WITAS

Wallenberg Laboratory for
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Dialogue Technologies and Cognitive Autonomous Systems

Overview and Publications

Related information can be obtained via the following WWW pages:

Linköping university:	http://www.liu.se/
WITAS Project:	http://www.ida.liu.se/ext/witas/
Author's Department:	http://www.ida.liu.se/
The author:	http://www.ida.liu.se/~erisa/

WITAS Phase I (1997-1999) addressed only the fully autonomous UAV, which could be given a goal at the beginning of its mission and which would then execute it without any further interactions with its operator. One of the extensions at the beginning of Phase II (2000-2003) was for the development of a dialogue subsystem whereby an operator can interact with the UAV during the mission. The term 'dialogue' refers to communication where spoken natural language is the primary modality, and where the interactions may express a variety of message types, such as high-level action commands ('fly to X'), exchanging observations in both directions between operator and UAV, proposing plans, reporting on the progress in the execution of actions and plans, and revising those plans. In other words, the dialogue is not restricted to direct remote control of the vehicle. Research activities towards that goal are conducted in the Dialogue Technologies branch of the project, which has had two parts:

- The WITAS-Stanford dialogue activity at Semlab, CSLI, Stanford, participating during 2000-2002
- The WITAS-Linköping dialogue activity in CASL, IDA, Linköping, together with partners, participating since late 2002.

The WITAS-Linköping dialogue activity is based both on its predecessor at Stanford, and on earlier work in a research agenda for cognitive autonomous systems that Erik Sandewall has been pursuing on a mostly individual basis before CASL was formed.

In the future, and assuming that the WITAS project can continue, we wish to address the 'network' scenario, where there are several UAV's, other autonomous vehicles, and/or sensor stations, as well as several operators in the various network nodes. This network scenario has ramifications for the dialogue, and the requirement of a dialogue has ramifications for some aspects of the network. During the period reported here we have not had any demonstrator-oriented activity with a network perspective. We have however prepared for that topic by building up cooperation with partners that contribute potentially relevant knowledge in the area. We also have some activities in the Linköping group that may appear marginal from the point of view of the present dialogue system, but which may become very useful when we go to the network level.

One particular aspect of the network scenario is that the system shall have a long period of operation, i.e., at least several months. This is unsurprising from the point of view of database technology, for example, but it is an aspect that is not regularly addressed in AI (artificial intelligence) and KR (knowledge representation) contexts. To what extent will current KR techniques have to be modified if they are to be used in autonomous operator's assistants that have to work for six months without interruption? Some of the present activities have been chosen so that we begin to familiarize ourselves with that problem.

The present memo gives an overview of these activities. More detailed information for the Stanford dialogue-system activity can be found in the memo "Multi-Modal Interface to an Autonomous UAV". More detailed information about the Linköping dialogue-system activity as well as the research agenda for cognitive autonomous systems can be found in the memo "Cognitive Autonomous Systems and the DOSAR Dialogue-System Project".

Publication lists are at the end of the present memo. Transcripts of dialogues are provided as attachments of the two other memos.

1 Dialogue System Demonstrators

1.1 The WITAS-Stanford Dialogue-System Project, 2000 - 2002

This project was performed at the Center for the Study of Language and Information (CSLI) at Stanford University, under the direction of Professor Stanley Peters, and with Dr. Oliver Lemon as the project leader. The system goal of this project was to develop a system for spoken (speech-in, speech-out) and graphic interaction between an operator and the WITAS UAV for the purpose of giving high-level commands to the UAV, for obtaining information about its observations, and for other interactions that may arise in the same context. The system includes a graphic user interface (GUI) which is auxiliary to the spoken interaction. Research goals included, in particular, developing a systematic approach to dialogue systems for interactions with real-world robots, and ensuing problems such as:

- communication about the physical actions of the robots, including both on-going actions, past actions, and intended future actions
- communication using spatial concepts, referring to the location of the UAV itself and to the objects that it observes on the ground
- multi-initiative dialogue resulting from the fact that both the operator and the UAV itself may initiate dialogue threads

A system of this kind was developed and delivered within the given timeframe, in September, 2002. The integration with other WITAS systems has been done in Linköping during 2003. The WITAS major result demonstration in October, 2003 included a demonstration of this system in the lecture room. The intended demo where the Stanford system actually commands the WITAS UAV during a flight has had to be postponed, but offers no difficulties in principle as far as we can see.

The work towards the research goals has also been successful, as witnessed by a number of publications in high-quality conferences as well as a journal article. The list of publications is found at the end of this memo.

A more detailed account of the WITAS-Stanford Dialogue-System Project and its results can be found in the memo "Multi-Modal Interface to an Autonomous UAV", which is attached to the present report.

1.2 The DOSAR Dialogue-System Project, 2003 - 2005?

This project is conducted in the Laboratory for Cognitive Autonomous Systems (CASL) at Linköping University, led by Professor Erik Sandewall, and building on the results from the WITAS-Stanford dialogue-system project. Besides the research per se, the DOSAR dialogue-system project aims at developing a system with the following characteristics in addition to those of the WITAS-Stanford system:

- Closer integration with the behavior and the dynamic parameters of the UAV and its on-board system, in particular, the video camera.
- Network awareness: dialogue shall occur in a network containing numerous dialogue agents and numerous UAV:s and other robotic systems.
- Longevity: each dialogue agent shall be capable of operating during a long time, at least for months, and shall maintain a memory of events during that period.

DOSAR was initially an acronym for 'Dialogue-Oriented Simulation And Reasoning'.

An additional consideration was that we wished to take home, to the extent possible, the know-how that had been built up during the project phase at Stanford.

Research goals of the DOSAR dialogue-system project include the study and development of software architecture principles for robotic dialogue agents, and the study of knowledge representations for such agents including logics of spatiotemporal phenomena, action, and change.

The network awareness and longevity goals imply several more concrete goals on various levels:

- Capability, for the dialogue agent, of interacting both with persons and with one or more other computerized dialogue agents. This requires appropriate interfaces and protocols as well as extensions to the dialogue management facility.
- Use of a database as long-term memory for actions, events, and observed facts that are recorded locally by each dialogue agent.
- Use of a Geographic Information System (GIS) and other joint information resources in the network.
- Ability, for the dialogue agents, of producing and interpreting descriptions of objects and events in terms that are jointly known between the participants in the dialogue.

These project goals pertain to the multi-year perspective that started in 2003 and extends at least into 2005. During its first year the project has developed an initial system with two goals in mind: the system should be incorporated into a scenario in the WITAS major result demonstration in October, 2003, and it should be an appropriate basis for continued work. The development of the initial system was therefore combined with a study of architectural issues.

Additional details about the approach that is being pursued for the DOSAR dialogue system is found in the memo "Cognitive Autonomous Systems and the DOSAR Dialogue-System Project", which is attached to this report. For natural reasons there is so far only one publication from this work, written in order to inform about the activity rather than to report major results.

1.3 Support activities

The work on dialogue systems also includes the following support activities. They serve both the main activities (Stanford project and DOSAR).

The DOSAR simulator (2000-2002). For the development of the dialogue system, it was necessary to have a simple simulator of a UAV and of suitable ground phenomena, in particular, automobile movements. The requirements on this simulator were different from those of the main WITAS simulator. For example, very simple algorithms for UAV flight are deemed sufficient as long as the only purpose is to run the dialogue against the simulated UAV. But on the other hand, in order to have a realistic distribution of tasks between the dialogue manager and the UAV, we needed a UAV simulator that provided some high-level control facilities for the (simulated) UAV well before the same were available to us in the actual on-board system. This included, for example, the capability to execute composite actions consisting of several steps, and to generate events from observation of the ground.

A separate simulator was therefore implemented, to be used as a development tool for the dialogue system. It is based on the Software Individuals Architecture and implements some aspects of the Double Helix Architecture. (Both of these will be described in section 2). The work was done in Linköping by Erik Sandewall with the help of several students in summer projects, and more recently by M.Sc. Karolina Eliasson.

The DOSAR Visualizer (2003). The simulation of the helicopter and associated ground phenomena must be accompanied by a visualizer so that the researcher or a visitor can easily see and understand the situations that occur in the course of the dialogue. The first visualizer was written in 2001. The presently used visualizer is at the same time a pilot experiment using the DeeDS distributed real-time database. This system has been developed at the University of Skövde under the direction of Professor Sten F. Andler. The visualizer has been implemented by Mr. Henrik Grimm.

Equipment platforms for dialogue in the field (continuously). It is part of our goals to experiment with, and to demonstrate our dialogue systems as well integrated subsystems when the UAV performs actual flights in realistic environments, in particular, in the Revinge testing-grounds. This requires the use of a ground station that serves as an intermediary between the UAV and the ground operator. Some of the computing equipment is also best located at the ground station, in particular for video recording and playback as requested by the operator.

We have also built a specialized 'backpack' for use in those situations when the operator communicates with the UAV while walking around. The backpack provides arrangements for graphical tablet, microphone and external sound card, wireless communication, and so forth. These facilities have been developed by Ms. Coynthia Hernandez and M.Sc. Tobias Nurmiranta under the direction of Erik Sandewall.

The Dosar-to-Witas switch (2003). Allowing for concurrent engineering has been an important consideration for the WITAS project as a whole. Subsystems that depend on each other have to be developed concurrently, which means that at least one of them has to work with a simulator that is used in place of the the other system while both are being developed. The

DOSAR simulator is one such placeholder.

As a consequence, we also needed a method whereby the dialogue systems can switch transparently between the DOSAR simulator, the WITAS simulator which is a precise simulator for the WITAS UAV, and finally the WITAS UAV itself as represented by its ground station. The Dosar-to-Witas switch (D2W) performs this essential task. It allows four parties to communicate:

- The dialogue subsystem, which can be either the WITAS-Stanford dialogue system or the DOSAR dialogue system
- The DOSAR simulator
- The ground-station DOR (Dynamic Object Repository) of the WITAS UAV system or its simulator
- The WITAS GIS system.

The Dosar-to-Witas switch has been developed by M.Sc. Peter Andersson.

2 Research on Cognitive Autonomous Systems

The following are the main categories in our research agenda for cognitive autonomous systems (CAS).

Cognitive Robotics Logic (CRL). This work is based on my research monograph 'Features and Fluents' from 1994, where I propose an underlying semantics for logics of actions and change, and use it for assessing the range of applicability of a number of nonmonotonic logics (more precisely: nonmonotonic entailment conditions) for actions and change. After that and also during Phase I of WITAS, I studied what would be needed for using a logic of this kind for characterizing sensoric and motoric processes in a cognitive robot, and also for characterizing goal-directed behavior there. This suggested a number of extensions to the logic that was used in the monograph, and I adopted the name 'Cognitive Robotics Logic' (CRL) for the resulting logic with those extensions.

Functions and architecture for CAS. One of the results here is the Double Helix Architecture (DHA) which is an abstract architecture (not an actual software system) that attempts to characterize the relationship between a robotic system and a logic of actions and change. It is intended that this characterization shall be useful both for defining a sufficiently rich semantics for actions and change, and as a guideline for future implementations. The relationship between the DOSAR simulator and the DOSAR dialogue manager has taken some ideas from the DHA, but there is not a full correspondence. We intend to continue the work by contrasting an idealized concept, such as the DHA, with the grounding in reality that emerges from software development of nontrivial size.

Software Infrastructure for CAS. The main result here is the Software Individuals Architecture (SIA). By a 'software individual' I mean an aggregate of data and programs that is capable of long life (months, years), capable of modelling its own structure, of self-modification, knowledge acquisition from peers, and non-trivial reproduction. A prototype kernel system has been designed, used for several applications, and then revised repeatedly. The DOSAR simulator and the DOSAR dialogue manager are both based on the SIA platform.

More details about these activities are in the memo "Cognitive Autonomous Systems and the DOSAR Dialogue-System Project: Details of Activities".

3 Network-Oriented Activities

WITAS as a whole is characterized by being both goal-directed and long-range. The support activities described above were goal-directed but not long-range, and it is natural that we should also have some activities in areas that are of long-range interest even though they do not contribute at all or only indirectly to the demonstrator goal of the present project period. This applies in particular for the following three activities, all of which prepare for a future extension towards network-centric systems.

3.1 The DeeDS distributed realtime database (2001-present)

This work is done at the University of Skövde, directed by Professor Sten F. Andler and with in addition M.Sc. Marcus Brohede and Mr. Henrik Grimm as key participants. It investigates the possibility of using a real-time database, and in particular the DeeDS distributed realtime database that has been developed by their group in Skövde, as a medium for shared information in a robotic dialogue system. The use of distributed realtime databases is of particular interest in a networked environment with multiple users and multiple robotic systems, UAV's or otherwise.

As a first step, DeeDS was used for implementing the visualizer for the DOSAR simulator that was mentioned above. This visualizer was used to illustrate the dialogue scenario in the WITAS major result demonstration in October, 2003. Besides its practical usefulness, this work also served to acquaint the DeeDS team in Skövde and the DOSAR team in Linköping with each other's systems.

3.2 Web resource objects (since mid 1990's, continuing)

Information objects of the kinds that we usually associate with office systems, such as memos, emails, webpages, and tables, will in fact also be important in a network of many UAV's and other robotic systems, as well as many operators. Operators will need to work with such information objects at the same time as they relate to the robotic agents, and information that is gathered by those agents will often have to be digested, aggregated, and presented to users with different needs.

Some aspects of our earlier and present work on the principles for 'office information systems' is therefore likely to be relevant when the Dialogue Technologies Group proceeds from dialogues with a single UAV, to dialogues in a network. This work is nowadays based on the Software Individuals Architecture, which is the same platform as is used for the DOSAR dialogue system. One recent result in this area has been the development of a software tool for high-level, object-oriented definition of active web pages in the spirit of the semantic web. The first use of this tool, called WRDL (Web Resource Definition Language) has been for implementing services for the editorial board of a major scientific journal. We see a use for it in our future work on networked dialogue systems as well.

3.3 Modelling object-oriented dynamic systems (since mid 1990's, continuing)

Dr. Choong-ho Yi presented his Ph.D. thesis *Modelling Object-Oriented Dynamic Systems Using a Logic-Based Framework* in Linköping in 2002. He had done his licentiate work in Linköping and then moved to the University of Karlstad, and further on to the Swedish Defence Research Agency (FOI) in Stockholm. The contact was maintained since Erik Sandewall was the thesis advisor also for the Ph.D. work, defining him as an affiliate of WITAS.

Dr. Yi's thesis consists of two parts. In the first part he relates two major modelling formalisms, the Universal Modelling Language (UML) and the Statecharts formalism, to a logic of actions and change that is derived from 'Features and Fluents' and related to CRL. In the second part he uses these results as a basis for an approach to reasoning about goal-directed behavior in enterprises.

The application used in Dr. Yi's work was chosen because of the interests in his academic environment in Karlstad, and may appear different from the one that occurs in WITAS. However, the basic problems of object-oriented modelling and goal-orientation are similar, and the formal basis is the same as we use in the DOSAR part of WITAS. In his present employment at FOI, Dr. Yi is engaged in projects that are quite close to our forthcoming, network-oriented activities, and increased cooperation with him and his group at FOI is being planned.

4 Refereed and invited publications

Ph.D., licentiate, and masters theses are also included, but preceded by an asterisk. (The Swedish 'licentiate' degree is a research degree considered to be half-way to a doctorate).

4.1 Joint WITAS publications

Patrick Doherty, Gösta Granlund, Krzysztof Kuchcinski, Erik Sandewall, Klas Nordberg, Erik Skarman, and Johan Wiklund. The WITAS Unmanned Aerial Vehicle Project. In: Werner Horn (ed): European Conference on Artificial Intelligence (ECAI), 2000, pp. 747-755. Invited paper.

Erik Sandewall, Patrick Doherty, Oliver Lemon, and Stanley Peters. Words at the Right Time: Real-Time Dialogues with the WITAS Unmanned Aerial Vehicle. In: Andreas Günter et al (eds), KI 2003: Proceedings of the 26th Annual German Conference on AI, pp. 52-63. Springer, 2003. Invited paper.

4.2 The Stanford-WITAS project

Oliver Lemon, Alexander Gruenstein, and Stanley Peters. Collaborative Activities and Multi-tasking in Dialogue Systems. Traitement Automatique des Langues (TAL), 43(2):131-154, special issue on dialogue, 2002.

Oliver Lemon, Anne Bracy, Alexander Gruenstein, and Stanley Peters. An information state approach in a multi-modal dialogue system for human-robot conversation. In: Hannes Rieser, Peter Kühnlein and Henk Zeevat (eds.), Perspectives on Dialogue in the New Millenium, pp. 229-242. Pragmatics and Beyond Series No. 114, John Benjamins, Amsterdam, 2003.

Oliver Lemon, Alexander Gruenstein, Randolph Gullett, Alexis Battle, Laura Hiatt, and Stanley Peters. Generation of collaborative spoken dialogue contributions in dynamic task environments. In: Reva Freedman and Charles Callaway (eds), Working Papers of the 2003 AAAI Spring Symposium on Natural Language Generation in Spoken and Written Dialogue, pp 85-90. AAAI Press, Menlo Park, California, 2003.

Hockey, B.A., Lemon, O., Campana, E., Hiatt, L., Aist, G., Hieronymus, J., Gruenstein, A., and Dowding, J. Targeted help for spoken dialogue systems: Intelligent feedback improves naïve users' performance. In the Proceedings of the 11th Conference of the European Chapter of the Association for Computational Linguistics (EACL), Budapest, Hungary, 2003.

Oliver Lemon, Alexander Gruenstein, Lawrence Cavedon, and Stanley Peters. Collaborative Dialogue for Controlling Autonomous Systems. In the proceedings of AAAI Fall Symposium, 2002.

Oliver Lemon, Alexander Gruenstein, Alexis Battle, and Stanley Peters. Multi-tasking and Collaborative Activities in Dialogue Systems. In the proceedings of 3rd SIGdial Workshop on Discourse and Dialogue, Philadelphia, pp 113-124, 2002.

Oliver Lemon, Prashant Parikh, and Stanley Peters. Probabilistic Dialogue Modelling. In the proceedings of 3rd SIGdial Workshop on Discourse and Dialogue, 2002.

Beth-Ann Hockey, Gregory Aist, Jim Hieronymous, Oliver Lemon, and John Dowding. Targeted Help: Embedded training and methods for evaluation. In the proceedings of Intelligent Tutoring Systems (ITS), 2002.

Oliver Lemon, Alexander Gruenstein, Alexis Battle, Elizabeth Bratt, and Stanley Peters. Multi-tasking in Practical Multi-modal Dialogue Systems. In the proceedings of the Association for Computational Linguistics conference (ACL), 2002.

Oliver Lemon. Transferable Multi-modal Dialogue Systems for Interactive Entertainment. In the proceedings of the AAAI Spring Symposium on Artificial Intelligence in Interactive Entertainment, 2002.

Oliver Lemon. Language Resources for Multi-modal Dialogue Systems. In the proceedings of LREC, 2002.

Brady Clark, Elizabeth Owen Bratt, Oliver Lemon, Stanley Peters, Heather Pon-Barry, Zack Thomsen-Gray, and Pucktada Treeratpituk. A General Purpose Architecture for Intelligent Tutoring Systems. In the proceedings of the CLASS workshop, 2002.

Oliver Lemon, Anne Bracy, Alexander Gruenstein, and Stanley Peters. Information States in a Multi-modal Dialogue System for Human-Robot Conversation. In the proceedings of 'Bi-Dialog', 5th Workshop on Formal Semantics and Pragmatics of Dialogue, pp 57 - 67, 2001.

Oliver Lemon, Anne Bracy, Alexander Gruenstein, and Stanley Peters. A Multi-Modal Dialogue System for Human-Robot Conversation (demonstration system). In the proceedings of NAACL 2001.

Oliver Lemon, Anne Bracy, Alexander Gruenstein, and Stanley Peters. The WITAS Multi-Modal Dialogue System I. In the proceedings of EuroSpeech, 2001.

Oliver Lemon, Anne Bracy, Alexander Gruenstein, and Stanley Peters. Multi-Modal Dialogue Systems Supporting Human-Robot Communication. In the proceedings of the 5th World Multi-Conference on Systemics, Cybernetics and Informatics (SCI), 2001.

*Alexander Gruenstein. Conversational Interfaces: A Domain-Independent Architecture for Task-Oriented Dialogues. M.Sc. Thesis, December 2002.

4.3 Linköping: CASL and DOSAR

4.3.1 Cognitive Robotics Logic

Erik Sandewall. Underlying semantics for actions and change with ramification. In: Oliviero Stock (ed), Spatial and Temporal Reasoning, pp 289-318. Kluwer, 1997.

Erik Sandewall. Cognitive Robotics Logic and its Metatheory: Features and Fluents Revisited. Electronic Transactions on Artificial Intelligence, Vol. 2 (1998), Issue 3-4, pp. 307-329. http://www.ep.liu.se/ej/etai/1998/010/.

Erik Sandewall. Relating high-level and low-level action descriptions in a logic of actions and change. In: Oded Maler (ed), Hybrid and real-time systems. International workshop, HART-97, pp 3-18. Springer Verlag, 1997.

4.3.2 Functions and architecture in CAS

Erik Sandewall. Logic-Based Modelling of Goal-Directed Behavior. Electronic Transactions on Artificial Intelligence, Vol. 1 (1997), Issue 4, pp. 105-128. http://www.ep.liu.se/ej/etai/1997/005/.

Erik Sandewall. The Logical Characterization of Goal-Directed Behavior in the Presence of Exogenous Events. In: Jürgen Dix et al (eds), Logics in Artificial Intelligence, Proceedings of the JELIA 1998 conference, pp. 382-384. Springer Verlag. (Invited talk, extended abstract).

Erik Sandewall. Logic-Based Modelling of Goal-Directed Behavior. Proc. International Conference on Knowledge Representation and Reasoning, 1998, pp. 304-315.

Erik Sandewall. Use of cognitive robotics logic in a double helix architecture for autonomous systems. In: Michael Beetz et al. (eds), Advances in Plan-Based Control of Robotic Agents, pp. 226-248, Proceedings from a Dagstuhl workshop, 2001, Springer Verlag.

[Erik Sandewall. What's in a decision. Unpublished manuscript].

4.3.3 Software infrastructure for CAS

Erik Sandewall. On the Design of Software Individuals. Electronic Transactions on Artificial Intelligence, Vol. 5 (2001), Section B, pp. 143-160. http://www.ep.liu.se/ej/etai/2001/009/.

Erik Sandewall. A software architecture for AI systems based on self-modifying software individuals. International Conference on Lisp, New York, NY, October, 2003. (Accepted to the conference without a referee's report, status as refereed article uncertain).

Erik Sandewall. High-level design of web servers in Allegro CommonLisp. International Conference on Lisp, New York, NY, October, 2003. (Accepted to the conference without a referee's report, status as refereed article uncertain).

4.3.4 Software tools for DOSAR

*Tomas Johansson and Kristian Nilsson. 3D-representation, dynamiska händelser och deras effekter på dialogsystemet i WITAS. (3D Representation, dynamic events and their effects on the dialogue system in WITAS). M.Sc. thesis, 2003.

4.3.5 Electronic publication

Besides the WITAS activity, Erik Sandewall has also been engaged in the creation and operation of ETAI, the Electronic Transactions on Artificial

Intelligence. This journal has pioneered a novel, Internet-based interactive reviewing scheme. The WITAS Board has approved that some WITAS funds can be used to support the operation of ETAI.

Erik Sandewall. Publishing and Reviewing in the ETAI. Electronic Transactions on Artificial Intelligence, Vol. 1, Nr, 1 (1997), pp. 1-12. (Editorial Note).

[Committee report, six authors]. Defining and Certifying Electronic Publication in Science. Learned Publishing, Vol. 13, No. 4, October, 2000, pp 251-258.

Erik Sandewall. Open Reviewing, Closed Refereeing: Where is the Publication?. In: E.H. Fredriksson (ed), A Century of Science Publishing. IOS Press, 2001.

4.3.6 Theory of computation

Erik Sandewall. An Early Use of Continuations and Partial Evaluation for Compiling Rules Written in First-Order Predicate Calculus. Higher-Order and Symbolic Computation, Volume 12, Number 1, 1999, pp 105-113. (A review of work we did in the early 1970's).

4.3.7 Persistent computation

*Tobias Nurmiranta. System för persistenta datastrukturer med skräpsamling baserat på IA32-arkitekturen. (System for persistent data structures with garbage collection based on the IA32 architecture). M.Sc. thesis, 2002.

4.4 Skövde: DeeDS Project

The following lists papers by those persons in Skövde that have participated in the cooperation with WITAS, and during the period of that cooperation.

Brohede, M. and Andler, S. F. Distributed Real-Time Database support for HLA (03E-SIW-009). In the European Simulation Interoperability Workshop, Stockholm, Sweden, 2003.

Ericsson, A., N. R. and Andler, F. S. Operator patterns for analysis of composite events in timed automata. In the 24th IEEE International Real-Time Systems Symposium, Cancun, Mexico, 2003. To appear.

Mathiason, G. and Andler, S. Virtual full replication: Achieving scalability in distributed real-time main-memory systems. In Euromicro Conference on Real-Time Systems '03, WiP session, pages 33-36, Porto, Portugal, 2003.

Brohede, M. and Andler, S. F. Distributed Simulation Communication through an Active Real-Time Database. In the 27th Annual NASA Goddard Software Engineering Workshop (IEEE/NASA SEW-27), pp 147-155, Greenbelt, MD. IEEE, 2002.

Gustavsson, S. and Andler, S. Self-stabilization and eventual consistency in replicated real-time databases. In the 1st ACM SIGSOFT Workshop on Self-Healing Systems (WOSS '02), pp 105-107, Charleston, SC, USA, 2002.

Lindström, B. Mellin, J. and Andler, S. Testability of dynamic real-time systems. In the 8th International Conference on Real-Time Computing Systems and Applications (RTCSA 2002), pp 93-97, Tokyo, Japan, 2002.

Mellin, J. and Andler, S. A formalized schema for event composition. In the 8th International Conference on Real-Time Computing Systems and Applications (RTCSA 2002), pp 201-210, Tokyo, Japan, 2002.

Nilsson, R.A.S., and Mellin, J. Towards a framework for automated testing of transaction-based real-time systems. In the 8th International Conference on Real-Time Computing Systems and Applications (RTCSA 2002), pp 109-113, Tokyo, Japan, 2002.

*Brohede, M. Real-time database support for distributed real-time simulations. M.Sc. thesis, University of Skövde, 2001.

*Mathiason, G. Segmentation in a distributed real-time main-memory database. M.Sc. thesis, University of Skövde, 2002.

4.5 Choong-ho Yi: Modelling Object-Oriented Dynamic Systems

Please see subsection 3.3 above for an explanation of Dr. Choong-ho Yi's affiliation with WITAS. The following are his publications since 1997.

*Choong-ho Yi. Modelling Object-Oriented Dynamic Systems Using a Logic-Based Framework. Ph.D. thesis, Linköping University, Computer Science Department, 2002.

Choong-ho Yi. A framework for representing and reasoning with information systems. In: Proceedings of the 10th International Conference of the Information Resources Management Association, Pennsylvania, USA, 1999.

Choong-ho Yi and P. Johannesson. Beyond goal representation: Checking goal satisfaction by temporal reasoning with business processes. In: M. Jarke and A. Oberweis (eds), Proceedings of CAiSE'99, 11th International Conference on Advanced Information Systems Engineering. LNCS 1626, Springer Verlag, 1999.

Choong-ho Yi and P. Johannesson. A many-sorted temporal logic for reasoning with business goals. In: Proceedings of Workshop on Futures in Information Systems and Software Engineering Research 1999, Stockholm, 1999.

Choong-ho Yi. Representing and reasoning with scenarios within information systems modelling. In: Proceedings of the 11th International Conference of the Information Resources Management Association, Pennsylvania, USA, 2000.