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MILESTONE REPORT COORDINATING COMMITTEE ON COMPUTER CONTROL

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1. INTRODUCTION

IFAC is concerned with 3 types of activities, which are mutually interrelated:

- The development of methodologies for control, based on a sound mathematical background and the development of analysis and design tools
- The application of Control Engineering methods to various application areas, varying from large scale and complicated applications to consumer products and varying from technical to non-technical applications
- The implementation of Control Algorithms. For this aim all kinds of support technologies are needed and developed, such as intelligent mechanical components, smart sensors and actuators, computer systems and sophisticated real-time software

The CC on Computer Control is within IFAC concerned with real-time software, distributed computer control systems, algorithms and architectures for real-time control, safety aspects of computer control systems and the real-time application of Intelligent systems (fuzzy sets and logic, neural networks, expert systems, etc).
Computer Control is situated in the overlapping area of Control Methodologies, Applications and Implementation issues. It has many ties with research activities, which are also served by other international organisations such as IEEE and IFIP. These organisations are many times larger than IFAC, which is also the case with working groups and societies within these organisations, which are involved in the same aspects of Computer Science, Software Engineering, Computer Technology and Intelligent Systems, which are served by the Technical Committees of the CC on Computer Control.
Control Engineering and Systems Science play important roles in many areas of scientific research and real-life applications, but are hardly accepted as a dominant and independent scientific area, such as Chemistry, Physics and Mathematics. There is, however, hardly any scientific area, which is involved in so many different applications as Control Engineering and Systems Science.

Although the importance of Computer Control within IFAC is clear and quite important, it is felt by the majority of researchers working in Control Engineering and Systems Science (a strong majority in the IFAC organisation) as an area which serves the Control Society and is merely providing tools to implement their control laws and control structures.
Control Engineering without applications and real-time implementations is not a high standard engineering activity. From the point of view of

Computer Control one could even claim that control and system theory should be rather considered as supporting activities.
However, the best solution is to consider theory, applications and implementation as activities within IFAC with equal merit and equal importance. This should finally result in an activity programme (events and publications in IFAC Journals), which is more equally distributed over theory, applications and implementation. In the past and also at present there is a strong emphasis on theoretical and methodological issues within the activities of IFAC, which might hamper the participation of application and implementation oriented people from industrial and research.
People are developing most sophisticated control algorithms but are less interested in the transfer of these algorithms to a well-defined real-time control system. Moreover, the application of control algorithms is in practice many times confined to the use of existing hard- and software solutions, which are in many cases application dependent or supplier dependent and sometimes developed for other purposes.
This is the reason that in many cases ad hoc solutions have been applied with sometimes unsatisfactory or unreliable results. There is relative little attention to study and to apply safe and well proven real-time software and computer architectures offered by the experts in those fields, which are active in the TC's on Computer Control.
Although there is a tendency in IFAC to stronger emphasise Applications of Control Engineering (IFAC Journal Control Engineering in Practice), there is still little attention for support technologies, such as Computer Control Systems, which are, however, of major importance in many application areas (aeronautical systems, nuclear power systems, etc.) in which only certificated system solution are accepted.
Besides, the complexity of systems to be controlled increases rapidly. Systems are subjected to many constraints concerning energy consumption, safety and reliability conditions, environment protection, next to the ever-increasing demands on economical production and trading-results.
These requirements necessitate even more the concern of our community on reliable, safe and secure real-time computer control systems.

Much attention is also paid during the last decade to the real-time implementation of Intelligent Control Systems. These systems got, however, also much attention in other organisations such as IEEE. Control Engineering applications played a dominant role in the application of Intelligent Systems and many organisations were active in organising events where these applications were highlighted. It was rather late that these activities were recognised by IFAC as a new and important development in Control Engineering. Recently there is a larger emphasis in IFAC on such items as non-linear systems, fault detection, fault diagnosis and control system reconfiguration, which was also beneficial for the acceptance of Intelligent Modelling and Control within the Control Community.
New and rapid developments are taking place in the areas of Computer Science and Communications, which will certainly influence the field of Computer Control.
Telecommunications and cognitive systems will influence in the near future very much the way control systems will be implemented and the field of application of control engineering. A key issue in control engineering will be the application to highly complex systems: the coupling of complicated and large heterogeneous systems in which different disciplines are involved and different types of information are available or has to be uncovered and to be discovered.
This new approach in Control Engineering could be called INFORMATION PROCESSING FOR ACTION in which Control, Computers, Communication and Cognition play equal roles in attacking real-life problems from very small-scale devices to very large scale industrial processes and non-technical applications.

2. CURRENT STATUS

In this section the most important technologies are summarised which play an important role in the subjects covered by the 5 TC's on Computer Control. When relevant a short introduction is given of the background and historical development.

Artificial Intelligence in Real-Time Control

Although the CCA on Artificial Intelligence in Real-Time Control (AIRTC) was established to emphasise real-time aspects by the implementation of expert systems, fuzzy systems and neural networks for various control engineering applications, the lacking of a TC on the analysis and synthesis of these intelligent systems till recently was the reason that these methodological aspects got also attention in the activities of the AIRTC committee.
The real-time use of expert systems and the application of fuzzy sets and fuzzy logic, incorporating the knowledge of experienced operators and designers in a rule base, were emphasised in the first events of the CCA.
Next, much attention has been paid to the modelling of (partly) unknown systems by the use of Fuzzy Modelling and Neural Networks. Remarkable results were obtained by fuzzy clustering methods, resulting in easy to interpret

models, which are also understandable to people experienced in operating complex systems. Although the seminal ideas of using fuzzy sets and fuzzy logic were not followed in these developments, it is a useful tool for modelling systems. An extensive set of model reduction methods has been developed which made the interpretation even simpler and allowed also the implementation of relative simple control algorithms based on these models.

At the same time remarkable results were obtained with neural networks, CMAC algorithms and B-splines in the modelling of systems, although the results are not as easy to interpret as most of the models obtained by fuzzy techniques. Genetic algorithms were also widely introduced as fast optimisation techniques. Finally, the combination of fuzzy and neural network techniques allowed the sharing of the benefits of both methods,

At first fuzzy control was introduced as the alternative of human operator control based on the experience of the operators. Next, PID-like controllers were developed using the inherent non-linear behaviour introduced by fuzzy sets. At this moment neural network controllers and fuzzy controllers are introduced as major components in sophisticated non-linear control algorithms, i.e. non-linear model-based predictive controllers.

The primary suspicion against these methods for modelling and control by the established control theory community has been abandoned after basic research on the stability and robustness of intelligent control systems. The application of these methods has been clearly demonstrated on a large number of real-life problems, which were even preceding the general acceptance of these methods by the Control Engineering and Systems Science community. A large number of regular papers, survey papers and communications have been published in IFAC Journals and the affiliated Journal Engineering Applications of Artificial Intelligence (EAAI). The majority of the results obtained and the research performed in this area are, however, still published in IEEE Journals, the Journal on Fuzzy Sets and Systems and a number of journals devoted to intelligent systems.

Intelligent techniques can be used for (partly) unknown systems and (highly) non-linear systems. They enable in a unified framework the combination of first principle knowledge, knowledge extracted from measurements and knowledge based on experience and rules.

Distributed Computer Control Systems

CCD on Distributed Computer Control Systems has already a two-decade history in applying sophisticated distributed computer systems in complicated control engineering applications. The development started right from instrumentation and computer industries delivering support technologies for Control Systems. They were the first to deliver distributed computer control systems (distributed in function and space) for the process industry and other complicated large industrial plants (plant-wide control).

The distributed computer control technology includes fundamental concepts and theoretical issues in system architectures, inter-computer communication, algorithms, scheduling, programming and man-machine interfaces for real-time distributed computer control systems.

More specifically the following items are highlighted:

- Theories and techniques for ensuring predictable timing, predictable behaviour under failure conditions, reliability and maintainability
- Methodologies and tools for specification, logical design, physical design, implementation, validation, verification and testing/evaluation
- Computer architectures, local-area networks, programmable logic controllers (PLC's), field bus and standards-based platforms and environments
- Computer networks for real-time distributed computer control systems

It is an accepted support technology for Control Engineering but it gained relatively few attention in the Control Engineering Community because it was felt to be a mature support tool to be mainly developed by the Computer Engineering and Instrumentation communities. There is, however, a strong relation to Control and System Engineering when the complexity of large-scale control problems and the hierarchical splitting up of these problems are taken into account. Many control engineers doesn't realise that control engineering applications ask much more effort on realising sophisticated methods for planning, scheduling, optimisation, fault diagnosis and fault detection, system reconfiguration than relatively straightforward applications of direct control methodologies.

Real-time Software Engineering

Real-time software is of outstanding importance for real-time control. TCR on Real-Time Software Engineering is already 3 decades active in this field within IFAC. The field was initially elaborated since the early sixties by electrical, chemical and control systems engineers. The research and development efforts aimed towards the improvement of the then unsatisfactory software situation. High-level real-time languages were defined and developed, such as RTL/2 and Coral 66 in the UK, Procol and LTR in France and PEARL in Germany. The Department of Defence of the USA developed the language Ada for programming embedded systems, but this language did not meet the functionality of PEARL with respect to real-time features, which gave rise to the revision Ada 95. In close connection to these languages highly efficient real-time operating systems were developed. Comprehensive software tools for supporting the entire engineering process of real-time systems from hardware configuration and software requirements specification to code generation and documentation were developed.

The significance of embedded systems is readily growing. Owing to the proliferation of embedded computerised control systems, the amount of software installed in these systems is presently doubling within less than 18 months, thus characterising the significance of the area of real-time programming and real-time software engineering, which has become an essential enabling discipline of both control engineering and computer science and engineering.

The accelerated growth in demands for functionality and dependability of real-time and embedded control systems challenge our intellectual and engineering abilities to come up with practical solutions to the problems faced in the design and development of these complex program controlled systems.

Control engineers were, however, not always aware of the significance of real-time software. They have, however, to keep in mind that the violation of the timing requirements of a real-time system is a failure whose consequences may be catastrophic. Hence, the correctness of real-time systems depends not only on the logical results of computations, but also on the time when the results are produced. More precisely, the standard DIN-44300 defines real-time processing as the operating mode of a computer system, in which the programs for processing of data arriving from the outside are permanently ready, so that their results will be available within predetermined periods of time. The arrival times of the data can be randomly distributed or be already a prior determined depending upon the application. This definition implies that some prevailing misconceptions about real-time systems need to be overcome: neither time-sharing nor just fast systems are necessarily real-time systems. Also the thinking in probabilistic terms is not appropriate in real-time environments. Instead, maximum run-times and worst case delays need to be considered.

CCA addresses all facets of this increasingly important area: the study and development of real-time software for computer control applications, including software engineering techniques for real-time systems and real-time software project management issues.

Existing international research activities in real-time systems are characterised by a number of parallel developments and repetitions, which can to a large extent be ascribed to the lack of communication between the different national research groups. The primary reasons for this are language barriers and difficulties in obtaining the right literature, which is scattered over many journals and conference proceedings due to its interdisciplinary nature, and often only available in the form of internal reports. Recently, the Journal Real-Time Systems, an affiliated IFAC Journal, will serve as an appropriate medium to foster international communication and to present the state of available knowledge.

Many new and challenging applications are being developed in the areas of command and control systems, process control systems, automated manufacturing, flight control systems, avionics and aerospace, automated defence systems, ship-board systems, submarine systems and robotics. Hence, there is a wealth of new results being produced in industry and academia and there is much need for experts in the field of real-time software engineering.

The following topics are of interest in this area:

- Requirements engineering methods and design tools
- Reliability engineering and software quality assurance in hard real-time environments
- High-level real-time programming languages and their implementation of tasking, concurrency, synchronisation and timing concepts
- Real-time operating systems and task scheduling algorithms
- Distributed and fault-tolerant novel real-time systems architectures
- Hardware and software support for process interfacing
- Artificial intelligence aspects with special emphasis on real-time expert systems
- Active and real-time data-base systems
- Field bus communication, predictable execution behaviour, clock synchronisation
- A real-time extension of the Unified Modelling Language
- Schedulability analysis of distributed systems
- Systematic re-use of system components in order to improve system reliability and to increase the productivity of designers and programmers

The above topics present the state of the art in this area, following the current trend to build even bigger distributed automation systems, many of which associated with safety critical tasks, raising new problems in these fields, and stressing the importance of building systems in such a way that they can be formally certified.

Safety of Computer Control Systems

CCS is concerned with Safety of Computer Control Systems. The key aspect in this area is the risk of harm, which can lead to loss of life, limbs, or large financial losses due to the failure of a computer system embedded in a larger application.

The technologies of providing safety assurance in computer control systems are all based on the architecture of feedback control, but they rarely use, if at all, results from Control Engineering and Systems Theory. Due to the discrete nature of the safety problem, methods of discrete mathematics are usually applied.

Algorithms and Architectures for Real-Time Control

CCT activity is concerned with Algorithms and Architectures for Real-Time Control. This TC has been active in this field within IFAC since 1990, stimulated by the availability of the INMOS transputer for embedded and parallel processing applications. The scope of the TC is clearly defined by the term embedded control systems. However, from the dictionary definition of the word embedded (i.e. to make something an integral part of…) it would appear that every control system is necessarily embedded. The term has, however, mainly been used to refer to control systems that are physically embedded in the enclosure of a machine or in a plant-wide control environment.

The nature of the requirements posed for a large variety of applications, and the availability of appropriate run-time resources, were the major driving forces that have scattered the field of computer-based controllers into technological niches with their own ideas, techniques, terminology and even technical communities. Depending on the particular application issues such as cost, simplicity, seize, robustness, weight, availability and ability to upgrade, to distribute or to make the system fault tolerant were emphasized.

Embedded software technology is perhaps regarded just as an implementation issue inside the IFAC community. However, computer science and computer technology are as critical for control purposes as any of the control theories used in the systems to be built. Therefore the level of awareness of people working in control engineering and control systems theory should be raised so that it is recognised that real-time software architectures are just as critical for dependable complex control systems as the components and control algorithms

Current automatic control applications are characterised by complexity, are event driven and potentially distributed. Under such circumstances an overriding concern is the architecture of the software. A well-designed software architecture should not only simplify the construction of a system satisfying all the current requirements, but should also easily accommodate changes forced by new system requirements and operating conditions.

Many control applications demand increasingly complex software of high quality and also distributed systems. The economics of networking are such that in the near future the network itself will constitute the computer.

Embedded control system technology is now starting to share tools from diverse applications to create a common discipline that can be exploited by all professionals involved in this field. Thus current research and development is focussing on producing processes that integrate heterogeneous methods originally devised for specific domains

This radical approach means that today we want to build systems that have all the properties that can possibly be required for any class of real-time controller. This demands new solutions to replace existing embedded software to make it easy to build, low cost and simple to maintain, while simultaneously being effective and dependable.

The importance and benefits of embedded control technology can therefore be summarised as follows:

- Lower costs and better control and satisfaction with products and the environment
- Increased satisfaction both with products and the environment
- Improved energy efficiency of products
- Enabling of more regulation of demand on central resources
- Reduced operational costs via the connection and control of currently antagonistic systems

3. FORECASTS

In this section an overview is given of the key challenges foreseen in the near future for Computer Control technology. Also new areas and new applications will be indicated.

Artificial Intelligence in Real-Time Control

Although many practical and theoretical results have been obtained in the area of intelligent systems during the last decade, there are still many issues open and research in this area is needed for some important concepts, which play an important role in control engineering.

Till now most control systems using intelligent techniques are rather simple and of low dimension. There is a need to develop sophisticated techniques for MIMO systems and the application of intelligent techniques to detect interaction and to give measures for decoupling of variables. Moreover, techniques should be developed to avoid unwanted interactions between variables. Keeping in mind that complete decoupling is hardly possible, intelligent techniques should provide means to decouple to a certain amount.

It has been shown that intelligent techniques are extremely useful in modelling unknown and complicated (non-linear) systems. These models should be used in Model-Based control methods, such as Model-based Predictive Control methods.

There is still need to perform research in some theoretical issues related to intelligent systems, such as fundamental research on model uncertainty, robustness of the control configuration, sensitivity to parameter variations and disturbances, etc.

Interesting ties with other TC's are expected, especially with the TC on Fuzzy Systems and Neural Networks for Control and the TC on Non-linear Systems.

A very important new research direction is the Reconfiguration of Control Systems. This issue is very much related to the research done in the area of Fault Detection and Fault Diagnosis. The results of the Diagnosis should directly influence remedial measures to be taken, resulting in adaptation of control laws or complete reconfiguration of the control strategy. In hazardous situations the real-time aspects related to these actions are of major importance.

Distributed Computer Control Systems

Internet techniques will play an important role in this area, such as internet-based communication and software technology, web-based remote sensing, monitoring and management. In complicated systems there will be more emphasis on Real-time computer control and Real-time communication. Also the issue of open control software architecture will be important for future research.

The most promising applications will be on the following areas:

- FMS (Flexible Manufacturing Systems)
- CIM (Computer Integrated Manufacturing)
- Remote monitoring and control over Internet
- Large-scale computer control systems

Real-Time Software Engineering

Nowadays the field is characterised by a large gap between academic research, user needs and industrial practice. Work is going on to establish theoretical fundamentals such as scheduling and formal specification. A "system" approach is needed as well technology related approaches especially in those cases where safety related real-time operation is concerned. There is need for new approaches to deal with the synchrony spectrum, especially when developing complex large-scale systems. Determinism and behavioural predictability are indispensable prerequisites for trusting mission critical and safety critical systems. As a consequence of the still rapidly decreasing hardware costs, the general design philosophy must shift from resource limitation to resource adequacy rendering more understandable solutions possible.

While formal descriptions are valuable, the state of the art has not evolved to a point yet, where formal methods can be widely applied. In particular, the number of people who are able to make formal descriptions of non-trivial systems is extremely low. In order to make formal descriptions useful, they must be augmented with appropriate means of decomposition.

An essential activity to be vigorously pursued is that of education. The parties involved in real time computing and control must become aware of each others' problems. One needs to work closer with various groups of application engineers, and to take into account the real needs of applications in developing appropriate solutions. Consequently, many studies must be documented and examined in this regard.

The paradigm of object orientation and especially the concept of distributed active objects as autonomous entities with concurrent behaviour is applied very successfully to the development of large and complex distributed real-time applications. Among the advantages achievable are:

- Comprehensibility and maintainability, as problem domain semantics can directly be mapped onto models being built,
- Modularity, because an object class represents a self-contained piece of a problem domain which can be examined separately from or within the context of a system,
- Concurrency, since objects are natural units for concurrent execution and allow the real- world concurrency of applications to be modelled in a natural way and
- Better management of complexity by providing powerful abstraction concepts.

Despite all this, it is counterproductive that both in academia and in industry the second step is taken before the first, viz., that the object oriented techniques are usually applied in the domain of real-time systems on the basis of inadequate languages with weak or even no adequate capabilities for the programming of real-time and distributed systems as this approach increases complexity again by difficult to survey workarounds and, thus, ruins the above advantages attainable by object orientation.

Safety of Computer Control

Formal verification of hardware and software is a key challenge. Methods currently offered are so complex that they are manageable only for simple systems, while the complexity of safety-related applications is usually high and continues to increase dramatically with the progress of computing technologies.

It would be fair to say that new problems show up every day, because computer-controlled systems are being increasingly applied in new areas related to human safety.

In addition to traditional areas concerning safety, such as all means of transportation: cars, airplanes, ships, medical electronic devices, nuclear power plants, chemical plants, etc., several new areas appear to be emerging with respect to safety of computer control systems such as: telecommunication systems, banking systems, fire protecting systems on oil/gas platforms, etc.

The research area covered by this TC has many ties with other TC's within IFAC such as the TC on Air Traffic Control, TC on Transportation Systems, TC on Power Plants, TC on Fault Detection.

Algorithms and Architectures for Real-Time Control

An important key issue within this field is the research on Distributed Embedded Controllers. These software-intensive control systems are structured as dynamic collections of autonomous real-time agents that interact which each other. They have the required levels of autonomy to be effective in their tasks while keeping interaction to achieve global objectives and modularisation to make them easy to use.

This means that a cohesive model of the whole system should be developed to achieve functional and non-functional requirements. This is made possible because hard- and software are maintaining a steady development pace, providing ample resources even in the smallest application platform. This means that developers can concentrate more on the design of the system to achieve functional objectives, rather than being overly concerned with exceeding platform capabilities.

Real-time component-based development is becoming a critical topic in this field because it simplifies the development of systems, Object-agent technology provides the general framework for the development, while real-time distributed software architectures provide the necessary patterns for the fast and safe construction of applications. Having a good architecture and a control component framework will simplify the tasks of design, construction, commissioning, monitoring and maintenance of complex controllers.

Having a user-friendly high-level programming environment will help developers (with varied levels of experience) to develop state-of-the art applications in less time, with less costs and without sacrificing the slightest bit of dependability.

Next to the above mentioned future activities the following issues will be of major importance in this area;

- Networking: choice and economic levels of transmission and processing at a node
- Remote diagnosis, maintenance and fault correction of systems
- Specific Hard- and software solutions: multiple systems corresponding to today's complex environments, e.g. mobile robots, car controllers or flexible manufacturing systems on a single chip
- Real-time operating systems functionality for control and supervisory control
- Embedded databases for look up tables, multi-process control tasks and adaptive learning
- Control algorithms in silicon: design complexity versus system capability and flexibility. Single chip reconfigurable logic development for control, communication, hierarchical management and delegating authority
- Micro-actuators, micro-sensing, micro-power and micro-control in new applications in the real-world. Development of distributed processing with a small amount of smart actuation processing

It is clear that this TC has many ties with the TC on Real-time Software Engineering resulting in workshops, which partly overlap.

The previous comments were more or less related to the areas in which each of the TC's is active. Important issues to be tackled are found in Embedded systems, Real-time systems, distributed systems, concurrent systems, multi-agent systems, intelligent systems and learning and self-organizing systems. There are, however, some general issues, which are important for the whole area of Computer Control. It can be expected the C2 paradigm of Computers for Control will shift to the C4 paradigm of Computers, Communication and Cognition for Control. This change is mainly due to new developments in Computers and Knowledge Management and the rapidly emerging field of Telecommunications providing a number of possible applications in Control.

At the level of computing systems, work is now being done on the concept of the Grid: an attempt to combine huge numbers of computers around the world to work seamlessly on large-scale problems. The Grid – the next major computer network initiative after the internet – would make processing power available as a commodity, and on demand anywhere, by allowing the user to tap it off the network as easy as electrical power. Many large-scale and complicated problems in modelling, simulation and control system design, such as encountered in the aircraft design process, the modelling of biological systems and the prediction in economical and environmental systems, would benefit from the Grid. However, also real-time applications, such as natural disaster control could benefit from the Grid-approach when sufficient real-time software, safety and certification requirements are foreseen. The challenge for the control community is twofold.

First, the control problems would have to be defined in a way that would allow them to be solved efficiently through identification of parallel computations that are carried out concurrently on different machines that do not need to wait for results from one another to proceed, thus optimising the parallel computing approach.

Second, and the more important challenge, would be to address the network problems, such as information flow control, brokerage of computer power, and the development of smart software to ensure just-in-time and certified data delivery. It should be noted that the communication network control is in its own right a control application area of growing importance, which is an emerging research area to be covered by the activities of one of the TC's of IFAC.

Research on entirely new computing technologies, such as quantum or genetic computers, has to be monitored with an aim to identify its utility for the control community and the challenges it presents in terms of novel control problems. Experts in those fields should be asked to present State of the Art surveys at IFAC events to detect possible applicability for control problems and the utility of control for their problems.

In the realm of communication systems, wireless technologies are increasingly used in control and telematics. An important issue for control engineering is the design and application of instruments and control schemes for tele-monitoring, tele-presence, tele-medicine, and other fields of telematics applications.

New developments in computer networks and communications, combined with new ways of information processing provide new possibilities also for control purposes. Transparent-for-the-user computer software offers a platform for the development of smart systems embedded in the operation of industrial plants as well as penetrating the everyday life of modern society. By combining this type of infrastructure with new developments in virtual environments, real-time systems, complex signal processing and AI algorithms, and user friendly interfaces, new intelligent control systems based on a multi-sensory perception of the state of the controlled process and its environment are currently emerging. These systems, called ubiquitous or pervasive systems encompass both communications and information technology, and give us tools to manage information easily. This opens the possible introduction of intelligent adaptive controllers in these systems to achieve specified goals in complex and continuously changing environmental situations. World models, built and maintained from information gathered by a multitude of sensors, provide a common abstract representation of the state of the environment. At the perception level, the world model is analysed to infer relationships between different objects and to assess the consequences of the controller's actions.

At the software level, large heterogeneous systems capable of handling diverse applications require middleware – a layer of software used for defining the kind of tools needed to extract processing power from different computers in the network. An important feature of middleware is its capability to adjust automatically to the device that is being used to gain access to the network a specially formatted data file, or a dedicated control device.

There are several key issues that relate to the algorithmic and cognitive level of computer and communication systems for control. The introduction of intelligent control systems incorporating AI-techniques was already quite successful, but a new interesting area essential for different types of applications is Knowledge Management (KM). Some of the issues that arise in the process of development of KM systems are: dealing with unstructured information, ontological issues, knowledge acquisition and representation. A crucial problem that calls for sound theoretical work is knowledge representation. Quantitative models and models that are built on first principles' knowledge and measurements are well known. The development of qualitative models is less successful, although good results have been obtained using expert systems and fuzzy logic. Hybrid models can be either a mixture of quantitative and qualitative, or based on hierarchical qualitative modelling. Some examples of open problems are multiple partially redundant representations, expressiveness versus complexity, hybrid structures (e.g. co-existence, integration), and architecture and communication structure.

An interdisciplinary area that has generated considerable research interest is the analysis of multidimensional spatial systems. Cognitive type problems that are dealt with in this analysis are spatial reasoning and cognitive distance. In general, they can be expressed as: “What it takes to go from position A to position B, or from situation A to situation B”. The distance between A and B depends on many factors: metric distance, costs to be invested, travel time, sense of direction, possible encounter of dangerous situations, and spatial conception. Analogous to model reduction in large-scale control systems is complexity reduction in spatial systems. It may often be performed in the presence of constraints that require the preservation of local geometrical and/or topological neighbourhood relationships. Solution of the complexity reduction problem paves way to implanting location-based services in transportation systems, environmental systems, meteorological systems and optimisation problems.

4. CONCLUSIONS

The area of Computer Control is an important area within the activities of IFAC. As already mentioned in the introduction, Computer Control belongs to the Support Technologies, which are of eminent importance for implementing control algorithms. It is felt by the researchers working in the field of Computer Control that their activities have not got the same attention within IFAC as the activities of the people working in the field of Control Theory. This might be the reason that many of the researchers active in the field of Computer Control have also many ties to other organisations active in the field of Computer Science, Information Technology and Artificial Intelligence. Key plenary sessions in major IFAC events are seldom devoted to major issues in Computer Control, which might strengthen the feeling that this area is less important in IFAC activities.

To strengthen the position of Computer Control within IFAC, a new concept for the activities of computer related areas for control has been proposed in order:

- to diminish possible overlaps between the areas covered by the existing Technical Committees in Computer Control and to diminish the number of Technical Committees according to the policy of IFAC
- to concentrate the activities of Intelligent Control
- to include recently started activities in the field of Telematics

The proposed new Coordinating Committee is called the 4 C’s Committee: Coordinating Committee on Computers, Cognition and Communication for Control, made up of 3 Technical Committees:

- Computers for Control
- Cognition and Control
- Computers and Telematics

Four of the previous 5 TC’s will return as Working Groups in the TC on Computers for Control. It is suggested to have a multi-track Conference each triennium of the activities of these Working Groups. By combining the activities of the former TC on AI in Real-time Control and the former TC on Fuzzy Systems and Neural Networks a better tuning of the activities of both former TC’s is obtained. Also for these activities, which are placed under the umbrella of the TC on Cognition and Control (perhaps the name Intelligent Control would be more appropriate) a multi- track Conference has been proposed in each triennium. The establishment of a new Working Group on Evolutionary Computing for Control has been foreseen. Finally, a new TC on Computers and Telematics has been proposed. There should be a strong cooperation with the TC on Computers for Control, especially with the Working Group on Distributed Computer Control Systems. Joint activities should be planned. Furthermore a close cooperation of the Working Group on Safety of Computer Control Systems with SAFEPROCESS should be established, resulting in joint activities.

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