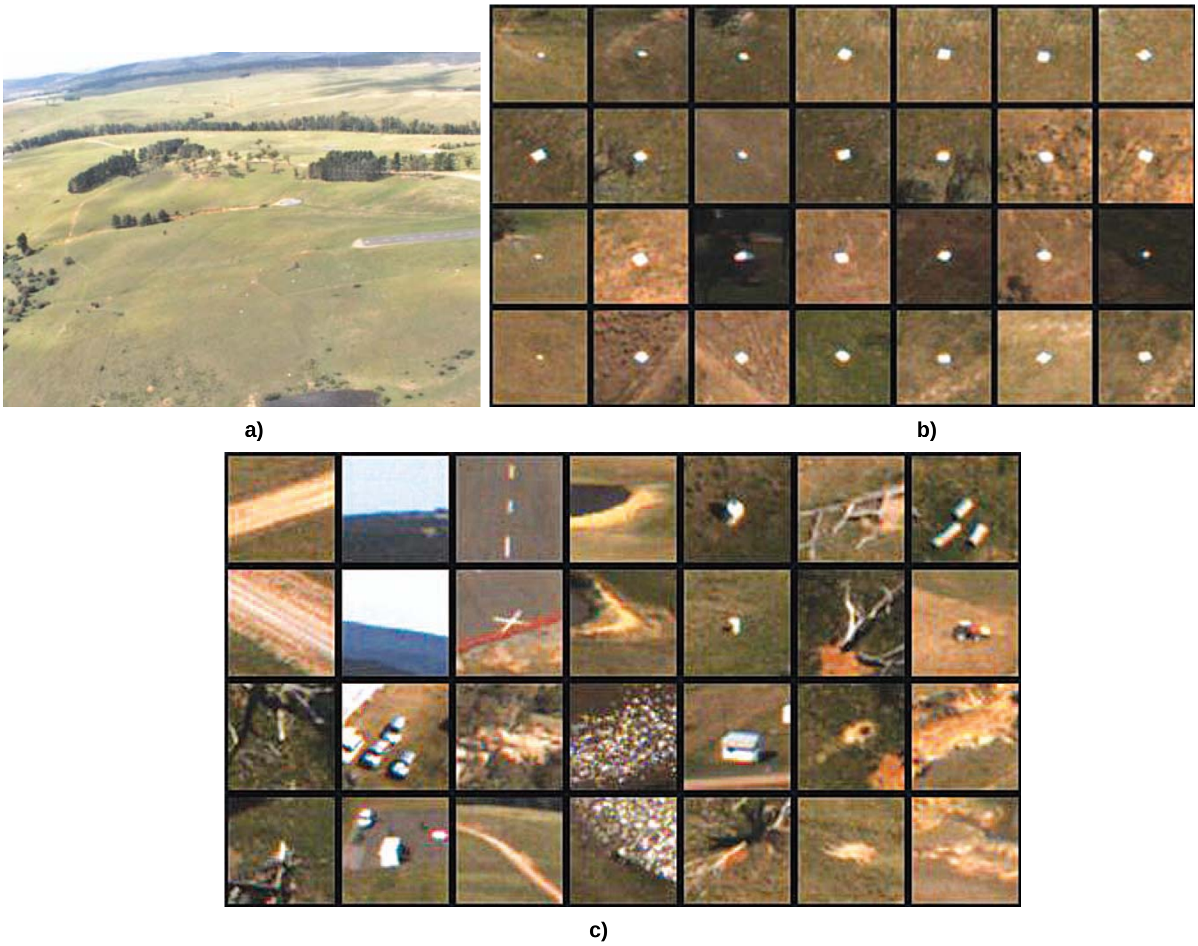

Figure 3 – a) An aerial image of the area of operation. b) The white targets that we were detected and used to train the SVM classifier. c) The non-targets that were used to train the SVM

Cooperative Path Planning and Control

The information shared across the DDF network represents the amount of information known about the targets. An information-based mission utility function was defined and the objectives of the UAVs were to calculate paths online that will maximize this information.

The dynamic paths take the form of Dubins curve. The UAVs orbit the ground features in a manner which lets the sideways mounted camera in the nose to continuously observe them and provide angular variation.

In choosing which feature to observe next the UAVs maximize a mission-utility function which is the mutual information gained divided by the time required to achieve it.

When a single UAV performs this mission it chooses the feature that maximizes its own local utility, then plans a path to that feature, and sends the path to the flight control computer. When the UAVs are cooperating they share information so that each one can choose the features that will maximize the global utility.

Demonstrations

We conducted a number of demonstrations where there was no communication, communication for DDF but no cooperative control, and DDF communication with cooperative control. This later test was the ultimate demonstration of the cooperative UAV system and the results of the individual paths are shown in figure 4.

Conclusions and Further Information

UAVs teams can be used for a number of different information-gathering tasks. The sharing of information while performing these tasks allows for higher levels of performance.

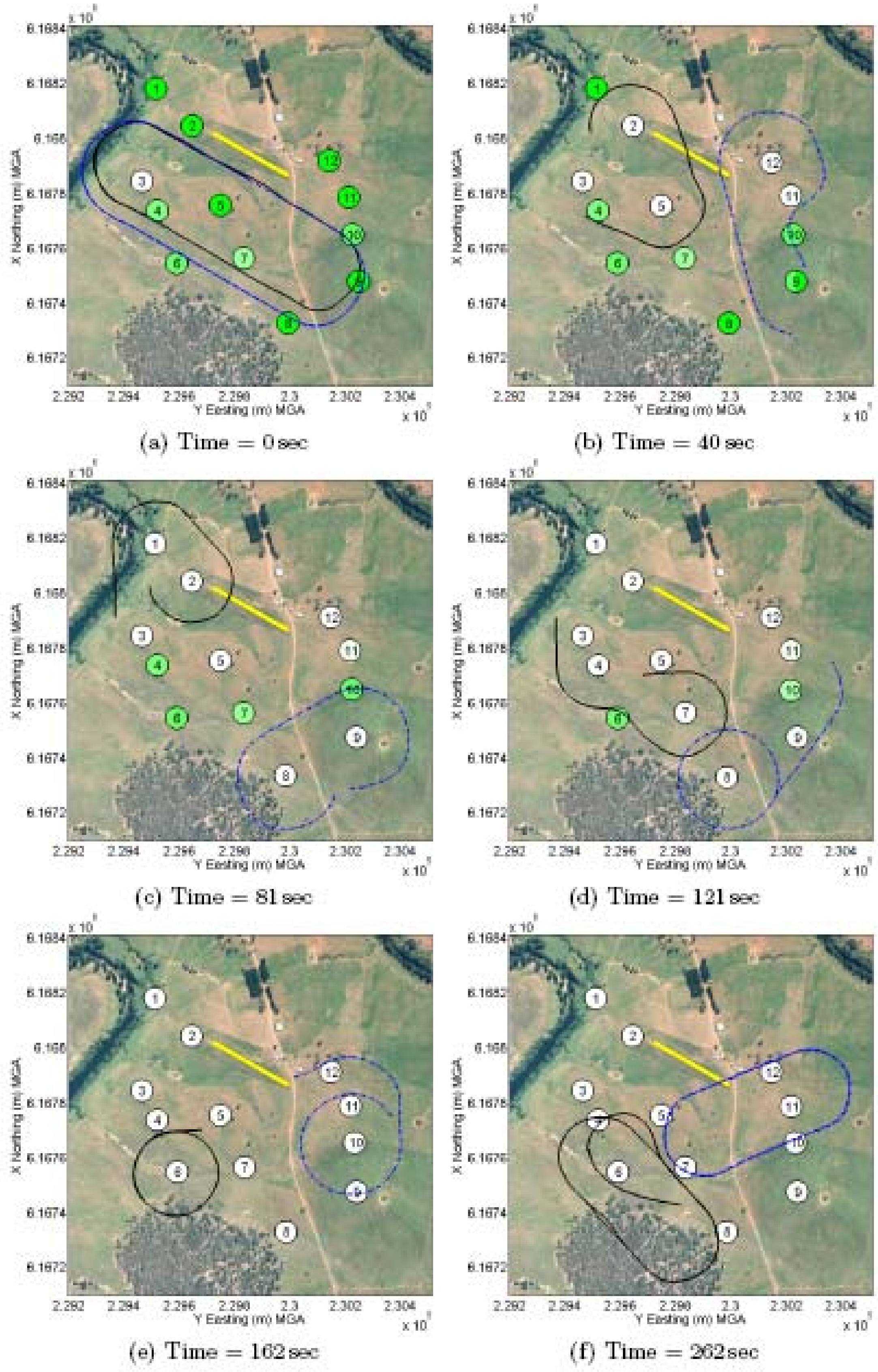

Figure 4 – Demonstrations

The demonstrations that we conducted proved that the use of DDF with cooperative control provided an increase in capability of the UAV team. The flights also successfully demonstrated the path following guidance module, online dynamic path planner and feature extraction implementations.

Further information on this particular demonstration can be found in a recent publication "**Mapping and Tracking Demonstration of UAV Cooperative Control**" in the IEEE Robotics and Automation Magazine June 2009. Related UAV implementations can be found at **http://www.acfr.usyd.edu.au/research/aerospace.shtml** ■

PECES - PErvasive Computing in Embedded Systems

PECES enables the seamless cooperation of embedded devices across various smart spaces on a global scale in a context-dependent, secure and trustworthy manner.

PECES consortium, prepared by UBONN

Main Objectives

The dramatic growth of the amount of information that is made available through computer systems and the increasing need to access relevant information anywhere at any time are more and more overwhelming the cognitive capacity of human users.

The vision of Pervasive Computing aims at solving this problem by providing seamless, accurate, and distraction-free support for user tasks with devices that are invisibly embedded into the environment.

While there are various approaches towards enabling this vision, existing approaches are mostly focusing on smart spaces, such as smart meeting rooms or offices. However, truly seamless support requires the integration of multiple smart spaces with each other and with information system infrastructure that exists.

Among others, enabling this overall vision raises the following research challenges:

- the definition of an adequate ontology to model device capabilities and resources in an extensible way that can support the ongoing evolution of technology,
- the development of middleware systems that provide efficient and secure runtime support for applications that are executed in a massively distributed environment,
- the development of new coordination mechanisms to enable the automated formation of dynamic groups of cooperative devices that are secure and trustworthy,
- the design of new and the adaptation of existing development tools to improve the cost-effectiveness of the application development process.

Communication

The PECES project is geared towards addressing the set of challenges described above in order to provide a truly integrated solution. To achieve its ambitious goals with the available project resources, the PECES consortium is reusing and extending BASE (http://www.3pc.info) – an open source communication middleware for pervasive applications – with additional mechanisms and services.

BASE enables a broad range of different devices to dynamically form networks in order to interact with each other spontaneously. To do this, BASE introduces an extensible plug-in architecture that enables the automatic composition of communication stacks at runtime. By means of plug-ins, the communication support of devices can be configured flexibly according to their capabilities and the needs of the applications for which they are used.

Since BASE has been geared towards enabling the interaction between devices connected through local networks, it is extended to support interaction through wide area networks during the course of the project. This will enable local and remote devices to interact with each other. Thereby, BASE will shield the application developer from many compilations resulting from differences in the underlying communication technologies and protocols.

Grouping

Since PECES is targeting at enabling the secure and trustworthy interaction of devices, solely enabling communication between arbitrary devices is not sufficient. Instead, it is necessary to enable applications to automatically determine groups of devices that shall interact to execute an application. Due to the dynamics and scope of the underlying networks, such groups need to be identified in a context-dependent manner and the grouping process needs to be secured.

At the lowest layer, such groups can be used to automatically determine the devices that shall form a smart space. Beyond the boundaries of a single smart space, the groups can also be used to identify sets of devices that are distributed among different remote locations which are interconnected via the Internet. As a consequence of the broad applicability of the grouping mechanisms, the group definition must be supported in a generic fashion. Furthermore, in order to enable the efficient formation, the group definition should allow hierarchical compositions.

The key concept introduced by PECES to provide the secure formation of groups is Generic Role Assignment. Generic Role Assignment tags devices with roles on the basis of a so-called role specification. The role specification defines contextual constraints that must be fulfilled by the devices to which a role is assigned. Thus, a role assignment represents a set of dynamic, context-dependent groups that can be referred to by roles.

Such groups can be used to form a smart space, which normally consists of devices which are able to communicate to each other through a local network. Furthermore, it can be used to define application-specific filters. For example, if one of the devices wants to search for other devices with certain capabilities or context, it can inject an adequate role specification into the system. The device will then get a dynamic list of all devices that match the specification. For other devices of the smart space it is possible to subscribe to a role specification that is executed. Any changes of the role distribution will then be reported to this device.

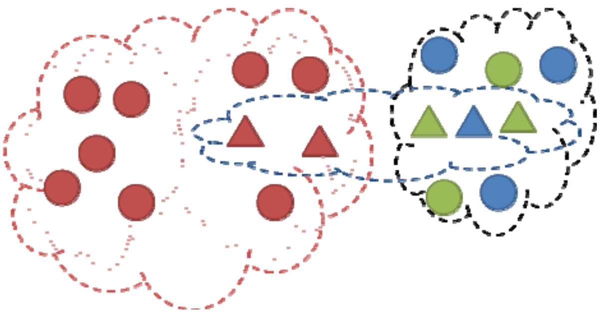

Figure 1 – Several groups formed by different context information and roles.

Besides forming a smart spaces or application-specific groups, PECES will enable the formation of a group which consists of more than one smart space. This is possible with the help of a group registry which can be reached via the Internet.

Security

A local group formation initiated by the application of one device that depends only on information which is publicly available is always possible. Forming groups which consists of many smart spaces however, will only be possible, if the security policies allow the deployment of remote role specifications on the respective local system.

To perform a secure Generic Role Assignment, a security specification will outline the impact of certain security goals to the role mechanisms and the communication. Every security related role will be cryptographically secured in a way that it is easy to verify even by devices which have strong resource constraints.

Therefore it is possible to use roles not only for grouping and addressing, but also for access control. The level of trust differs for every group and depends on the hierarchy the group is located and on the trust in the participating devices.

Status

In the current phase, the PECES consortium is specifying the mechanisms and services to provide a robust middleware which allows the application developers to concentrate on their applications. If you are interested in the PECES project, you can retrieve more information via the project website http://www.ict-peces.eu. There you can also subscribe to the PECES newsletter to keep informed about the progress on a regular basis. ■

Announcements

IEEE International Conference on Robotics and Automation, ICRA 2010

May 3-8, Anchorage, ALASKA

ⓘ **http://icra2010.grasp.upenn.edu/**

Papers: 15 September 2009
Notification: 7 January 2010
Final Contributions: 8 February 2010

5th ACM/IEEE International Conference on Human-Robot Interaction, HRI 2010

March 2-5, Osaka, JAPAN

ⓘ **http://hri2010.org/**

Papers: 27 September 2009
Video and late-breaking reports: 15 Dec.2009

CPSWEEK

April 12-16, 2010, Stockholm, SWEDEN,

ⓘ **http://www.cpsweek2010.se/**

The CPSWeek brings together four leading conferences – HSCC, IPSN, LCTES, and RTAS – as well as several workshops and tutorials on various aspects on the research and development of cyber-physical systems: Embedded Systems, Hybrid Systems, Real-Time and Sensor Networks.

16th IEEE Real-Time and Embedded Technology and Applications Symposium, RTAS 2010

April 12-15, 2010, Stockholm, SWEDEN,

ⓘ **http://www.rtas.org/**

Papers: 5 October 2009
Notification: 18 December 2009
Camera-ready: 22 January 2010

7th European Conference on Wireless Sensor Networks, EWSN 2010

17-19 February, Coimbra, PORTUGAL

ⓘ **http://ewsn2010.uc.pt/**

Registration: 5 October 2009
Papers: 12 October 2009
Notification: 30 November 2009
Camera-ready: 11 December 2009

First International Workshop on the Web of Things, WoT 2010
March 29, 2010, Mannheim, GERMANY

ⓘ **http://www.webofthings.com/wot/2010/WoT_2010_cfp.txt**

Papers: 18 October 2009
Notification: 21 December 2009
Camera-ready: 22 January 2009

International Conference on Information Processing in Sensor Networks, IPSN 2010

April 12-16, 2010, Stockholm, SWEDEN,

ⓘ **http://ipsn.acm.org/2010/**

Abstract deadline: 23 October, 2009
Full papers due: 30 October, 2009
Author notification: 22 January, 2010
Camera ready due: 19 February, 2010

8th IEEE International Workshop On Factory Communication Systems, WFCS 2010

May 18-21, Nancy, FRANCE

ⓘ **http://wfcs2010.loria.fr/**

Regular Papers: 13 November, 2009
Notification: 23 February, 2010
Work in progress Papers: 1 March, 2010
Notification: 6 April, 2010
Final Contributions (RP & WIP): 12 April, 2010

IEEE/ASME International Conference on Advanced Intelligent Mechatronic, AIM 2010

July 6-9, Montreal CANADA

ⓘ **https://engineering.purdue.edu/AIM2010/**

Papers: 1st February 2010
Notification: 7 April 2010
Final Contributions: 30 April 2010

19th European Conference on Artificial Intelligence, ECAI 2010

August 16-20, Lisbon, PORTUGAL

ⓘ **http://ecai2010.appia.pt/**

Abstract deadline: 15 February 2010
Papers: 22 February 2010
Notification: 30 April 2010
Camera-ready: 28 May 2010

IEEE/RSJ International Conference on Intelligent Robots and Systems, IROS 2010

October 18-22, Taipei, TAIWAN

ⓘ **http://www.iros.org/**

Papers: 28 February 2010
Notification: 15 June 2010
Camera-ready: 15 July 2010

Latest News

- **CONet** has been invited to present the project and the related activities at the **EU-Brazil - Networked Embedded Intelligence Workshop**, on 9 September 2009, in São Paulo, Brazil. AICIA on behalf of CONet consortium gave a general presentation about the Cooperating Objects Network of Excellence and also presented a poster.
- The Chairs of the 7th European Conference on Wireless Sensor Networks (EWSN 2010) and the CONET Consortium are pleased to announce the **Master and PhD Thesis Award Competitions** in the area of Cooperating Objects. The prize is donated by CONET. Details in: http://www.cooperating-objects.eu/
- The **Cooperating Objects Roadmap** is now officially available for public download, see http://www.cooperating-objects.eu/roadmap/download/

Register @ http://www.cooperating-objects.eu/ to receive future issues of the CONET Newsletter