SEEDS — Simulation Environment for the Evaluation of Distributed Traffic Control Systems

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Abstract. The goal of the SEEDS project is to develop a simulation environment for the analysis and evaluation of distributed traffic control systems. It provides a general purpose tool kit for the simulation of applications like e.g. air and maritime traffic control systems. The environment will be composed of a cluster of workstations running the distributed simulator software. HPCN issues will be considered in order to set up a suitable HW/SW environment for the simulator.

1 Introduction

In the SEEDS project an open distributed interactive Simulation Environment (SE) for the analysis and evaluation of distributed traffic control systems is designed, set-up and tested. The SE provides a general purpose tool kit for the simulation of a wide range of industrial applications of strategic relevance, such as air and maritime traffic control systems.

In the frame of this project the application area chosen as case study is the ground traffic control in airports, that is the A-SMGCS (Advanced Surface Movement Guidance and Control System).

This system is devoted to support the safe, orderly and expeditious movement of aircrafts and vehicles on aerodromes under all circumstances and will be installed in airports or will replace/upgrade the existing ones to provide adequate capacity and safety in relation to the ever growing traffic density and bad weather conditions. The A-SMGCS has to be designed so as to facilitate its integration in existing systems in order that current investments are taking place in a cost-effective way.

Current research on air traffic management states that the limiting factors for the future of air traffic evolution are in principle the procedures for traffic management at airports, because new strategies are going to be applied for en-route traffic (ADS, free flight, etc.) which allow an increment of traffic efficiency.

Several international organisations, such as ICAO, are leading a standardisation effort for surface operations in airports through the FANS (Future Air Navigation System) Committee. With regard to Europe EU has started ECARDA (European Coherent Approach to Research and Technological Development for Air Traffic Management), in the frame of the Fourth Framework Programme; ECAC (European Civil Aviation Conference) has proposed the EATMS (European Air Traffic Management System) in the frame of the EATCHIP (European Air Traffic Control Harmonisation and Integration Programme), whose aim is the harmonisation among all the European air traffic services; EUROCONTROL is implementing EATCHIP and is going to put into effect EATMS.

The project is partially funded by the European Community in the Information Technology Programme: High Performance Computing and Networking task 6.2; the duration of the project is 30 months. The consortium, which is in charge of the project, is composed of Alenia (I), as co-ordinator, Sogitec (F), Rigel (B), as industrial partners, University of Siena (I) and Technical University of Munich (D), as associated partners, and Sicta (I) as final user-partner. Sicta is a consortium including as partner Enav (Italian Agency for Air Traffic Services). An European User Group (UG), composed of airport service and/or flight assistance Administrations, participates to all the phases of the project as associated partners of Sicta. Sogel working for Airport of Luxembourg and SEA (Società Esercizio Aeroportuale) of Milan Airport are members of the UG.

2 Simulation Environment

The SE is composed of powerful commercial workstations connected through a high performance LAN to cope with the application requirements. The use of HPCN is mandatory for this kind of application system because of the power capacity requested to simulate the distributed application environment where a team of human operators should co-operate. Heterogeneity of the HW and SW components of the SE should be faced; suitable programming paradigms have to be adopted to design and configure a portable, powerful, flexible and low-cost HPCN system in which should be possible to collect statistics and analyse performance, to generate 3-D high resolution scenarios and to organise distributed data-bases.

The basic functions supported by SE are traffic generator, actors' modelling and decision support tools. The traffic generator produces the scenario as seen by various actors using different set of sensors (eye, radar, camera, GPS, etc.) with the fidelity and accuracy of real world. Interactions which modify the predefined evolution of simulation are allowed. The actors' modelling simulates the behaviours of various actors at airport (pilots, controllers, drivers) and of the external world (airlines, airport managers, weather data, etc.): it is possible to mould new behaviours, to define new actors and to modify the stimuli of the external world . The decision support tools are introduced to help operators in the decision making process, which today relies only on the operator's mental capacity: many tasks, such as planning, re-planning, guidance can benefit of suggestions or decisions from automatic tools.

The SE does not reproduce a complete A-SMGCS but it is a friendly platform which can be used to introduce new values into traditional systems and is a support for various aspects of A-SMGCS design: change or redefinition of airport lay-out, definition of new procedures and their validation, simulation of new behaviours and interfaces. It is a validation environment for A-SMGCS defined by international organisations and it can be used for training purposes to allow traffic operators to learn new procedures and interfaces without interfere with the operativity of the real system.

In the future a complete A-SMGCS could be mapped onto the SE to test and validate a full system.

A test case suite is defined to verify the performance and to validate the SE at two typical airports: these test cases are potentially capable to represent the overall requirements, applications and operational realities.

3 SEEDS Functional Units

The SE is a distributed, modular, expandable, flexible and interactive HPCN architecture; it is composed of commercial off-the-shelf components and is open to be connected to other simulators.

The main functional units are:

- Scenario generation (SG): the sensors used at airports (radar, camera, eye, GPS, etc.) are modelled and the scenario is generated with the fidelity and accuracy of real world. The same scene can be viewed at the same time by different actors, using different set of sensors.
- Surveillance: a module to provide an accurate report and monitoring of all the movements within the aerodrome is produced to perform constraint checking in order to detect critical events and conflicts.
- Planning: tools to optimise taxi routes, traffic sequences and co-ordinate arrivals and departures are available to help operators in their routinely work. These tools are able to perform a re-planning to face critical situations or deviations.
- Guidance: this function provides all concerned operators with the methods of guiding aircraft and vehicles on the movement area from their current position to the intended destination in a fully automatic mode.
- Airport actors' modelling: the behaviours of the actors in an airport are simulated. They can interact with each other exchanging messages and commands with the possibility of modifying the evolution of the simulation session.
- Administration station: this subsystem configures the application and starts-up the simulation session, collecting performance measurements and statistics

Fig.1 shows a schema of the simulator environment as reported: it contains the main actors of the airport and the principal modules of the simulator.

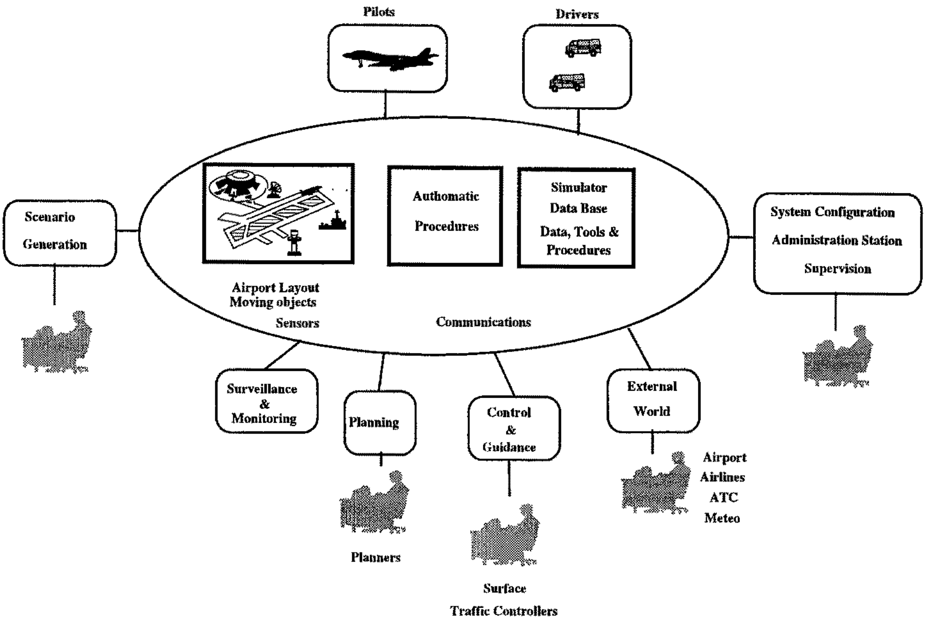

Fig. 1. Simulation environment: main actors and principal modules

4 Integration of HPCN Concepts

HPCN technology is needed to cope with the performance requirements of the application system. To realise a flexible and modular SE a network of powerful graphic workstations, on which the different actor models, scenario generation engine, and monitoring and supervision functions are mapped, is the most suitable architecture.

In defining such an SE architecture some requirements derived from industrial constraints should be taken into account: standard off-the-shelf platforms, that is commercial workstations with graphic features and largely diffused software tools, should be considered to obtain the following objective: to design and configure a portable, powerful, flexible and low-cost HPCN system in which it should be possible to collect statistics and analyse performance, to generate 3-D high resolution scenarios, and to organise a distributed data base. In particular the following HPCN related issues have to be investigated concerning their suitability for our project:

- environments for heterogeneous network computing: CORBA (Common Object Request Broker Architecture) and DCE (Distributed Computing Environment);
- distributed programming models like PVM (Parallel Virtual Machine) and MPI (Message Passing Interface);
- tools for debugging distributed programs;
- performance analysis tools for distributed applications;

- run time support tools for load and resource management;
- distributed data base systems;
- efficient network facilities such as FDDI, ATM, and Fast Ethernet.

In fact the composition of such a simulator environment has to be carefully planned as it comprises heterogeneous HW and SW components. A well balanced design of the SE should combine well known techniques from HPCN with standardised components suitable for commercial products. First a requirement analysis has to be performed to identify HW, SW, and performance related constraints of the SE. Especially performance issues like throughput, response time, and system load have to be considered carefully.

A HPCN oriented design of the SE will at first have to consider the degree of internal heterogeneity. Different workstation types with different operating systems will be used. An appropriate programming model for SW design and implementation has to be selected. High level programming paradigms like CORBA and DCE possibly handle problems arising from heterogeneity very well. However, ease of program development and performance might not fulfil the project specification. Medium level paradigms like PVM or MPI might be better suited for time critical applications. As a drawback commercial products can hardly be found here and programming is more difficult and error-prone. Possibly, a combination of high level programming platforms like CORBA with medium level programming models like PVM can provide a flexible environment for the management of the SE and fulfil the given performance requirements simultaneously.

Finally, the HW of the workstations and the interconnection network has to be selected such as to meet given requirements concerning e.g. graphics capabilties, computing power needed for planning tasks, and network throughput necessary for the scenario distribution.

All decisions will be made with respect to availability of HPCN program development and program maintenance tools. As said before, a large variety of commercial and public domain products for e.g. specification, debugging, performance analysis, or load and resource management, including tools from completed or ongoing Esprit projects has to be evaluated.

5 Conclusion and Future Work

The project started in January 1997 and has a duration of 30 months. Due to the schedule there are only few results to be reported yet. Up to now, specifications concerning SE functional requirements and A-SMGCS application requirements have been issued. Currently, these requirements are analysed in order to specify the hard- and software architecture of the SE subsequently. By December a deliverable is due that describes the architecture of the SE with respect to HPCN HW and SW. It lays the basis for the development of the simulator itself.

The main objectives of the SEEDS project are:

- to test scenario generation and interactivity between actors and SG;
- to evaluate the effectiveness of automatic supports (decision support tools, automatic agents, new HCI, etc.) to be used by different actors to reduce workload and to solve critical situations;
- to support analysis and design of new A-SMGCS;
- to validate new A-SMGCS (they can be mapped on SE);
- to experiment new procedures to be introduced at airports;
- to train operators to use new procedures, without interfere with the operativity of real system;
- to introduce HPCN methodologies in industrial applications;
- to evaluate HPCN tools and programming libraries;
- to propose high performance as well as low cost HPCN solutions for the software to be developed in order to occupy several market segments with our product.

The simulator being developed within the SEEDS project represents a prototype that shows how the listed objectives can be realised.