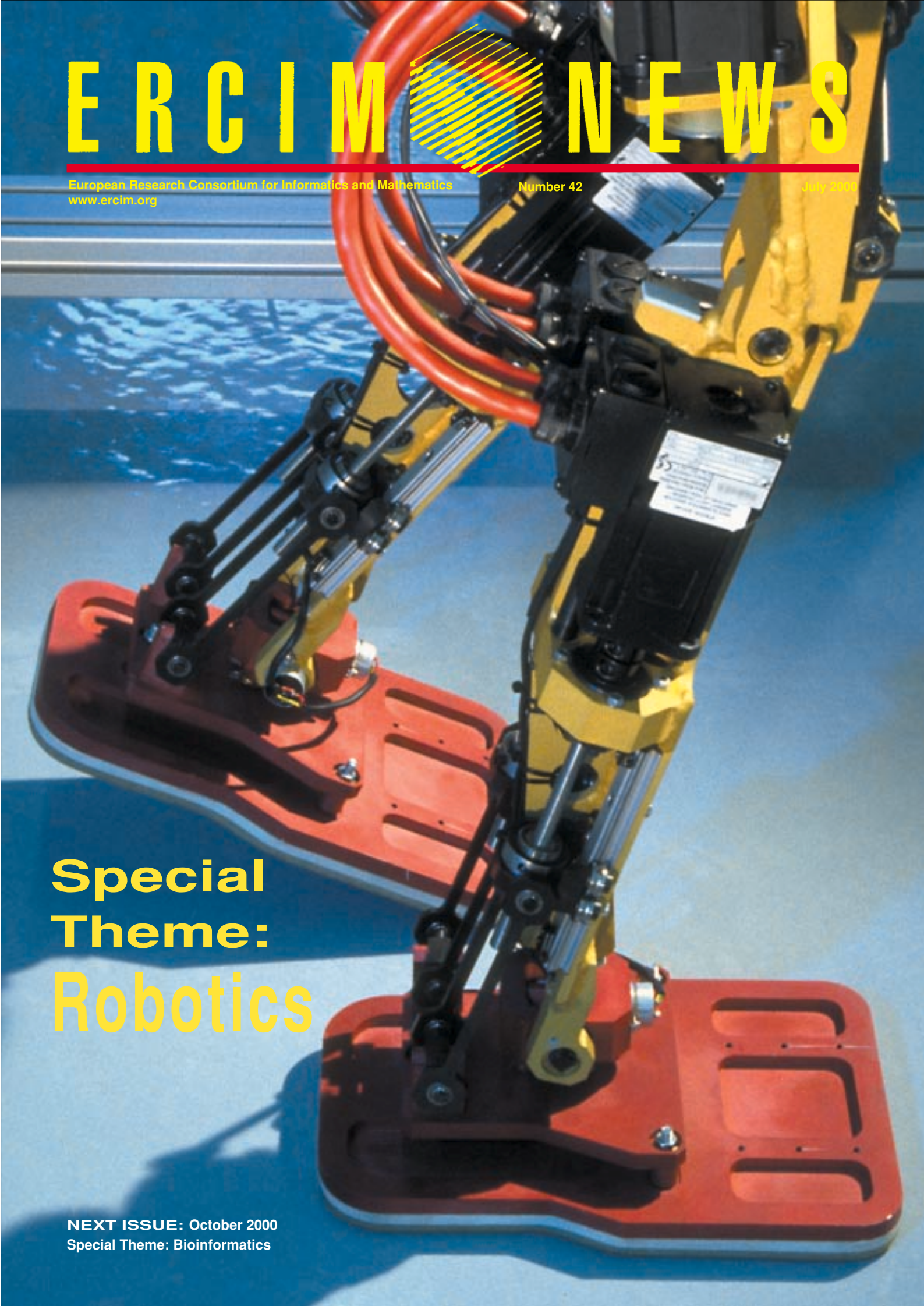

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Cover image: BIP2000, an anthropomorphic robot (see article 'Stability Issues in the Control of Anthropomorphic Biped Robots' on page 37). Photo: A. Eidelman, INRIA.

"We see membership of ERCIM as crucial to the policy of growing our R&D base"

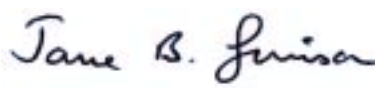
Jane Grimson, Trinity College. Representative on ERCIM's Board of Directors

Ireland is currently enjoying unprecedented economic growth. GDP is increasing at a rate of 8% per annum for the past 5 years, over three times the EU average. Unemployment has fallen from 20% in the mid-1980's to around 5% today. For the first time in over 150 years, the population is increasing. There are many factors which have brought this about starting with the removal of very high, protectionist trade barriers at the end of the 1950's, encouragement of foreign investment, membership of the European Community in 1973, and investment in education.

In the 1980's there was a specific move to encourage inward investment principally by US multinationals in the electronics, software and pharmaceutical sectors. The main advantages which Ireland offered were access to European markets, an English-speaking, well educated, young labour force, low corporate taxation, and a good telecommunications infrastructure. This policy has proved to be a spectacular success and has been a major driving force behind the so-called 'Celtic Tiger'. Intel, Dell, HP, Motorola, IBM, Xerox all have major manufacturing plants in Ireland and thanks largely to the fact that Microsoft's European software localisation plant is located near Dublin, Ireland is now the second largest exporter of software in the world. Current government policy is focused on establishing Ireland as the e-commerce hub of Europe.

The big challenge for Ireland is to sustain this growth – to ensure that the multinationals sink deeper roots, to encourage growth of indigenous industry, and to address the growing skills shortage in the "high tech" sector. The government is acutely aware of the serious implications of the skills shortage in the software sector, in particular, and has provided significant funding for the provision of additional places in third level colleges and universities. Almost 6% of Ireland's third level student population are studying computing – the second highest proportion among the OECD countries. Furthermore, over the next 5 years, the plan is to increase expenditure – both by government and by industry – on Research and Development (R&D). Starting from a very low base only 5 years ago, the government is committed to an expenditure of 2.5 billion Euros on R&D over the next 5 to 7 years. 711 million Euros will be invested in a Technology Foresight Fund to support basic research in two key areas – Biotechnology and Information and Communications Technology (ICT).

Ireland is a small economy on the periphery of Europe; we cannot expect to become a world leader in research across the whole of the ICT sector, but, as we have already demonstrated, we can develop expertise in a number of key areas. In the global research 'market' of today, it is unlikely that we will achieve this in isolation and we see membership of ERCIM as crucial to the policy of growing our R&D base. ERCIM provides a network of world class research, a melting pot of innovative and exciting ideas. Creativity and innovation, the essence of research, like the gene pool, require diversity to be vigorous and thrive. ERCIM brings together a heterogeneous mixture of cultures, expertise and experience in the software area. Ireland's computing research community has much to gain from joining ERCIM and looks forward to playing an active role.



ERCIM welcomes Trinity College

by Jane Grimson, Pádraig Cunningham and Carol O'Sullivan

During the ERCIM spring meetings in Pisa from 29-31 May, Trinity College signed a scientific agreement with ERCIM, becoming ERCIM's 15th member. Trinity College, represented through its Computer Science Department will be ERCIM's gateway to the Irish Information Technology research community.

Trinity College Dublin (TCD) was founded by Queen Elizabeth I in 1592 as the first and only constituent College of the University of Dublin. The College occupies a 42 acre site right in the heart of Dublin. It was not until the 18th century that the university began to acquire the broad shape that it has today with its famous Georgian architecture and cobbled Front Square dominated by the Campanile. The College is famous for its magnificent Library which houses the Book of Kells, an 8th century illuminated manuscript.

Trinity College Dublin: front square and the Campanile.

The O'Reilly building, the home of the Computer Science Department.

Trinity's famous alumni include literary figures such as Jonathan Swift, Oliver Goldsmith, Oscar Wilde and Samuel Beckett, philosopher George Berkeley, historian William Lecky, mathematician William Rowan Hamilton, medical pioneers William Stokes and Denis Burkitt, physicist George Francis FitzGerald and Nobel prize-winner Ernest Walton.

Today the College is divided into 6 Faculties covering virtually all of the arts and sciences. Membership of ERCIM is being led by the Department of Computer Science, which belongs to the Engineering School within the Faculty of Engineering and Systems Sciences. Founded in 1842, Trinity's Engineering School was one of the first in Ireland and the UK. It started by offering degrees in Civil Engineering, followed by Mechanical and then Electrical Engineering. The School acquired its first computer – an IBM1620 – in 1963.

The Department of Computer Science was established in 1969 and has grown and prospered under the leadership of Professor John Byrne since the start. The Department is by far the largest academic department in the College with over 50 academic staff, 100 researchers/ postgraduate students, and 18 technical and support staff. Research income amounts to approximately 2 million Euros per annum, of which approximately 60% currently comes from EU framework programmes.

The Department is deeply committed to research with groups spanning virtually all areas of computing from formal methods to applied information systems and computer architecture. Members of the Department publish widely in International Journals and Conference Proceedings and have received many awards for their research. The Department also publishes a Technical Report series, which is available on the Web.

The Department has a long record of participation in EU funded research programmes going back to the first framework programme in the early 1980's. Over the years it has developed close links with industry, both nationally and internationally. The Department is strongly committed to technology transfer and commercial exploitation of its research. Over its 31 year history, the Department has spun-off a number of companies of which the most well-known is Iona Technologies (http://www.iona.com), founded by Chris Horn and Sean Baker, both graduates of and lecturers in the Department, together with Annraí O'Toole, one of their Research Assistants and also a graduate. Iona is one of a growing number of internationally successful Irish software companies. Other spin-offs include Ireland's first Internet Service Provider, IEUnet, now EsatNet (http://www.esatnet.ie), X-Communications in multimedia technology (http://www.xcomms.ie/), MVT in machine vision (http://www.mvt.ie/), and most recently Havok.com which develops software tools for the computer games industry (http://www.havok.com).

While Trinity College, through the Department of Computer Science, will be the member of ERCIM from Ireland, it is the intention to involve researchers from other Irish universities in the activities of ERCIM, particularly in the various working groups. TCD will act as a gateway to the computing research community in Ireland. The Department has worked on a number of projects with other members of ERCIM and looks forward to strengthening and extending these collaborations.

Links:
http://www.cs.tcd.ie/ERCIM

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Developing the European Research Area

by Gerard van Oortmerssen

The European Commission released a Communication entitled 'Towards a European Research Area' with the aim to contribute to the creation of better overall framework conditions for research in Europe. As a pan-European network of centres of excellence in Information Technology and Applied Mathematics, representing over 7000 researchers, ERCIM is directly concerned by the future European Research Area. ERICM is very enthusiastic about the initiative of launching the debate and has supplied Commissioner Philippe Busquin with propositions and ideas.

The document adopted by the European Commission suggests a frontier-free area for research where scientific resources are used more to create jobs and increase Europe's competitiveness. Special attention will be given to the networking of centres of excellence, and developing a European approach to large research infrastructures. This will be combined with measures to promote spin-offs from research. The problems of fragmentation and lack of collaboration between public and industrial research in Europe are to be addressed through better co-ordination and by encouraging the mobility of researchers. Philippe Busquin, EU Research Commissioner sees the Commission as a co-ordinator and analyst, as well as a body that could persuade the Member States to open up their national research programmes to non-nationals.

ERCIM is convinced that the document shows the right direction and is pleased to offer some comments on the communication in general, solicited by the Commissioner. We think that Europe should innovate not only in technological terms, but also on how to transfer know-how and know-why from research institutions into industry. We should look for innovative methods of ensuring that European industry acquires what it really needs to compete in the international arena. In particular, Europe must balance basic versus applied research. Both are absolutely necessary for the long-term success and prosperity of Europe. The balance is currently tilting heavily towards applied research, and this will be detrimental to the survival of the European industry in the long-term in the emerging global competition. In order to succeed in today's fast evolving IT field with very short product cycles, basic and applied research as well as development work should be carried out parallel rather than as a long chain. This should not only enhance the role of basic research but also require closer contacts between industry and research communities.

The European Research Area is an opportunity that may bring about fresh new attitudes concerning scientists with a business sense. This may necessitate the establishment of new 'rules of employment' compatible and competitive with the ones in the USA. Particular emphasis should be placed on ensuring that the attitudes of industry are also changed: more high-risk investment is required from European industry. New incentives should not focus only on financial benefits, but also on other indirect benefits that support sustainability of growth and competitive advantage on the international level. Europe must also decide whether SMEs form the backbone of its infrastructure and act accordingly. The paradox in recent years has been that, despite the rhetoric, European SMEs are battling to survive, rather than striving for success on an international level. Absence of appropriate national policies in some EU countries on the one hand, and too much EC bureaucracy (eg, procedures that are just too heavy for SMEs in the 5th Framework Programme) on the other are creating a negative environment.

ERCIM's Comments and Proposals for Future actions

Comments and proposals concern mainly the field of Information Technology (IT), but there are other themes involved through cross-linking. The following points are a selection of propositions in reply to Commissioner Busquin.

•**Networking of centres of excellence and creation of virtual centres:** ERCIM has 10 years of experience in this area on the European level and has already established co-operation between centres of excellence. Therefore, networking of centres of excellence and the creation of virtual centres looks to us to be a prime area for ERCIM to act as the underpinning consortium leader. The value of the ERCIM concept is emphasised by its growing membership, organisational vitality and international standing. Most European nations are represented in ERCIM, and good contacts are maintained with non-members. Several suggestions made in the Commission's document have already been realised by ERCIM. For instance, ERCIM is already co-operating on staff exchanges, is running a fellowship programme, with fellows from the whole world having rotating visits at selected ERCIM institutes. ERCIM is also highly involved in EU co-operation with non EU-countries. ERCIM is well aware of national and European research programmes, and hence is able to co-ordinate them as far as possible. ERCIM is active in technology transfer (eg, W3C Offices, senior management in W3C) and a significant number of spin-off companies are issued from ERCIM institutes.
Proposals: ERCIM is willing to apply the new 'decentralisation' policy concerning the management of EU actions in the IT area. ERCIM is ready to provide the necessary infrastructure in Europe to support virtual research centres. For this purpose, ERCIM would use its knowledge on new technologies (WWW, GRID technology, heterogeneous data sources, digital libraries, etc.)

•Defining a European approach to research infrastructures: Virtual laboratories rely on real networks and require permanent funding. Electronic networks should be considered as a research infrastructure on the same footing as particle accelerators, high power lasers or ocean platforms.
Proposals: ERCIM could help defining life cycles for Centres of Excellence .

•Better use of the potential offered by electronic networks:
Proposals: ERCIM would be the natural candidate to start experiments on the Very High Speed Transeuropean Network for electronic scientific communications.

• More co-ordinated implementation of national and European research programmes: Evaluation of European organisations should include USA referees to ensure a good comparison and to get new visions and suggestions. Participating in programmes of other countries should not lead to more paper work for the researchers.

•Closer relations between European organisations for scientific and technological co-operation: Better co-ordination and simpler organisation are very much needed in this domain. ERCIM is already a good model for scientific co-operation. In addition, ERCIM is already involved in the evaluation of projects for the World Bank.
Proposals: ERCIM could provide expertise to evaluate projects

• Better use of instruments or indirect support of research: Appropriate technological infrastructure can contribute to the increase of private investment in R&D in Europe. An important part of such an infrastructure should be a European Digital Library containing all the information which could encourage and stimulate a private investment in research.
Proposals: ERCIM proposes to take the responsibility to develop this Digital Library.

•Support for start-up companies: The individual ERCIM members, within their limited boundaries, are very active in helping their researchers to create high tech companies. From ERCIM's point of view it would be very desirable to ramp up this support and to bring it to a real European dimension. For example, by providing some matching European funds it could be possible to harmonise different conditions in various countries and to add more than just a European flavour to it: the mentioned qualification of European researchers could be done at a European level. Hence the process of being trained for commercial and entrepreneurial skills could be done throughout Europe. Researchers would be also trained in another country than their home country, thus also offering chances to find strategic partners and canvassing customers all over Europe. Especially in the field of ICT, there is a global rather than a regional market. It would therefore be very advantageous also for new high tech companies to have access to the bigger part of the European market right from the beginning.

•Risk capital investment: It would be a good idea to foster a European fund, for which new high tech companies from all over Europe could apply to. This would create an international, European environment, which would offer good conditions for high tech start up companies all over Europe, and would be especially attractive to companies from countries where chance capital is not yet that abundant.

•Giving the young a taste of research and careers in science: In several European countries, science is seen as an unattractive option. There needs to be a clearer commitment of both national governments and EU to scientific career management. European Science Weeks should be organised within European countries. Such weeks already exist on the national level in some European countries.
Proposals: ERCIM would be interested in organising European Science Weeks within European countries in the domain of IT.

•Integration of the scientific communities of western and eastern Europe: With our partners from the Czech Republic (CRCIM), Hungary (SZTAKI) and Slovakia (SRCIM), ERCIM has proved to be an excellent platform to integrate scientific communities of western, central and eastern Europe. Research co-operation resulted in joint submissions of scientific projects (in particular within the fifth framework programme), the active participation in ERCIM activitities (working groups, fellowship programme, etc.)
Proposals: ERCIM could contribute to the integration of western and eastern Europe in IT.

•Making Europe attractive to researchers from the rest of the world: The post-doctoral ERCIM Fellowship Programme has proved to be extremely successful in attracting researchers from all over the world and should serve as an example. This programme is open to third country participation. A help from the European Union allowing the post-doc positions in the Networks of the 'Human Potential' programme to be filled by nationals of third countries would improve the situation.
Proposals: The Marie-Curie scheme would be more effective if it were open to non-Europeans like in the ERCIM Fellowship Programme. Non-European participants should be allowed to submit applications in order to compete with the Fulbright Fellowships (covering any graduate studies). There should be a high degree of transparency in International Marie-Curie Fellowships. Only researchers coming to Europe would be eligible.

• Development of a shared vision of the ethical issues of science and technologies
Proposals: ERCIM could contribute to the discussion on open software and internet policy.

Links:
'Towards a European Research Area', Communication from the Commission:
http://europa.eu.int/comm/research/area.html

ERCIM's comments and suggestions:
http://www.ercim.org/

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ERCIM's Latin American Action

by Marie-Christine Imbert

Co-operation with Latin America has been ongoing for many years on a bilateral basis within several of the ERCIM institutes. Yet there had never been a common, multi-lateral action towards the region until ERCIM was prompted by the DG External Relations of the European Commission and officers of the IST programme to produce recommendations for future European actions.

ERCIM created a Task Force involving representatives from GMD, IEI-CNR, INRIA and Universitat Politecnica Catalunya, which undertook to investigate the state of the region's research in Information Technologies and to discuss with many of its main teams.

Following a request by the International part of the IST programme, the missions to Latin America were coupled with the organisation of several seminars with the objective to inform the local research community and their authorities of the forthcoming calls of the IST programme, their content and the procedures to participate.

These 'Information Days' were organised in Mexico DF, Rio de Janeiro and Buenos Aires. They gave focus and momentum to the action, due to the participation of European Commission Officers (Jean-Yves Roger in Mexico and Mario Campolargo in Rio de Janeiro) and of representatives from the main research funding agencies and universities in each country, as well as of researchers interested in the programme.

The Mexico seminar was very successful, due to the excellent local organisation and hosting of Instituto Politecnico Nacional (IPN), represented by Dr. Enrique Villa, to whom we address our acknowledgements. The research community demonstrated its interest in co-operating with Europe and this was followed by their authorities, which agreed to sign a Memorandum of Understanding with the IST programme, establishing a mechanism to fund the Mexican participation to EU projects. This outcome was one of the objectives that ERCIM had set for its action and it was favourably achieved.

The seminar also gave the opportunity to announce the establishment of a European Union Liaison centre, co-ordinated by Ambassador Manuel Armendariz, which will work as an information centre, helping in the establishment of links among local universities and industries and potential partners from Europe.

One of the present main problems identified by ERCIM in the European Union-Latin America (EU-LA) research co-operation is the lack of direct high-speed network links between the two regions. If this were to continue, the fall-outs of research coming in the form of new applications used in common commercial activities would not be developed. As the most active country in the region in the establishment of international links for research, Brazil seemed as a clear choice to initiate the discussion leading towards a common infrastructure of this kind. With this objective, the Rio de Janeiro seminar, hosted by Pontificia Universidad Catolica (PUC), brought together the EU Unit in charge of Research Networking, represented by Mario Campolargo and the co-ordinator of the national Brazilian network RNP. We consider the discussions which started in the framework of a friendly environment, one of the main achievements of this action.

The Rio seminar was attended by representatives of the funding agencies, of the Brazilian Information Society programme, and by the professors in charge of their respective international relations. Some of the main universities were represented, but there was a lack in the participation of plain researchers, stating perhaps their lesser interest in multi-lateral co-operation.

Another need already identified in the Rio EU-LA Heads of State Summit declaration, is the lack of common infrastructure for training. Concerning research in the field of Information Technologies, ERCIM considers that this could be addressed by the establishment of a joint EU-LA Institute for Information Technology, perhaps on the model of what exists with China (the EU-China Institute of Management). In this case the Institute would be one with two or more subsidiaries in the region. It could endeavour to establish joint research, including industrial contracts, and to train new researchers in a spirit of co-operation with Europe.

Discussions are on-going with local interested parties in order to advance in this sense. The forthcoming Buenos Aires seminar, might as well be the opportunity to explore this concept further.

Links:
http://www.ercim.org/EU-LA/

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Photo: Lego Lab/University of Aarhus

Toy robots like MindStorms by Lego, are expected to become one of the real frontiers for the next decade.

Trends in Robotics

by Liliane Peters

The United Nations Economic Commission for Europe estimated that in the year 2002, there will be 800,000 operating industrial robots. Nearly 500,000 vacuum cleaning robots are expected to be installed in offices, public areas and homes by the same year. Based on the sales figures of toy robots like AIBO built by Sony Corp. or MindStorms built by Lego, it is expected that entertainment robots will become one of the real frontiers for the next decade. These are only some of the robot applications with market potential in this decade. To understand the application potential and the future trends in the field of robotics we have to look into more details to the latest technological improvements.

Developing Robots through Artificial Evolution: Predator and prey, page 12.

In the last decade the major improvements in the field of robotics came through technological breakthroughs in the areas of computing, telecommunication, software, electronic devices, etc.

The miniaturisation and power reduction of the processors made mobile computing possible and with it increased the 'brain' capabilities of mobile robots. The development and introduction of a standardised wireless communication protocol transformed the robots into a internet plugged system accessing all available information within the net.

The impact of the internet application and especially the web-based ones gave a boast to the development of embedded system applications in general. Through the integration of internet technologies into these 'intelligent' devices, the user-friendliness programming and remote monitoring capabilities increased. These capabilities on their turn contributed to the spreading and integration of a new generation of embedded systems into larger and more complex applications and environments. The robots on their turn started using these internet plugged devices and by this started increasing their area of operation and capabilities. In addition to this the improvement of haptic interfaces enlarged the capabilities of tele-operated robots. Tele-operated robots in hazardous environment and space as well as tele-medical assistance systems benefited from these improvements.

The 'intelligence' of systems or components increased over the last decade too, as reasoning and decision making methods were developed by the artificial intelligence or computational intelligence research communities and became state-of the art technologies. These technologies enabled the design of 'intelligent sensors', 'intelligent actuators', 'intelligent planers' or 'intelligent decision making units', which on their turn became subsystems of more complex 'intelligent robots'. The improvement in areas like speech recognition, gesture recognition, image processing in general enabled the robots to become more 'human-like' in their communication interface with humans. These features increased their acceptance level outside the research labs, becoming museum guides, mobile information centres, etc.

In the area of 'electronic business' the industrial robots are changing too. The high competition existing on the global market requires 'just in time' products, a better utilisation of raw materials, a better utilisation of resources, and a lower consumption of energy. All these requirements imply new features for the industrial robots. First of all they have to be able to integrate into the software agent organised and monitored production line. The robots need communication capabilities with these 'supervisors' (software agents) and with other heterogeneous robots co-working in the

Photo: E. Rome/GMD

A tele-operated robot for sewer inspection, page 25.

A tele-operated interactive tour-guide robot for a museum, page 28.

same environment. Secondly they have to be able to adapt autonomously to production changes. Thirdly they have to be able to co-operate in a work team supporting reconfigurable production lines. These changes are under way.

While energy saving, miniaturisation and 'intelligence' become hallmarks of today's industrial automation and robotics new developments in the area of new light materials, sensorless control and out-door navigation will improve the robots of the next decade. A car navigation system supporting the driver in foggy areas or a construction bulldozer supporting the driver to execute exact construction plans from a blueprint are just the beginning of the collaboration between humans and 'robots'. Light manipulator and the improvement of haptic interfaces installed on mobile systems will increase the capabilities of today's service robots. Not only one could be virtually at home by monitoring and requesting services from the 'home butler' remotely, but many elderly peoples could stay longer in their own house with a 24 hour support from a robot nurse that helps them, monitors their health status, calls the doctor, family, etc. in case of an emergency.

The latest trends in 'robotic intelligence' are towards imitating life. Biomimetic robots, evolutionary robots, emotion controlled robots are just some new research ideas. Although these approaches are very different in their nature all have a common goal, to improve the adaptivity and learning capabilities of robots, 'breeding' a new generation of robots with better 'survival' chances in their specific operational environment. Another area of technological challenge for the next decade is the development of microrobots and nanorobots for medical applications. Here we are just at the beginning of a long journey. Robots cleaning clogged blood vessels or repairing damaged tissues are still to be developed. But still the biggest challenge in robotics for the next decade will be to find the proper balance between human-assisted systems and fully autonomous ones, thus to combine technological capabilities with social expectation and requirements.

The present special issue reflects through the number and variety of presented topics that robotics has become an important IT field of research. I hope you will enjoy reading the very interesting reports the way I did, and find some new ideas or wish to join the robotic research community.

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International Workshops on Human Centered Robotics

by Georges Giralt

Currently robotics research is undergoing a dramatic change in scope with the important perspective of a large host of real world applications that take the robot out of well engineered work-sites in the shop-floor.

In particular, human-centred robotics, a multi-faced frontline and most challenging domain, stresses the issues and problems arising when the robot has to operate in human environments and directly to interact with a non-professional user. Thus, with the objective to assess novel perspectives, to clarify research directions and to foster international co-operation, two special events with limited number of invited participants were organised in 1999.

1. US/Europe Workshop

The US/Europe Workshop on Personal Personal Robotics: from Service Robotics to the Personal Robot and Personal Robotics – Challenges and problems - was organized in Toulouse, France, on 14-15 January 1999. This workshop was supported by the US National Science Foundation and for the European side by CNRS and the Midi-Pyrenees Regional Authorities. John Canny (Berkeley) and Rachid Alami (LAAS-CNRS) were the two co-organisers. Worth to mention is that besides the twenty researchers representing Europe (Finland, France, Germany, Italy, Spain, Sweden) and the ten US representatives, four leading Japanese researchers were invited and outstadingly contributed to the workshop. Five observers were also invited.

The two-day program was set as a real WS with a few introductory subject-situation presentations followed by three working-group discussions that were reported to open an half day general discussion. The core themes covered showed both commonalties of interest and differences in viewpoints. EU participants highlighted the aspects related to Service and Personal Robots ranging from professional to domestic contexts. US participants emphasised the issues of Interface Robotics: wearable computing and sensing, human augmentation, telepresence, intelligent objects and smart rooms.

2. First Europe-Jan Symposium

The First Europe-Jan Symposium on Human Friendly Robotics was held in Tokyo, 8-9 November 1999. The symposium was sponsored by the French and Italian embassies in Tokyo, the European Commission, and held in co-operation with the AIST-MITI.

The objectives of the symposium were to discuss and to encourage future developments of fundamental technologies, to assess current field trends, to look at research perspectives as well as real world applications opportunities, and to foster international co-operation.

The symposium comprised two parts. First, one and a half days of workshop convening invited participants, with technical presentations and panel discussions. Second, one final afternoon session open to a larger public and to the press to present the WS highlights and achievements. Participation comprised eighteen experts from Japan and fifteen from Europe (Finland, France, Germany, Italy, Spain, Sweden). Furthermore, two experts and four sponsors' delegates participated to the full symposium as observers and about thirty invitees attended the open session the second day.

Besides important commonalties in interest and perspectives, two central aspects can be reported to differently categorise the on-going work in Japan and in Europe. The presentations from Japan highlighted:

- the major effort on humanoid robots with a clear objective to provide a set of research platforms.
- human machine interface development emphasising the role of the "Kansei" concept and tele-existence.
- effective market penetration with artificial pets.

The presentations from Europe appeared clearly rooted in recent work in the field of service robots with similar views on machine intelligence for human-robot interaction, domain-oriented research issues and key applications:

- public service oriented robots and assistive devices such as autonomous cleaning robots are considered with an attempt to find realistic short or mid-term applications
- assistive robotics for elderly and impaired people
- operational robot dependability.

Concluding Comments

One of the major benefits of both events lies in the importance of the viewpoint exchanges that brings to share a broader understanding of the key-issues and trends of a fast moving domain.

Current research developments related to Human Centred Robotics, based in the same shift in paradigm, sketch slightly different domain definitions and conceptual frameworks:

- Japan's human friendly robotics emphasises the central problem of human-robot coexistence, the Kansei concept in Human-Machine interaction, and network based tele-robotics
- Europe, streaming from past work in service robots which stresses the broad range of applications, develops the concepts of public-oriented and personal robots for servicing, assistance and entertainment
- the paradigm of personal robotics strongly advocated by several researchers mostly in the US which expands the concept of personal robot to distributed robotics functionalities and to human augmentation.

Specially worth to mention are the possibilities open for increased exchanges and co-operation between laboratories and the initiative to create an European Robotics Research Network, EURON.

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European Robotics Research Network – EURON

by Henrik I. Christensen

Japan and USA have strong research communities in robotics. In terms of volume there is probably relatively a similar research effort in Europe. It is, however, not obvious that there is a similar communication and dissemination within the European community. This poses a problem as researchers, engineers and students might look to the communities in Asia and USA for results, inspiration, etc. To address this problem the European Robotics Research Network has been established. The acronym for the network is EURON.

The network attempts to discuss activities according to five major topics: research co-ordination, education and training, publishing and meetings, industrial links and international links.

Research co-ordination attempts to define road maps for research and technology. Research road maps will in particular try to define long-term issues of relevance to Europe in general and the industry in particular. In addition it will explore cultural differences between Asia, USA and Europe, to ensure that research of particular relevance to Europe is identified (see also 'International Workshops on Robotics'). The technology map will identify state-of-the-art and technological issues. In addition this area will define bench-marks that allow comparison of research results. Standards that allow exchange of results between laboratories and transfer of results to industry will also be discussed. Finally the network will attempt to set up a Web-based encyclopaedia in robotics.

In terms of education and training there are already significant activities such as TMR and HCM networks. There is, however, a need for identification of common curricula and exchange of teaching material. There is also an interest in use of common exercises and software that can be used as part of education. Finally there is a need for databases that identify major educational institutions, vacant positions and students interested in short and/or long-term foreign placement.

There are already a large number of conferences in robotics and there is no need for new conferences, but there might be a need for brain-storming workshop that identify major new trends, etc. There is also an interest in a common body that can assist organisers whenever major conferences are organised in Europe. In addition there is a need for a European news-letter that provides information about on-going activities etc. The network will thus provide sponsorship for conferences organised in Europe and an electronic news-letters is presently being set-up.

Today there are no common facilities for access to research results and expertise. It is thus often easier for companies to establish contact to groups in USA and Japan. To address this problem the industrial links activity will attempt to provide yellow-pages for research and development in the area of robotics in Europe. In addition the group will explore various facilities to enable closer contact between academia and industry to facilitate added economic growth.

There is of course a need to maintain strong links with researchers on other continents and there are several other bodies that discuss and co-ordinate R&D on robotics. To this end the international links effort is building collaborative links to these other initiatives.

The co-ordination and communication within the network is first and foremost achieved through an electronic infra-structure that include electronic mailing lists and access to a common collaborative workspace (based on BSCW). The common electronic mailing list (euron@nada.kth.se) for the network at present includes about 150 European researchers and engineers.

For focussed activities the network is setting up ad-hoc interest groups that address a specific issue, such as RoboCup, manipulation, systems integration, haptics, learning, formal methods, etc.

The overall activities of the network are co-ordinated through an international advisory committee that includes many of the leading researchers and industrial players in Europe.

The network was established at a joint meeting in Salford, UK in April 2000. The meeting was attended by 40 researchers from all over Europe. At present it is investigated if the network can be supported by the European Community.

The network is open to all European research groups and industrial companies that have a reasonable level of activity on Robotics.

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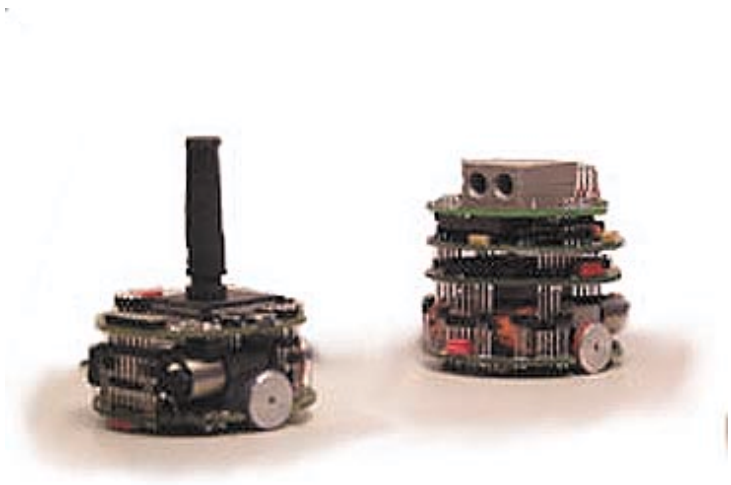
Evolutionary Robotics: Developing Robots through Artificial Evolution

by Stefano Nolfi and Dario Floreano

Evolutionary Robotics is a new technique for the automatic creation of autonomous robots that gains its inspiration from the Darwinian principle of selective reproduction of the fittest. It is a new approach that looks at robots as autonomous artificial organisms, which develop their own skills in close interaction with the environment and without human intervention.

One of the main problems in designing mobile robots is that their behaviour is the result of the dynamic interaction between the robot and the environment. The robot and the environment can be described as a dynamic system because the sensory state of the robot at any given time is a function of both the environment and of the robot's previous actions. The fact that behaviour is an emergent property of the interaction between the robot and the environment has the interesting consequence that simple robots can produce complex behaviour. However it also implies that the properties of the emergent behaviour cannot easily be predicted or inferred from a knowledge of the rules governing the interactions. The reverse is also true: it is difficult to predict which rules will produce a given behaviour, since behaviour is the emergent result of the dynamic interaction between the robot and the environment. This problem can be overcome by viewing robots as autonomous artificial organisms that develop their own skills in close interaction with the environment through an automatic process based on artificial evolution. By relying on an evaluation of the entire behaviour of individuals, this scheme releases the designer from the burden of identifying the rules that will result in the desired behaviour and allows the exploitation of emergent forms of behaviour (ie behaviour which heavily relies on the interaction between the robot and the environment).

Artificial evolution has been used to develop robots displaying non-trivial behaviour such as navigating and exploring a non-stationary environment, collecting garbage and discriminating different types of objects, walking, navigating in an environment by periodically returning to a recharging station, etc. Current research aims both to increase our understanding of natural systems by developing bio-inspired applications and to develop applications that are interesting from an engineering point of view.



The predator and prey robots consist of two Khepera robots. The predator is equipped with a vision module while the prey has a maximum available speed set to twice that of the predator. Both species were also provided with eight infrared proximity sensors (six on the front side and two on the back). Khepera has been developed at the Laboratory of Microcomputing of the Swiss Federal Institute of Technology (EPFL) in Lausanne.

A key question in evolutionary robotics is how artificial evolution can select individuals capable of displaying complex behaviour (eg navigating in a complex environment). A related problem in evolutionary biology is to understand how and under what circumstances natural evolution may discover new competencies (eg, the ability to fly or build a nest). If one wishes to select individuals capable of solving a task that requires a specific competence through artificial evolution, the easiest thing to do is to select the individuals for their ability to solve that specific task. This amounts to designing a fitness criterion that scores individuals according to their ability to solve the task. However, it is easy to show that this simple strategy can only work for simple tasks. As the complexity of the task increases, the probability that some individuals of the first generation are able to accomplish, at least in part, the task is inversely proportional to the complexity of the task itself. For complex tasks, all individuals of the first generations are scored with the same null value, and as a consequence the selection process cannot operate.

One way to solve this problem is to set up a self-organizing process capable of producing incremental evolution (ie an evolutionary process in which the complexity of the selection criterion progressively increases with new generations). This ideal situation spontaneously arises in competing co-evolving populations with coupled fitness.

For this reason we recently carried out a joint project in which we co-evolved two populations of predator and prey robots that were selected for their ability to catch prey and to escape predators, respectively.

At the beginning of the evolutionary process, predators should be able to catch prey which have a very simple behaviour and are therefore easy to catch; likewise, prey should be able to escape simple predators. However, later on, both populations and their evolving challenges become increasingly complex. Therefore, even if the selection criterion remains the same, the adaptation task becomes progressively more difficult. Results obtained demonstrate that competitive co-evolution can lead to an open-ended process where the emergence of progressively more complex solutions can be observed.

The latest results obtained in the field of Evolutionary Robotics and, in particular, the experiments carried out at the Institute of Psychology of National Research Council (CNR) in Rome and at the Laboratory of Microcomputing of the Swiss Federal Institute of Technology (EPFL) in Lausanne will be reported in a forthcoming book [Nolfi and Floreano (in press). Evolutionary Robotics: The Biology, Intelligence, and Technology of Self-Organizing Machines. Cambridge, MA: MIT Press/Bradford Books]

Links:
http://gral.ip.rm.cnr.it/nolfi/robotics.html
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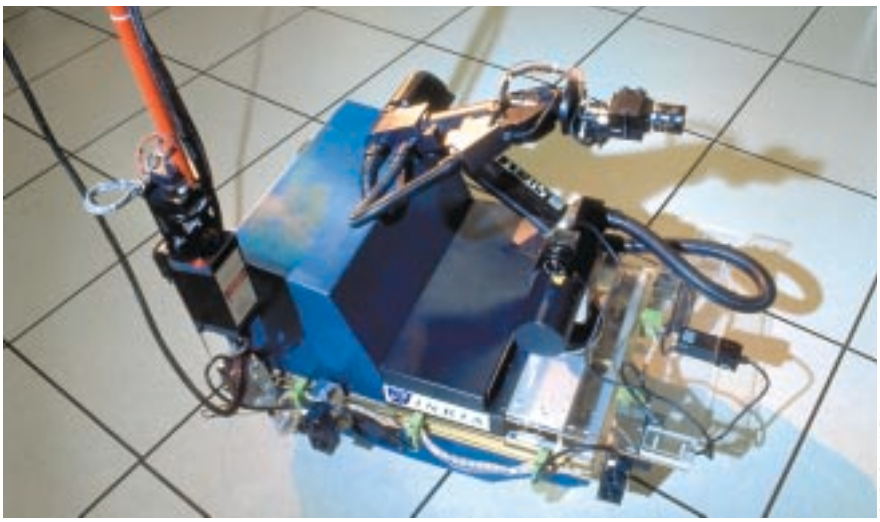
Map Building and Robot Localization

by Patrick Rives and Alessandro Corrêa-Victorino

Safety navigation and reliable localization are two elementary functions absolutely necessary to operate autonomous vehicles in unknown environment. In many applications of mobile robotics, the localization can be carried out by integrating the odometry data but it is not very reliable because of the wheels slipping and the uncertainties about the mechanical structure of the robot. It is then interesting to be able to compensate this drift while being readjusted with respect to the environment.

In the ICARE research team at INRIA, we are dealing with techniques which allows us to locate the robot and to build a map of the environment simultaneously. The difficulty of the problem lies on the fact that a reliable localization depends on the quality of the map building process carried out from the elements of the environment previously observed and which remain visible at current time. On the other hand, more the accuracy on the localization will be large, more the map building step will be reliable. A trade-off is thus to be made between the function of exploration (ie discover the maximum of unknown elements of environment) and the function of localization (ie keep the maximum of known landmarks during the motion). It will be the role of the strategy of perception.



The robot ANIS.

In the ICARE research team, we developped an approach based on the fusion of 2-D Laser Range Finder data and odometry data for the mapping and the localization of a mobile robot moving in a structured but unknown environment. We showed that the robustness of these tasks can be notably increased when the robot is constrained to move on certain trajectories during its exploration. These trajectories must have some properties such as:

- to be locally defined for each current location
- to belong to the free space
- to ensure a complete exploration of the environment
- to capture topology and accessibility of the map for a robot with a given size.

The Voronoi Diagram satisfies such requirements and, moreover, can be incrementally built from the laser data in a straightforward manner. With a sensor based control technique using the laser data as feedback, we are able to constrain the robot to move along the Voronoi Diagram. Thanks to the closed loop control, we ensure a bounded error during the robot displacement.

The localization of the robot is obtained by the fusion between the range sensor readings and the odometry data, using an

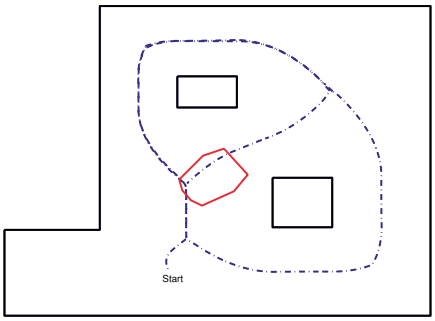


Figure 2: Map building using the Voronoi Diagram.

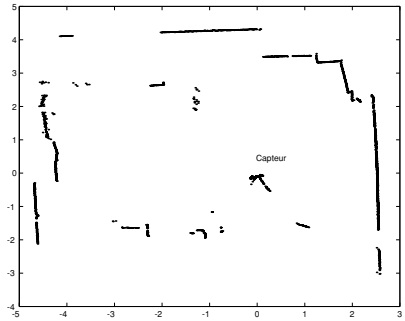


Figure 3: An example of map provided by the 2D-Laser Range Finder.

Extended Kalman Filter in order to cope with the occasional and systematic uncertainties of the observations and getting an optimal state estimate of the robot. A map of the environment is incrementally built and updated using both the laser scans and the Voronoi Diagram constraints (see Figure 2).

This approach has been validated with the Robot ANIS (see Figure 1) developped in the ICARE research team at INRIA-Sophia Antipolis. This robot is instrumented with a 2D-Laser Ranging Finder which provides 2000 points of readings at 80ms rate, thanks to the microelectronics developed in our Laboratory.

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Plan-Based Control of Autonomous Robots

by Joachim Hertzberg and Frank Schönherr

A robot control system is a special piece of software. It must cope with data in many different grades of granularity, from sensor readings to user-supplied mission data; it must yield purposeful action on different time scales, from collision reflexes to optimal long-term mission organization. Accordingly, a robot control program needs a special structure and organization that integrate these incoherent pieces into coherent overall action—it needs a special architecture. The Robot Control Architectures (ARC) team investigates robot control architectures that amalgamate reactive components working in close sensor-motor coupling, on the one hand, and deliberative, plan-based components working on an explicit symbol level, on the other hand. DD&P is one such architecture currently under development.

The reactive and the deliberative, plan-based aspects of robot control cannot a priori be ordered by importance or precedence: On a short term, reaction is first in order to avoid bumping into walls or falling down staircases; on a longer term, deliberated action is first in order to care about fulfilling the mission goals. Modern robot control architectures are hybrid, i.e., they contain different layers for reactive and for deliberative control components. Typically, a middle layer (often called sequencing layer) mediates between the reactive and the deliberative components, resulting in a three-layer architecture.

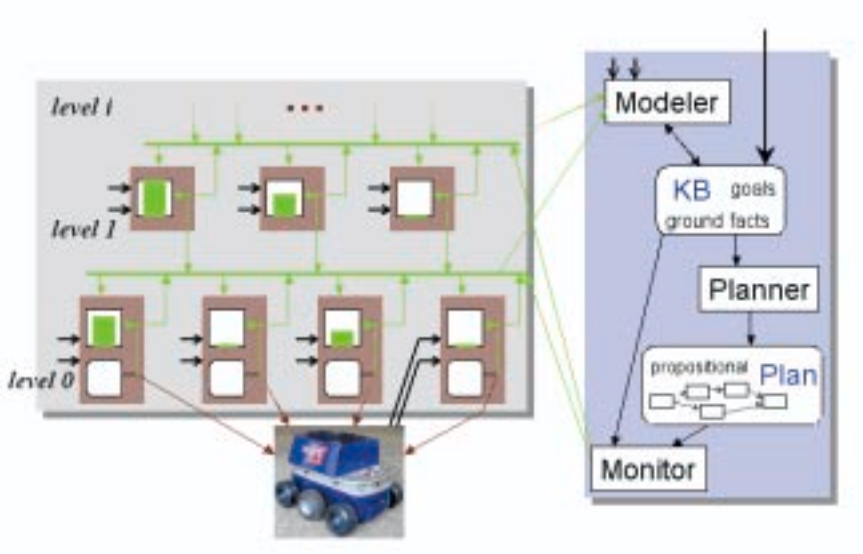
Dual Dynamics:
A Robot Control Framework

DD&P is a hybrid, two-layer robot control architecture. Its reactive layer is formulated in terms of Dual Dynamics (DD), a framework for specifying a set of robot behaviors as a continuous dynamical system, expressed as ordinary differential equations. It has been developed prior to our work. DD helps design and debug complex behavior systems that permit fast reactions to highly dynamical environments. Running DD applications include controllers for RoboCup players both within GMD (the mid-size league team of AiS.BE, see the paper by Bredenfeld in this issue) and outside GMD (the small-size league team of Free University of Berlin, which scored vice-champion in the IJCAI-99 world championship).

As is typical for behavior-based approaches, behavior sequencing can only be expressed somewhat clumsily in DD, and goals can be given to the robot only in form of a behavior program, which makes them difficult to change and communicate. Symbolic AI action planning approaches can do both much more elegantly, but they have difficulties expressing real physical action, at which behavior-based approaches are good. Combining the best of both worlds is mandatory, as all existing multi-layer robot control architectures attempt to do.

DD&P:
Coupling DD and Plan Deliberation

DD&P allows DD robot controllers to be coupled with a deliberative layer in a principled way, thereby designing a robot control architecture from existing and well-understood approaches both on the behavior and the planning side. DD is attractive to that end for the separation that it makes in every behavior between specifying physical action that the behavior proposes – the target dynamics for low-level behaviors, in DD terms – and a scalar value for its 'subjective' convincedness how appropriate its own



Schema of the DD&P robot control architecture. See text for explanations.

contribution would be at the moment, the activation dynamics. The sketch of the DD&P structure in the figure has the DD part in the large grey box on the left, with single behaviors represented as brown boxes. Activation values of single behaviors and the flow of these values, respectively, are represented by green bars and arrows, respectively. Input from the robot sensors is shown by black arrows with open heads.

In its planning part (cf. the blue box at the right of the figure), DD&P proposes to use classical propositional action planning as the Planner component; we use existing modern, fast propositional systems like the planning graph planner IPP (Freiburg University). The idea is to make a quite abstract, typically short propositional Plan very quickly, make it available to the Monitor component, and start making the next plan or updating the current one immediately, thereby essentially planning all the time and overwriting plans as soon as new information becomes available. The hypothesis is that this throw-away-plan approach is practically superior to generating and using more expressive plans that take uncertainties into account, yet take much longer to be generated and suffer from problems of eliciting the required information about event and outcome probabilities in the first place; on the other hand, the approach promises to preserve the advantage of using plans for sequencing behavior and for projecting longer-term consequences of immediate actions.

Kurt II Robot.

As soon as the Monitor component finishes (with or without success) executing a Plan, it will pick as its next one the most recent one as generated by the Planner as current, and starts executing it as indicated by the Plan's action order. Execution of an action in the current Plan is finished if its specified postconditions hold in the knowledge base (see below) or if some timeout condition is true. Executing an action means exactly to push up the activation values of behaviors that work in favor of that Plan operator, and to dampen the activation values of all behaviors counteracting that operator. In consequence, the Plan under execution does not determine the physical action of the robot; it rather biases the action towards that end. This philosophy is appropriate for a robot control that is supposed to be both reactive to unforseen changes in the world, and goal-directed in its long-term tactical or strategic behavior.

Information about current facts and goals gets into the propositional knowledge base by input from the user (the arrow entering there from top) or from a Modeler component. In general, the information in the knowledge base cannot be assumed to be timely and consistent, due to possible changes in the environment and to incomplete and inaccurate sensor information. The Planner must be able to work in the presence of such inconsistencies, and the Monitor must be able to recover from invalid plans or plan steps. In addition to sensor information and to the recent state of the knowledge base, the Modeler has access to the time series of the activation values of all DD behaviors. This data represents particularly aggregated sensor readings, namely, the world as percieved through the eyes of the behaviors, which

allows certain action-relevant fact changes in the environment to be derived quite directly. In consequence, the DD part influences the plan part, or rather, the knowledge base, by providing via its activation values recent information about the environment and, in particular, about behavior alternatives in it. Of course, the regular sensor output and information from other agents or users, if available, are also used for knowledge base update.

All components within the plan part work in logical concurrence, as do the DD part and the plan part and all DD behaviors among each other. This logical concurrency is exploited in a physically concurrent implementation of the DD&P architecture that is currently under development.

Summary and State of Work

DD&P is a hybrid robot control architecture featuring the following three points:

- it is a two-layer hybrid architecture combining a reactive and a deliberative part by the structure of information flow rather than by a separate middle layer
- plans are aids for improving and communicating robot behavior rather than rigid control regimes
- the reactive and the deliberative parts as well as the components within the two parts logically concur to a very high degree.

Current work on the DD&P architecture builds on existing DD knowledge and DD programming tools as well as on a programming environment and methodology for concurrent programming (the Flip-Tick Architecture, FTA), all available within GMD's institute for Autonomous intelligent Systems (GMD.AiS). We are currently implementing a prototype of a DD&P system in terms of FTA, aiming at a demo version of a controller of a KURT-II robot platform, as depicted in the photo in Fig.1.

Acknowledgements

Our work builds in its theoretical and practical aspects upon that of colleagues in GMD.AiS, most notably on DD and FTA. The respective co-operation is gratefully acknowledged.

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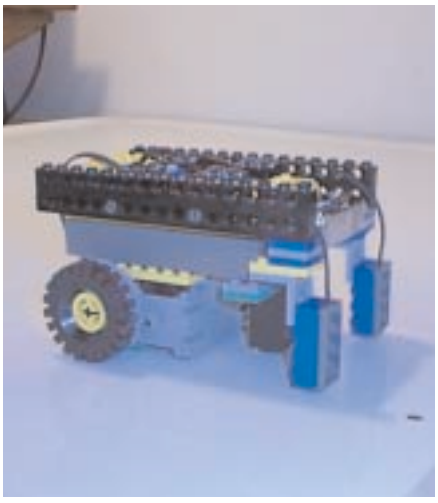
Large Adaptive Critics and Mobile Robotics

by Rudolf Jakša and Peter Sin ák

The Computational Intelligence Group at TU Košice is doing research in application of CI tools in image processing, prediction problems and in mobile robot control. Considering mobile robotics, recent work is focused on reinforcement learning methods and their application on LEGO Mindstroms mobile robots.

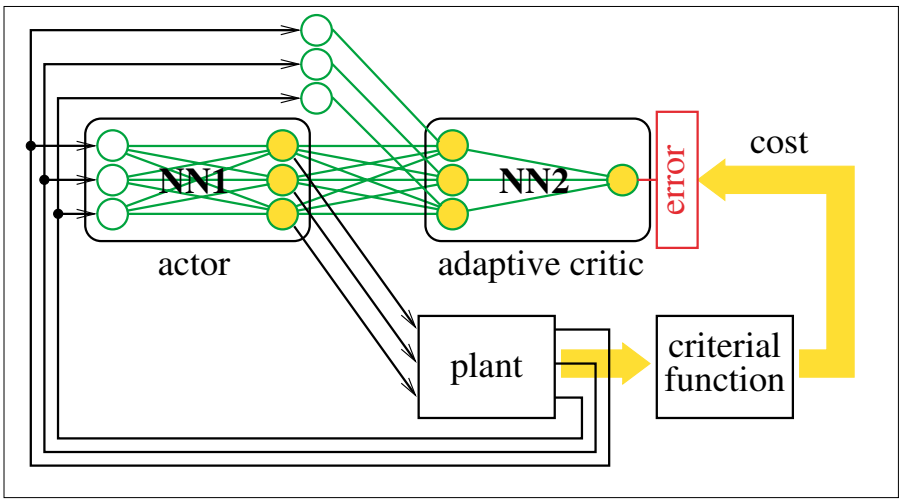
Mobile robotics is typical area for application of advanced intelligent control methods including artifical neural networks (ANNs), evolutionary strategies, fuzzy systems, etc. A common problem in this area is the navigation of robot, like following the desired trajectory, searching the path to the target position, wall following or obstacle avoidance. In practical applications these tasks represent problems like automatic parking and driving of a car, driving flexible automated guided vehicles without a prescribed path or control of autonomous robots without direct manual supervision. Nowadays are popular so called Internet robots, although they operate in a very different environment than classical mobile robots, they face very similar navigation problems and can use techniques developed for a mobile robot navigation. It can be claimed that ANNs are one of the key technologies in a mobile robotics area.

Most advanced methods in neurocontrol are based on reinforcement learning techniques, sometimes called also approximate dynamic programming. These methods are able to control processes such a way, that is approximately optimal with respect to any given criteria. For instance, when searching for an optimal trajectory to the target position, distance of the robot from this target position can be simply used as a criterial function. The algorithm will compute proper steering and acceleration signals for control of vehicle and the resulting trajectory of vehicle will be close to optimal. During few trials (the number depends on the problem and the algorithm used) will the system improve performance and resulting trajectory will be close to optimal. The freedom of choice of criterial function and the ability to derive a control strategy only from trial/error experience are very strong advantages of this method.



A LEGO Mindstorm mobile robot.

There are number of various reinforcement learning modifications. Common class of these algorithms is based on the adaptive critic (AC) approach. In this approach they are two main components, one is an adaptive critic, which evaluate behavior of whole control, and second element is so called actor, which is adapted in order to optimize the evaluation produced by the



Structure of the adaptive critic controller based on artifical neural networks.

adaptive critic. Both elements can be realized using ANNs. Our research is focused in the study of the role of actor and adaptive critic networks complexity and their influence to the control performance. The figure shows the structure of AC controller based on ANNs.

Our recent experiments were done on software simulator of the mobile robot. This simulator was used also in experiments with supervised neurocontrol and fuzzy control of mobile robot. Beside the simulation, the control of a real LEGO robot was accomplished. Our first goal was achieved recently and we can repeat experiments with a sufficient accuracy in simulation environment and using a real robot. Generally we can confirm that the reinforcement learning based neurocontrollers are progressive part of control technology and we do believe that they will play important role in intelligent technologies of 21-st century.

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Modelling Non-linear Phenomena in Joints of Robots with Neural Networks

by Jozef Suchy

Some types of artificial neural networks have the potential to model non-linear relations between input and output variables of systems. The structure of this non-linearity need not be known in advance. Joints of robots are known to posses non-linear properties like friction, non-linear stiffness or backlash. Usual way how to model these phenomena is to assume some analytical model and to identify its para-meters. At the Faculty of Natural Sciences of Matej Bel University, an approach is based on using the convenient measurements, which enable to model the joint of a robot as non-linear system.

Knowledge of non-linearity in joints of geared robots may be very important. Friction, eg, causes that part of the moment generated by the motor in the joint is lost to overcome the friction moment of the joint. If these losses of the moment caused by friction, stiffness/ compliance (eg compliance of harmonic drive), and backlash were known in advance one could compensate for them by generating some extra torque. This may be significant in those situations where it is important that some amount of torque is transferred through the joint without losses. Typical example is the so-called force or compliance control of robots.

With this type of robot control one desires that the robot apply some well-defined force or moment to the working environment. This force depends in general on torque in all joints. If the torque in some joint is insufficient, it may not be possible to generate the desired force or moment in the environment. Besides, as the amount of lost torque is not known, the Cartesian force may be generated with low precision.

In current practice the problem is solved by force feedback. The 6-component force/torque sensors are used to measure the intensity of contact (three Cartesian forces and three Cartesian moments) and the measured forces or moments are fed back. On this basis the motor currents, which are equivalent to the torque are controlled in such a way that the desired Cartesian values are attained. Disadvantage of this approach is the use of comparatively expensive sophisticated sensor and also narrower bandwidth caused by additional control loops.

On the contrary, this problem is not so serious with direct drive robots where the absence of gearing removes the majority of sources of non-linearity. In principle, using direct drive robots, the intensity of contact with the environment could be satisfactorily controlled by defining equivalent joint's torque. As there are only minor losses of torque in joints in this case, the equivalent joint's torque may be computed by multiplying the desired Cartesian force/moment with transposed Jacobi matrix of the manipulator.

We have begun neural network modelling with the most significant non-linear phenomenon in robot joints – friction. To separate friction from other phenomena we used data measured on one joint of direct drive robot EDDA built at the Institute of Robotics, University of Technology, Braunschweig, Germany. In spite of absence of gearing, some friction is still present in joints. It was our desire to utilize as simple measurements as possible. We developed methodology of modelling joint friction with ANN for this simple two-degree-of-freedom robot based on the measurements of angular position and of corresponding current. However, the knowledge of dynamic model of the manipulator was assumed.

Methodology is based on obtaining friction data from the knowledge of angular position, motor current/moment and from the dynamical model of the manipulator. This leads to the inevitability to compute angular acceleration. As the by-product, also this procedure was developed, which works satisfactorily.

Multi-layer perceptron network was used in most of cases for the modelling although it was worked also with CMAC neural network. The inputs to the network are present and past values of angular position and past values of friction torque. The output of the network is actual value of friction torque. Network was learnt by back-propagation algorithm with the momentum term and with the adaptive learning rate. The batch version of the algorithm was used. The number of training epochs was chosen as 10 000, while the training set consisted of 2000 samples. The sum square error was diminished to 0.707 on the training set and to 2.95 for the whole set of samples. It goes out from this that the friction torque is modelled with good quality.

There was also experimented with the depth of history of signals used for modelling as it was assumed that the structure of non-linearity including the order of the system is not known. It goes out from these experiments that the system of first or second order sufficiently model the joint properties. This procedure makes up for the procedure of system's order identification.

One may object that friction changes with time and depends on temperature. Temperature dependence may be modelled if the additional measurement of temperature is available. Temperature and temperature gradient would be possibly further inputs to the ANN. However, in the present time such measurements are not available for us. This possibility is the subject of our further research.

There is the potential to make this method adaptive, which means that the measurements could be performed continually and the model would be up-dated on their basis. This does not in principle need any extra sensors, as the sensors needed are available in every joint. Would the model be built also on the basis of temperature measurement, simple temperature measuring scheme would have to be built.

An attempt has also been made to model complex properties of the joint. This research will continue in the future. One goal of this research consists in constructing what we call generalised Jacobi matrix, ie Jacobi matrix, which includes also the properties of joints. Such a matrix could serve to transform the Cartesian forces and moments to joint torque or motor current.

This work was performed due to the grants of the Slovak Scientific Grant Agency VEGA.

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High Performance Haptic and Teleoperative Interfaces

by Ron Daniel

Force Reflecting Teleoperation and Haptic Interfaces present a number of mechatronic design challenges. Some solutions exist, some challenges are open. Here are described some of the challenges faced and solved at Oxford University.

Remote manipulation of hazardous environments, or human-machine interaction with virtual environments, requires devices and systems that are able to provide a human with a rich set of sensory inputs. There are a number of Mechatronic design challenges in order to develop the interfaces plus a number of unresolved problems in control and sensor integration. Haptics is the science of human touch, and a device giving the impression of touch when running a computer simulator is called a haptic interface. Haptic feedback systems are becoming more important now that Virtual Reality simulators are able to present accurate renditions of object contact. There are applications from improving design simulation in CAD through to improving diagnostic tools for medical scanning.

Mechatronic design concentrates on the investigation of methods to integrate mechanical, electronic and computer systems to achieve a solution that is not easily envisaged when considered as, say, a purely mechanical problem. For example, techniques developed for the design of controllers can be inverted to inform mechanical design, mechanical design principles can be inverted to generate high performance computer algorithms, differential mechanical drives can be utilised to overcome electronic resolution problems on encoder

interfaces. Each of these examples has yielded a novel solution to a particular design problem presented by the design of force feedback devices.

The Oxford University Robotics Research Group has been developing a mechatronic approach to the design of contact interface systems for a number of years. Mechanical principles of parallel actuation, together with powerful algorithms themselves based on principles of equivalence in mechanisms, led us to suggest a powered Stewart Platform as an input device, now marketed by AEA Technology as the BSP or Bilateral Stewart Platform. This is a parallel kinematic device that delivers a high bandwidth force signal to the user and is able to convey the sense of touch that complex assembly tasks require when performed by a remote robot under human control. The problems solved to achieve this include:

- **The Real Time Forward Kinematic Solution for Parallel Mechanisms**
  The robotic interface used to transmit commands to the remote manipulator has a parallel kinematic structure. The generation of Cartesian position from joint measurements is difficult and not easily generated in real time. A new algorithm has been developed, based on the directional derivatives of the singular values of a related mechanism, that is robust to singularities in the real mechanism and can be solved iteratively in 10 microseconds on a 200 MHz PC. The algorithm was integrated into a real-time control platform developed at Oxford under the operating system QNX. This controller is based on a Virtual Machine for control that is itself robust and easy to program.
- **The Non-Minimum Phase Characterisation of Robot Drives**
  Geared electric robots have complex contact dynamics when pushing against a stiff environment. Many remote tasks present such stiff environments and lead to partial locking of the gears as torque is applied from the motor. We discovered that an almost stationary geared drive presents multiple paths for transmitting torque, the paths depending on the internal dynamics of the reduction gear train. Such multiple paths can generate non-minimum phase zeros in the linearised contact dynamics that rapidly destabilise any remote force controller. We also discovered that replacing ordinary geared drives with differential drives removes these zeros. This suggests that robots designed for force servoing, such as for assembly, should have redundant actuation. Further to this, redundant actuation means that a mechanism can carry out a contact task while maintaining internal motion. This has important implications for the resolution of dynamic signals such as joint velocity when derived from encoders. Much higher control bandwidths at low speed can, in principle, be attained by following this path.
- **The Specification of Achievable Teleoperation Performance**
  Until recently, little was known about how the physics of a teleoperator limits the achievable performance of the complete system. Important questions that must be answerable are: 'What is the highest force reflection ratio that can be achieved with this particular system?', 'To achieve the specified performance, what should be the main characteristics of the mechanisms used in the system?'. These questions have been addressed and partially answered by appeal to simple physical laws that place bounds on what can be achieved using computer control. For example, we have shown that it is particularly important to get the right distribution of mass within the mechanism and to ensure that the right sensors are available given the mass distribution.
- **The Design of Force Reflecting Filters**
  If it is known that a given performance specification is achievable with a particular system, it is still necessary for tuning rules to be available for setting up the system for a specific task. We have developed simple rules for carrying out this necessary task that relate the characteristic modes of a teleoperation system to the choice of filter bandwidths in the controller.
- **The Integration of Computer Vision and Impact Control**
  Data fusion is an important task when there are many sensors being used to monitor contact. Unfortunately there has been little well-founded work on achieving the fusion of contact and visual information. We have developed a new approach that transforms uncertainty in a vision sensor into a probability of impact and expresses the cost of impact as a functional based on this uncertainty. Variational techniques may then be used to generate a predictive signal that specifies the optimal kinematic path in real-time up to the point of contact. Such control can be used to assist an operator trying to achieve remote contact during a tricky remote assembly task. It can also be integrated into a predictive dynamic controller to optimise speed of contact.
- **The Multiple Camera Tracking of Man-Made Objects**
  Remote systems normally have viewing systems based on multiple cameras. We have developed a multiple camera object pose tracker that is able to reconstruct a virtual view of a scene from a position not covered by the viewing cameras. Such a system compensates for errors in any model that might exist of the remote environment and can be integrated with the dynamic information being generated by the robot joint-sensors to achieve accurate object tracking for tasks such as assembly.

The above is a taste of the types of problems that remote handling can present. Our current research is aimed at Haptic, rather than force-reflecting, interfaces and involves the extension of the above work to diagnostic aids for surgeons. Here the problem is to build a real-time interface to a finite-element model of human flesh so that realistic forces can be reproduced within a simulation of a surgical or diagnostic intervention. There are the usual problems of large deformation finite elements together with how such a model can be interfaced with a high-speed local model of interaction. The key is minimisation of latency in deep-contact simulation. This is an active area of research that we aim to report on in the near future.

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JERRY: An Interactive Planning Tool for Space Robotics

by Amedeo Cesta, Enrico Giunchiglia, Paola Riccucci, Paolo Traverso

JERRY is a modular system for the interactive design, planning, control and supervision of the operation of autonomous robot systems in space. In such a highly critical environment, JERRY can effectively support the robot operators in both ordinary and emergency situations and make their work easier, safer and faster. JERRY can also provide scientists with no specific competence in robotics with a higher-level support for the automated execution of complex robot activities, with limited contributions from specialized operators.

JERRY has been developed in a collaboration between the Mechanized Reasoning Groups at both the University of Genoa and the Institute for Scientific and Technological Research (IRST), Trento, together with the Institute of Psychology, CNR, Rome, as part of an ongoing and more ambitious project funded by ASI, the Italian Space Agency. In this application, JERRY provides its functionality to different kinds of users who have to design, control and monitor a robot arm performing complex tasks, such as the setting up of experiments in a space workcell.

The system integrates different Artificial Intelligence techniques into an interactive environment to synthesize plans for the robot to execute. The high level goal of the system is to simplify the interaction of users at various levels of expertise with a rather complex robotic device.

JERRY has been designed to enable robot operation in Interactive Autonomy, ie the system can perform all of its tasks autonomously (including recovery from various non-nominal situations), but the user is able to easily monitor and possibly override autonomous operations, in a collaborative fashion. Effectiveness is guaranteed by a set of tightly integrated specialized modules, each dedicated to a specific task. Interactive autonomy is attained through a user-centered architecture, where the user asks for services from the specialized modules.

The key AI feature of the project lies in the definition of an experiment as a planning problem, which is then processed by the Planning and Execution modules.

The Planning Module requests a high-level description of the task to be performed by the robot and performs the synthesis of an equivalent abstract plan (in a user-oriented symbolic language), ie a sequence of high-level actions for the robotic system to execute.

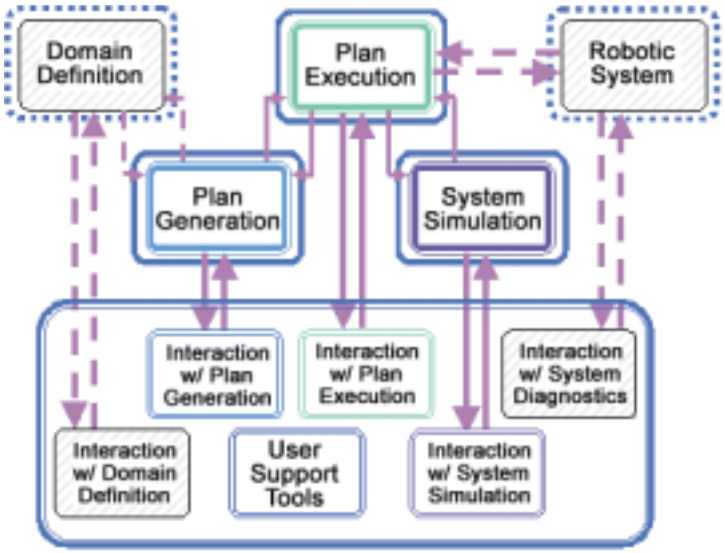

Figure1: Jerry Architecture.

The Execution Module transforms an abstract plan (describing the given task as a sequence of high-level actions) into an executable plan, where high-level actions are expressed in terms of the basic actions the robot system can perform, taking into account constraints related to the geometry and physics of the robot system and its operating domain. The executable plan is then encoded into the robot's control language, thus generating an executable code in system-specific language. The resulting code can be visually validated by submitting it to the Software Simulator of the robotic system.

Prototype

At present, a complete prototype has been developed that considers the SPIDER arm developed by ASI as the target robotic device. The system is able to synthesize low level programs coded in PDL2, the SPIDER command language.

From a software perspective, JERRY features a client/server architecture as shown in Figure 1. Each specialized module (top) is made accessible remotely (via TCP-IP) as a server. The User Interaction Module (bottom) acts as a client, connecting to the appropriate server at each step of the experiment's lifecycle and requesting its processing services.

Such an architecture results in a rather 'lightweight' Interaction Module, thus enabling users to run the earlier stages of development on computers of limited resources, such as laptops; for a wider portability, the module is written in Java.

Figure 2 shows JERRY as seen by the user, through its Interaction Module. In the main window (left), four viewports show the resources of the specialized servers: the planning problem specification window (left); the plan in execution (top-right); the PDL2 code corresponding to the action being executed (middle-right); and the visual simulation of the plan coming from the simulator (bottom-right). At any moment, for better readability, users can move the module on which their attention is focused to the main viewport. At the bottom of

the main window, a Console Area shows information on the status of communications with the remote servers and the data exchanged.

The HTML User Guide (right) appears in a separate window. It can be also viewed independently of the User Interaction Module, through any HTML browser.

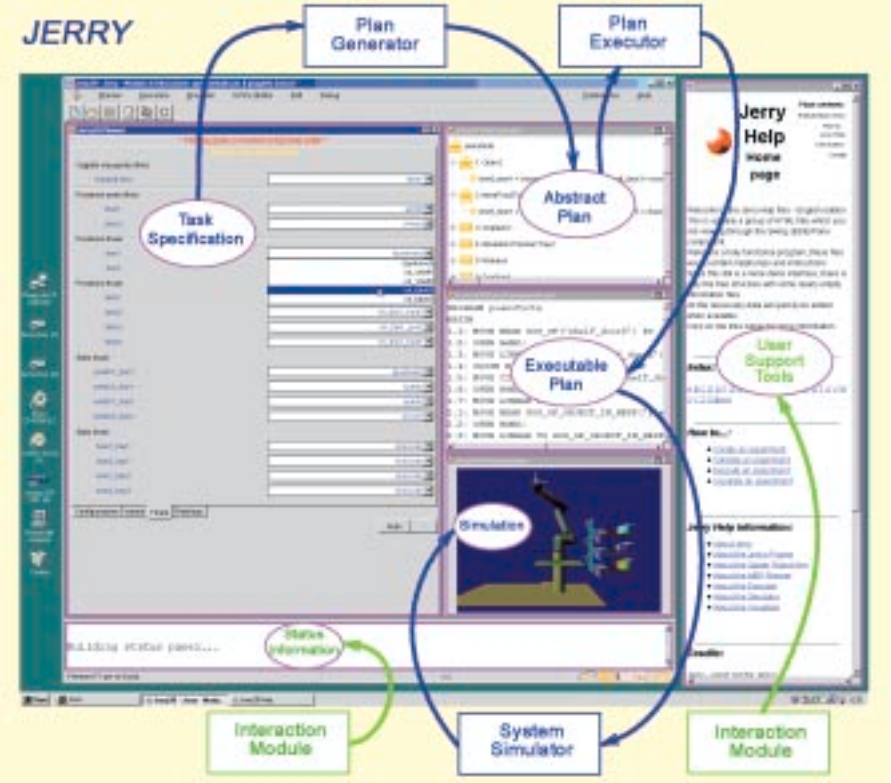

Figure 2: Jerry user interface.

Future Developments

Although the project is still running, a first working prototype is now available for experimentation. The current scenario concerns the SPIDER arm extracting a tray from a shelf, fixing it to one of two tables and then automatically performing experiments moving objects contained in the tray.

Further development will enhance the capabilities of the planning problem specification window. While the current design is centered on the selection of text parameters, the next release will enable users to specify all the settings via direct manipulation of graphical objects. Further work will be aimed at making the whole architecture completely domain-independent, in order to obtain a powerful tool for robot software development and verification, starting from a high level specification language.

Links

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Mobile Robots with Dual Dynamics

by Ansgar Bredenfeld, Herbert Jaeger and Thomas Christaller

Speed and complexity of behaviors are key factors for mobile robots acting in unpredictable, dynamic environments. The Behavior Engineering (BE) team of the GMD Institute for Autonomous intelligent Systems (AiS) focuses on the combination of these two research issues. We use soccer playing robots as demonstrator platform since they provide an ideal benchmark environment for interdisciplinary research on mobile robotics.

Our approach to robot programming is based on a mathematical model for robot behaviors which we developed. It integrates central aspects of a behavior-based approach, robust control, and a dynamical systems representation of actions and goals. Robot behaviors are specified through ordinary differential equations, forming a global dynamical system made of behavior subsystems which interact through specific coupling and bifurcation-induction mechanisms. Behaviors are organized in levels where higher levels have a larger time scale than lower levels. Since at the elementary level the activation of behaviors (activation dynamics) is separated from their actuator control laws (target dynamics), we named our approach 'Dual Dynamics'. An important feature of Dual Dynamics is that it allows for robust and smooth changes between different behavior modes, which results in very reactive, fast and natural motions of the robots.

Dual Dynamics Design Environment

The successful design of robot software requires means to specify, implement and simulate as well as to run and debug the robot software in real-time on physical robots. It was a major challenge to make the Dual Dynamics approach productive in a state-of-the-art design flow. The result of our work is the integrated Dual Dynamics Design Environment. It allows to design Dual Dynamics models on a high level of abstraction and to synthesize all code artifacts required to make Dual Dynamics models operative in practice: a documentation, a simulation model, control programs for physical robots and a parameter set for generic test and debug

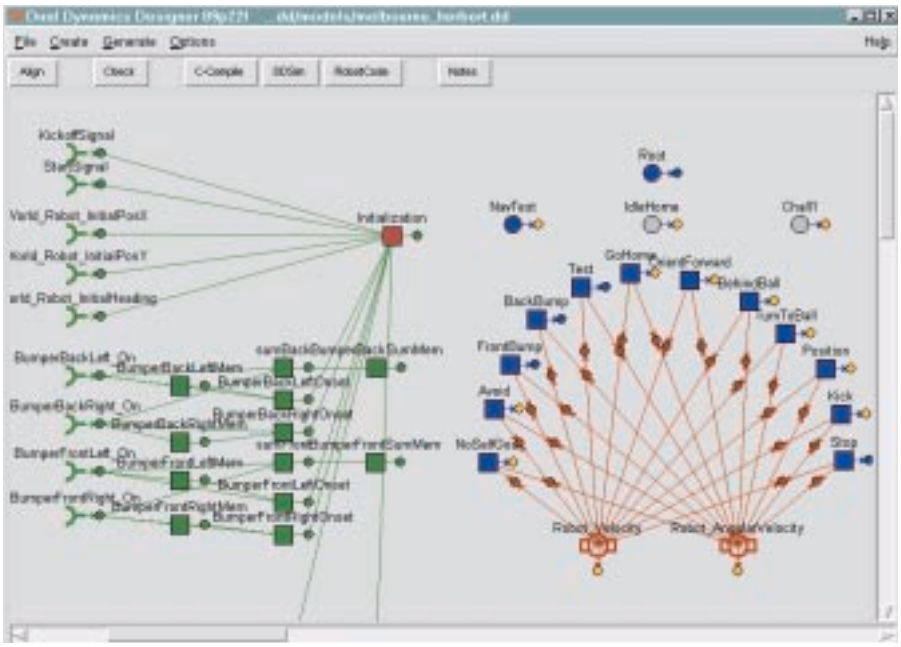

Figure 2: DD-Designer with a graphical specification of a Dual Dynamics behavior system.

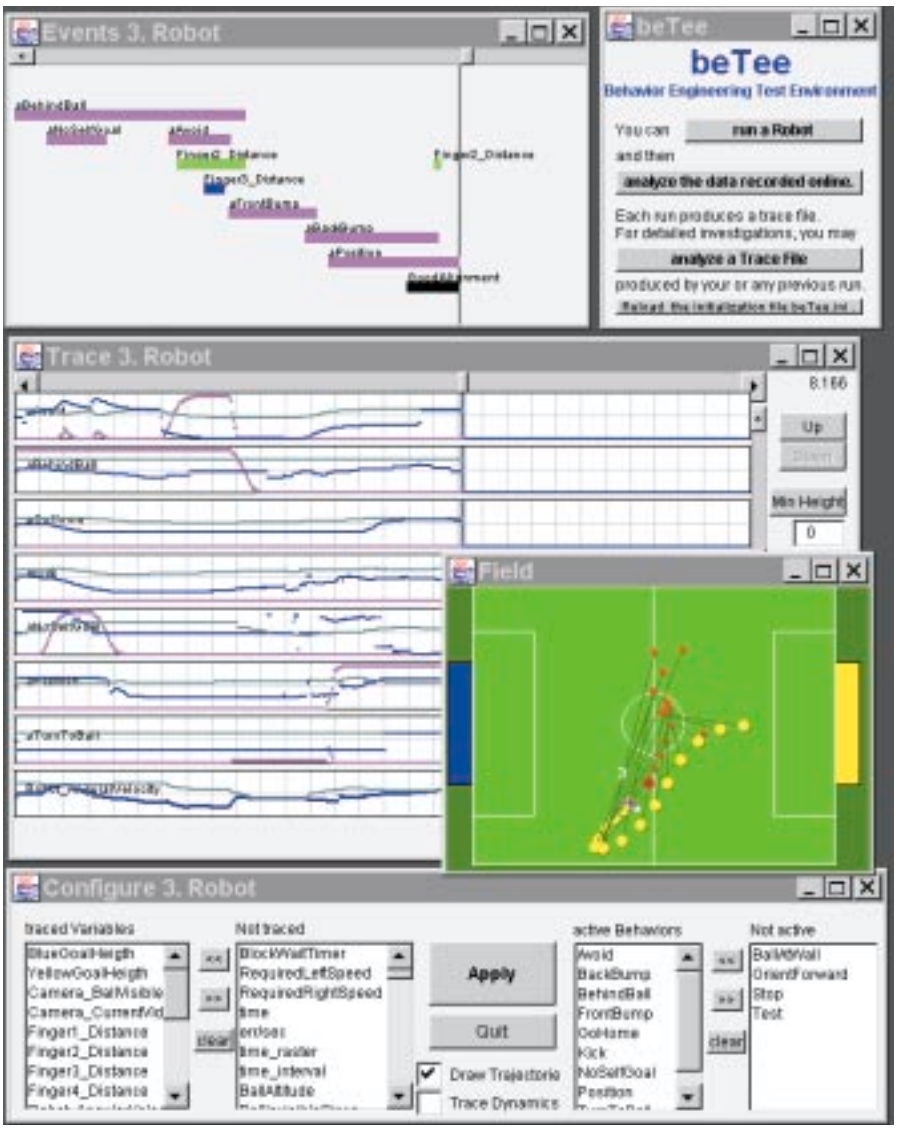

Figure 3: Real-time monitoring tool beTee with symbolized playground, variable state waveforms and event traces.

tools. The Dual Dynamics Design Environment comprises the graphical specification and code generation tool Dual Dynamics-Designer, the simulator DDSim and the real-time monitoring tool beTee:

- DD-Designer allows to specify a Dual Dynamics model in terms of sensors, actuators, sensor pre-processing elements and a hierarchy of coupled behaviors. Each of the processing elements is formulated using a combination of control data flow and differential equations. This specification is the basis for an automatic refinement of all code artifacts required by the tools in our design environment.
- DDSim allows to simulate a team of robots on a playground. It provides sophisticated simulations of the ball and the sensors of the robots. This includes laser scanner simulation and an emulation of the vision system used by our robots. Since each robot is configured with different behavior systems, we are able to benchmark behavior systems against each other.
- beTee is a real-time monitoring tool for tracing arbitrary variables of the simulated or (via wireless LAN) the physical robot.

GMD-Robots

The test bed and demonstrator application for our Dual Dynamics approach are soccer playing robots. They take part in the mid-size league tournaments of the international RoboCup contest, a very demanding benchmark for mobile robots. RoboCup tournaments have been organized since 1997 with a yearly increasing number of participating teams from over the world. This year, the first European competition will be held in Amsterdam at the beginning of June.

Our robots were custom-built in the Institute for Autonomous intelligent Systems. As hardware we employ 2 degree of freedom, 1-PC-3-micro controller equipped robots that rely on a commercial vision system for ball and goal detection, infrared-based distant sensors, standard bumper sensors, odometry and a piezo-gyro. Two robots are equipped with laser scanners. We utilize the DD design environment to specify, document, simulate, run, test and debug these robots.

Figure1: GMD-Robot.

Future Research Directions

The sensory uncertainty a robot faces must be captured by 'non-additive noise' models, which are mathematically similar to the models used in speech understanding: Hidden Markov Models (HMMs) and Partially Observable Markov Decision Processes (POMDPs). Known learning algorithms for such models are computationally challenging, which impedes their use beyond simple cases. A novel mathematical approach to stochastic modeling, observable operator models (OOMs) has been developed in the BE team. OOMs are more expressive than HMMs or POMDPs, but actually can be learnt more quickly. Furthermore, OOMs allow to compute reward-optimal action decisions extremely quickly. In the future, therefore, our soccer robots will be equipped with OOM modules - first, for sensor preprocessing and state estimation, but second, we will also stepwise recast entire DD behaviors from deterministic differential systems into fully stochastic OOM modules.

Conclusions

The integrated DD Design Environment and our RoboCup robots are the ideal test bed for research on autonomous, mobile robots. Here, we focus on extensions to the Dual Dynamics scheme and on 'Observable Operator Models'. Both emphasize the dynamical systems nature of behaviors, with OOMs additionally capturing the stochastic nature of a robot's experience and acting.

Since DD-Designer was constructed using a novel generative approach to rapid software prototyping (APICES), we were able to continuously evolve the DD Design Environment from a first shot prototype in late 1998 until now. This prototype evolution fosters incremental design and allows us to add new features to the environment without breaking a productive design flow.

At present, we plan to transfer the DD Design Environment to a broader community in education, research and industry. To our conviction, it is a well suited tool kit to learn and explore different behavior-based approaches to robot control not just DD. Furthermore, the openness of our environment, its well-defined interfaces and its adaptable code generators make it worthwhile to tailor the DD Design Environment to other application domains besides soccer robots.

Links

RoboCup: http://www.robocup.org
Behavior Engineering Team: http://ais.gmd.de/BE
Dual Dynamics Design Environment: http://ais.gmd.de/DD
OOMs: http://www.gmd.de/People/Herbert.Jaeger/Publications.html

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Self-reconfigurable Modular Robots

by Martin Nilsson

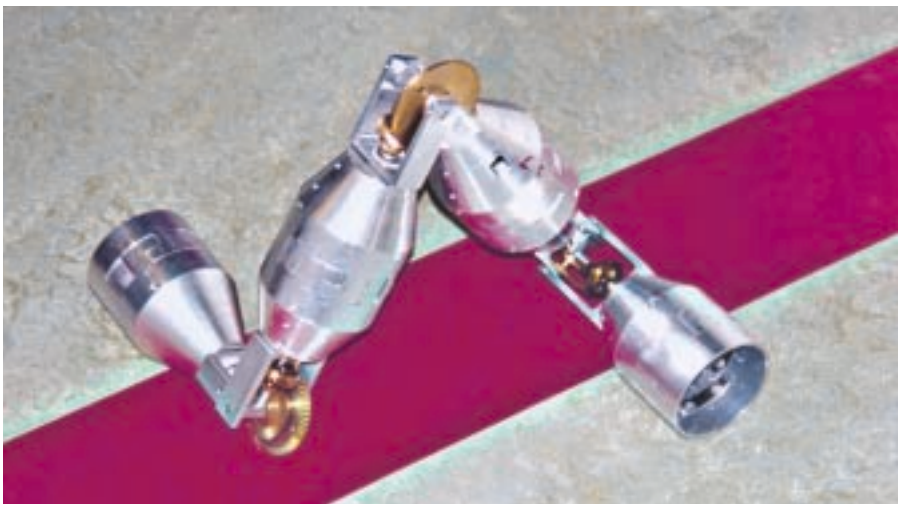
The DRAGON research project at SICS studies problems occurring in a framework of autonomous robots, which build structures by connecting to and disconnecting from each other. Research topics include methods for learning and adaptation of locomotion and reconfiguration; sensing and control of distributed mechatronic systems; and the closely related complexities of algorithms and mechanisms.

A characteristic of robotics is its wide interdisciplinary span from theory to practice in Applied Mathematics, Computer Science, Electrical Engineering, and Mechanical Engineering. Optimal – or perhaps even successful – performance of a robot system requires skillful application of all these disciplines, as well as close interplay between far ends of the spectrum. Software can never fully compensate for hardware mistakes, and vice versa. This is a recurring observation through our research results, some of which are described below.

The bottom line motivation of this research at SICS is the focus on interaction and communication between software and the physical environment, the 'real world'. Potential applications exist in health care, service robotics, and entertainment industry. Further ahead lie more speculative applications, such as reconnaissance and rescue missions after accidents or catastrophes.

Learning Snake Robot Locomotion

Snake robots have many degrees of freedom, and it is difficult for a human programmer to write a program for controlling all the degrees of freedom. We have used reinforcement learning with on-line simulation in order to learn



The joints are designed to have special kinematic properties simplifing control, and allowing efficient locomotion. For instance, using the configuration illustrated in the picture, the snake robot can move on flat surfaces without slip friction.

The project mascot 'Giftschlange' is a gift from the Snake robot group at GMD in Sankt Augustin.

creeping locomotion. Care must be taken when designing the robot, so that an efficiently computable mathematical model can describe it for achieving fast simulation. This is one example where the mechanical design directly determines algorithmic performance (see left figure). Another example is when we want to compute the closed-form inverse kinematics of sections of the snake robot. The complexity of Grobner base methods is exponential in the number of variables in the equations describing the robot joints. Thus, it is essential that the joints be designed to maximize the number of symmetries, since each symmetry eliminates one variable.

Single-wire Tactile Sensors

Autonomous robots need tactile sensors to feel the environment. If the sensors are distributed all over the surface of the robot, the extensive wiring can become a problem. We have shown that an LC network can be used as a tactile sensor with a minimal amount of wiring. Here, the LC network is used as a filter. Pressure applied on the sensor changes the filter characteristics, and can be computed unsing the filter's impulse response. For practical application of this technique, it is necessary to find a fast way of computing the Neumann expansion of a function, ie expansion in terms of Bessel functions. We have developed a method which computes the expansion in O (n log n) time, the same complexity as an FFT. This is a case where the existence of a fast algorithm allows an particularly efficient mechatronic solution.

Autonomous Docking

Docking two robots autonomously is a difficult task, especially in the real world, which includes noise and dirt. A robust interconnection usually involves a phase of precise navigation, which is hard to accomplish with ordinary sensors and connecting devices. We have studied how geometric optimization can be used in robots for autonomous docking, so that they become self-alignable to a high degree.

'Best' Possible Mechanisms

The complexity and limits of what a robot control algorithm can do depend on the complexity and capabilities of the physical robot. For instance, algorithms for vertical climbing by a snake robot depend critically on joint range and strength. The determining component in the joint itself is neither the motor, nor the transmission, but the brakes, holding the joint in a fixed position. We have found that it is possible to calculate a non-trivial lower bound on the size of a brake over all possible mechanisms, given a certain load. A brake can be designed which approaches this bound to within an order of magnitude, while conventional brakes are typically three orders of magnitude weaker.

About the Project

DRAGON is an abbreviation of 'Distributed Real-time Autonomously Guided OrgaNisms', and belongs to the Real-World Computing Project (RWCP), together with several other international and Japanese partners. RWCP is financed by the Japanese Ministry for Trade and Industry (MITI). DRAGON is a five-year project ending in 2002. It is a continuation of the RWCP PIRAIA project, which started in 1993. We have enjoyed many rewarding discussions with members of the Snake robot group of GMD in Sankt Augustin.

Links:
PIRAIA DRAGON:
http://www.sics.se/~mn/dragon.htm

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A Hybrid Model-Based Vision System for Autonomous Navigation of a Sewer Inspection Robot

by Marina Kolesnik and Gregory Baratoff

State-of-the-art inspection of inaccessible sewers is by teleoperated visual surveying. In practice, the inspection process is both complicated and labour-intensive. This inspired research activities targeted at developing an autonomous robot for sewer surveying. Out of four institutions from research and industry a multidisciplinary team was chosen, working on the three-year project 'MAKRO' which started in September 1997. A Hybrid Model-Based Vision System has been developed at GMD-Research Center for Information Technology at Sankt-Augustin. The Vision System will facilitate the orientation and navigation of the autonomous MAKRO robot while moving in the sewer.

Maintenance of thousands of kilometres of sewers requires their permanent surveying. State-of-the-art inspection of inaccessible sewers is by visual surveying. A human teleoperates a wheeled platform equipped with a high-resolution color camera and a lighting system, producing a video record of the sewer condition. An operator-guided process of sewer surveying is labour intensive, costly, and prone to human error. A radical change in sewer surveying technology, based on the use of autonomous mobile robots, could accelerate the inspection process, enhance inspection quality, and reduce cost.

The research project MAKRO is being conducted by four partners from research and industry and aims at developing an autonomous robot for surveying of modern concrete sewers. The task of such a robot will be to collect a video record about sewer conditions. The multi-segment robot consists of a mobile base platform, and is equipped with a set of sensors, a light source, a laser crosshair projector and a camera, it must be able to drive autonomously through a long system of sewer pipes. An on-line Hybrid Model Vision-Based System has been developed at GMD to navigate the MAKRO robot when it moves along sewer pipes, approaches manhole junction areas, and proceeds to enter the next pipe. The Vision System comprises two different algorithms. The first one, called the orientation algorithm, assesses the robot's relative orientation with respect to the pipe axis, in order to guide the robot through a pipe. The second one, called the 3D interpretation algorithm, recognizes the end of the current pipe at a manhole entrance and locates the next pipe opening to move into when the MAKRO robot is positioned before a manhole area of the sewer.

Photo: E. Rome/GMD

Figure 1: Sensor Haed of MAKRO: Cameras, laser projector, LED light, infrared sensors and ultrasound sensor.

Photo: E. Rome/GMD

Figure 2: Guided by the data of its infrared and image sensors, MAKRO can automatically perform turns and overcome steps. The robot can operate in sewer pipes of diameters within a range of 300 to 600 millimeters.

Figure 3: The laser crosshair projector used for MAKRO robot orientation in the sewer.

The Vision System relies on a hybrid sensing strategy consisting of two modes: a fast laser footprint analysis mode and a slower, but more thorough, full image analysis mode. In the first mode the laser crosshair projector is on and the flashlight is off, causing the camera to record a predominantly dark image with a bright laser footprint. The analysis of such an image is very fast, and in most cases it can adequately support the robot's navigation as if travelling through a pipe segment. At some points in time, however, the robot needs to acquire more accurate information about the sewer. For example, when the robot approaches a manhole area, or when it decides to move into a pipe which has a smaller radius than a manhole area, it needs to determine the distance and direction of the pipe end with high accuracy in order to execute a collision-free turn. In these cases, the flashlight is used to illuminate the sewer. Since the structure of such an image is much more complex, the processing is more time-consuming. But it allows to obtain more accurate information about the location of relevant sewer structures.

The robot relies on the 'fast & rough' sensing mode to navigate through a pipe segment in a closed-loop fashion, continuously analyzing the laser footprint to determine its orientation within the pipe, and using this information to correct its heading, so as to keep its orientation in the direction of the pipe axis. The laser footprint also allows the end of a pipe to be detected. Using this information, the robot knows when it has arrived in the manhole area. Upon arrival it stops, snaps a few images, analyzes them, and makes a decision in which direction to proceed, ie which pipe to enter next. In this situation, the robot relies on the 'slow & thorough' sensing strategy to get an accurate evaluation to base its decision on.

A further characteristic of the Vision System lies in the fact that the visual processing is model-based. Modern concrete pipes are mostly cylindrical with a standard diameter of 60cm or 30cm. When illuminated by the laser crosshair projector they give rise to a pair of conic sections whose shape encodes relative orientation of the robot within the pipe. This information is extracted and used to align the robot with the pipe axis. In addition to the pipes being cylindrical, their ends are circular. Important circular landmarks are pipe ends and entrances at sewer manhole areas as well as ends of house inlet pipes. These circular structures appear in the fully illuminated image as ellipses. Using a calibrated camera, the 3D orientation of these circular structures is determined by their image ellipses. This provides the robot with an estimate of its instantaneous position relative to these landmarks.

In general the image of a circle is an ellipse, except when the camera's viewing direction is perpendicular to the supporting plane of the 3D circle, in which case it is a circle. The vision algorithm processes ellipses when reconstructing circular structures generated by house inlets. It uses the orientation algorithm which is based on the images of a laser footprint to ensure an approximately parallel viewing direction of the robot camera with respect to the pipe axis. This setup allows to work with circles in the images, hence eliminating two of the main problems with the general ellipse as compared with the circle case: (1) the more time and memory consuming detection procedure, and (2) an inherent two-fold 3D orientation ambiguity of the 3D circle of which it is an image.

The Hybrid Model-Based Vision System operates on-line and is integrated in the onboard control system of the MAKRO robot. Future work will be directed at introducing new functions to the onboard Vision System, which will enable the MAKRO robot to perform automatic vision monitoring of sewer conditions while moving in the sewer.

Links:
MAKRO project and related publications:
http://ais.gmd.de/~kolesnik/

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Motion Planning for Autonomous Car-like Vehicles

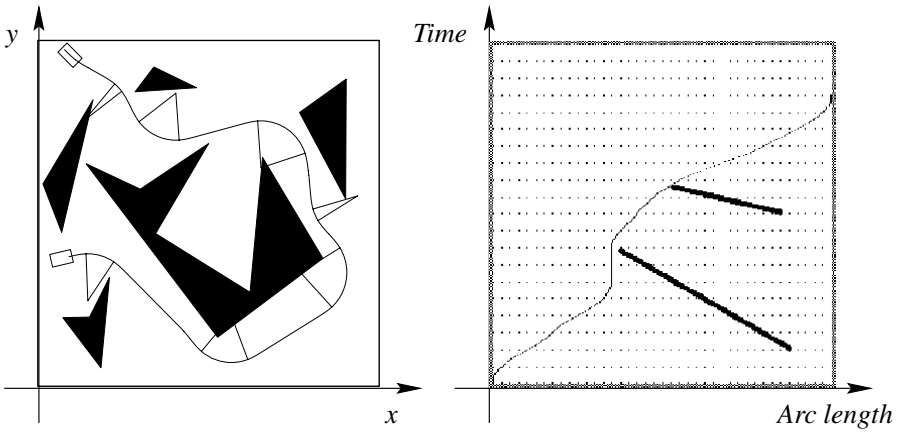
by Thierry Fraichard

As part of an effort to design an autonomous car-like vehicle, the Sharp research group at INRIA Rhône-Alpes develops new motion planning techniques that take into account the various constraints that restricts the motion capabilities of such a vehicle (kinematics, dynamics, uncertainty).

Motion planning deals with the a priori computation of the motion that is to be executed by a robotic system. In its basic form, motion planning addresses primarily collision avoidance with the stationary obstacles of the environment. However, when the robotic system considered is a car-like vehicle, there is much more to motion planning than that. For a start, such a vehicle is subject to kinematic and dynamic constraints that restricts its motion capabilities. Then it moves among moving obstacles that should be avoided too. Finally, it is affected by various sources of uncertainty (control, sensing and model errors), that may lead to failure at execution time.

Configuration space is the fundamental tool introduced in the late seventies to address the basic motion planning problem. The configuration of a robot is a set of parametres representing the position and orientation of every part of the robot. In its configuration space, a robot is represented as a point, stationary obstacles are represented as forbidden regions and motion planning is reduced to finding a path, ie a continuous sequence of configurations, that avoids the

Cycab, a vehicle developed by INRIA.



A motion planning example: first, a path with continuous-curvature and upper-bounded curvature derivative that avoids the stationary obstacles is computed (left). then, the velocity profile along this path is computed, it respects the vehicle's dynamics and permits to avoid the moving obstacles (right).

forbidden regions. When time-dependent constraints such as moving obstacles and robot dynamics are considered, it is necessary to plan a trajectory, ie a path parameterized by time. Configuration space does not permit to take into account time-dependent constraints.

Our first contribution has been to introduce state-time space as a tool to deal with time-dependent constraints. The state-time space of a robot is its state space, ie the space of the configuration parametres and their derivatives, augmented of the time dimension. In this framework, the constraints imposed by both the moving obstacles and the robot dynamics can be represented by static forbidden regions of state-time space. A trajectory maps to a curve in state-time space and motion planning can be reduced to finding a curve that avoids the forbidden regions. Such a curve must respect additional constraints due to the fact that time is irreversible and that velocity and acceleration constraints translate to geometric constraints on the slope and the curvature along the time dimension. However, it is possible to extend existing methods for path planning in configuration space in order to solve the problem at hand. In particular, we developed a general approach to solve motion planning problems formulated in the state-time space framework. The approach places a regular grid in state-time space and searches the grid for a trajectory using dynamic programming.

The environment of a car-like vehicle is structured, it can be viewed as a network of roadlanes. We decided to take advantage of this structure in order to reduce the overall complexity of motion planning by decomposing it into two complementary stages of lesser complexity: (1) planning a path avoiding the stationary obstacles, and (2) planning the velocity along this path so as to avoid the moving obstacles. The velocity planning stage deals with the time-dependent constraints, namely the moving obstacles and the vehicle's dynamics. It applies the state-time space approach presented above. The time-independent constraints are taken into account in the path planning stage: its purpose is to compute a path that avoids the stationary obstacles and respects the vehicle's kinematic constraints.

A car-like vehicle is a nonholonomic system: it is subject to kinematic constraints that restricts its admissible directions of motion. Thus it can only move forward or backward in a direction perpendicular to the orientation of its rear wheels axle; besides its turning radius is lower bounded (because of the mechanical limits on the steering angle).

Nonholonomy appeared in path planning in the mid-eighties and a lot of results have been obtained since. For car-like vehicles, most of the existing works compute paths made up of line segments connected with tangential circular arcs of minimum radius. One reason for this choice is that the shortest path between two configurations for a car-like vehicle is such a path. However the curvature of this type of path is discontinuous: discontinuities occur at the transitions between segments and arcs. The curvature is directly related to the orientation of the front wheels of the car. Accordingly, if a car were to track precisely such a type of path, it would have to stop at each curvature discontinuity so as to reorient its front wheels. It is therefore desirable to plan continuous-curvature paths. Besides, since the derivative of the curvature is directly related to the steering velocity of the car, it is also desirable that the derivative of the curvature be upper-bounded.

Our main contribution here has been to propose one of the first algorithms that compute collision-free paths with continuous-curvature and upper-bounded curvature derivative for car-like vehicles. The paths computed are made up of line segments and circular arcs connected by clothoids, ie curves whose curvature varies linearly with their arc length. They are locally optimal and it is conjectured that they are globally suboptimal, ie longer than the optimal paths of no more than a given constant. Experiments carried out with a real car have demonstrated the superiority, in terms of tracking precision, of this type of paths.

The underlying assumption of the trajectory planning technique presented above (and of most of the existing ones for that matter), is that the vehicle should be able to follow the trajectory accurately enough. A challenging problem is that

this assumption hardly holds for a real vehicle operating in the real world. To begin with, such vehicles usually rely on odometry to estimate their configuration. As these techniques yield increasing and unbounded configuration uncertainty, failure to follow a planned trajectory is bound to occur. To overcome this problem, the vehicles are often equipped with absolute localization devices. These devices usually rely on sensors identifying environmental features that are then matched against a priori models of the environment in order to estimate the vehicle's configuration. However if a planned trajectory does not allow the detection of the appropriate environmental features, the vehicle may once again fail to reach its goal. A solution to these two problems (drift, feature detection), both related to the various sources of uncertainty affecting the vehicle, is to explicitly take into account uncertainty so as to compute safe trajectories, ie trajectories that guarantee that the goal will be reached in spite of these uncertainties.

We have developed a safe motion planner for a car-like vehicle that estimates its configuration with odometry and an absolute localization device based on environmental feature matching. Our solution relies upon: (a) simulations of the vehicle's odometry and feature matching localization procedure in order to estimate in a conservative way how the configuration uncertainty evolves when the vehicles moves or localizes itself, and (b) a novel type of landmarks characterized by: (1) a region of the configuration space, (2) a set of best features for localization in the region, and (3) a perception uncertainty field that measures how well a given feature is perceived at each configuration in the region. The landmarks are built automatically, they simplify and improve localization. The solution algorithm uses a roadmap, ie a graph in the configuration space whose edges are collision-free paths that respects the nonholonomic constraints of a car-like vehicle. The roadmap is searched for the shortest path to the goal. Safeness along each edge-path is checked thanks to the odometry simulation. Whenever a node included in a landmark region is reached, feature matching localization takes place and configuration uncertainty is reduced accordingly. The algorithm returns a motion plan that alternates motions along safe paths and localization operations.

Future activities are aimed at improving and extending the different techniques presented above, and mainly at integrating them inside a single motion planner.

This work was carried out in the framework of a number of European and French research programmes focused on the development of novel road transport technologies: Prometheus, Praxitèle and La Route Automatisée.

Links:
Sharp:
http://www.inria.fr/Equipes/SHARP-eng.html
Prometheus:
http://www3.eureka.be/home/
Praxitèle:
http://www-rocq.inria.fr/praxitele/
La Route Automatisée:
http://www.lara.prd.fr/
Thierry Fraichard's home page:
http://www.inrialpes.fr/sharp/people/frchard/

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TOURBOT – Interactive Museum Tele-presence through Robotic Avatars

by Panos E. Trahanias

The TOURBOT project is a R&D activity funded by the Information Society Technologies Programme of the European Commission. TOURBOT aims at developing alternative ways for interactive museum tele-presence, employing the novel approach of site viewing through the 'eyes' of robotic avatars.

The goal of this project is the development of an interactive TOUr-guide RoBOT (TOURBOT) able to provide individual access to museums' exhibits and cultural heritage over the Internet. TOURBOT operates as the user's avatar in a museum by accepting commands over the Web that direct it to move in its workspace and visit specific exhibits. The communication network is, thus, effectively extended by the introduction of interactive, mobile robotic platforms as terminal nodes. The imaged scene of the museum and the exhibits, is communicated over the Internet to a remote visitor. As a result the user enjoys a personalized tele-presence to the museum, being able to choose the exhibits to visit, as well as the preferred viewing conditions (point of view, distance to the exhibit, resolution, etc). At the same time, TOURBOT is able to guide on-site museum visitors providing either group or personalized tours.

In order to realize the TOURBOT system, a multimedia Web interface will allow people to interact with the tour-guide system over the Internet. Furthermore, an on-board interface will facilitate interaction with on-site visitors of the museum. Using the Web interface, people all over the world will be able to tele-control the robot and to specify target positions for the TOURBOT system. Camera controls will be used to choose the part of the exhibition the user wants to inspect in more detail. The robotic tour-guide will possess a multimedia information base providing a variety of information about the exhibition at various levels of detail. Thus, the TOURBOT system will serve as an interactive and remotely controllable tour-guide, which provides personalized access to exhibits with a large amount of additional information.

A tele-operated interactive tour-guide robot requires a high degree of autonomy since it operates in a populated environment in

Figure 1: The Robot RHINO in the 'Deutsches Museum Bonn'.

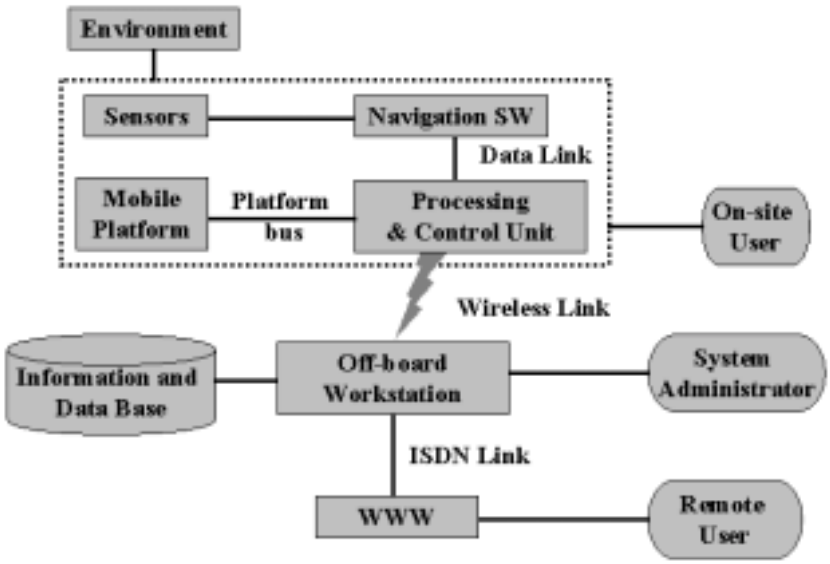

Figure 2: TOURBOT system architecture.

which humans are also present. Therefore, the project includes the development of a safe and reliable navigation system for TOURBOT. The robotic avatar will be equipped with a series of state-of-the-art sensors that allow it to acquire information about its environment. The navigation system uses this sensory information to adapt the robot's internal model of the environment and to plan the robot actions.

A New Paradigm in Remote Access

The TOURBOT project introduces a new paradigm in providing access to cultural heritage exhibits. Through the introduction of museum visiting via a robotic avatar, it facilitates immersive tele-presence with advanced visualization capabilities. Full access to cultural exhibits is granted to the user, in the sense that the latter is able to choose the exhibits to visit, as well as the preferred viewing specification (point of view, distance to the exhibit, resolution, etc). The approach employed in the current project introduces a novel model of augmented environments, in that it allows human interaction with and workspace exploration of remote sites by means of a robotic avatar.

As a unified service to remote users, TOURBOT extends current communication networks by allowing mobile robots to be part of the overall structure. Such a mobile agent acts as the user's avatar, operating in a physical environment that is perceived by the user through the robot's sensors. Therefore, TOURBOT results contribute towards the seamless integration of networks and mobile agents for providing full user access to exhibitions.

The Internet is a very fast evolving technology that electronically connects distant sites; however, up to now, electronic networks serve mainly to exchange and acquire information. In some cases this information is pictorial by means of images taken in "real time" with a stationary Web-camera. To take full advantage of a network such as the Internet, it would be desirable to get real physical interaction with the remote site being visited. Robots, and especially mobile platforms, can extend the Internet towards an interactive platform that allows actions to be carried out and dynamic information to be exchanged between distant sites. The TOURBOT project implements exactly the above concept for the particular case of museums as remote sites. In other words, it augments current networks by substituting a terminal node with a mobile platform.

Workplan

The TOURBOT project addresses the development of a robotic avatar, able to provide individual access to museums' exhibits over the Internet. Such mobile agents allow virtual tele-presence in physical environments, effectively supplementing existent network infrastructure by allowing mobile avatars to replace network terminal nodes. Early experiments prior to TOURBOT have been conducted at the Deutsches Museum Bonn with RHINO (see figure 1).

Preliminary System Architecture

A preliminary architecture of the TOURBOT system is illustrated in figure 2. It shows the various system modules and the communication links that interconect them. As can be observed, there are two basic system components: (a) the mobile platform, including the sensors, navigation SW and processing & control unit and, (b) the off-board workstation that has access to the information base and also administers the internet connection to remote users.

The Consortium

The TOURBOT project is pursued by a consortium that comprises an ideal blend of technical partners (Foundation for Research and Technology - Hellas, Greece; University of Bonn, Germany; THEON Mobile Platforms, Greece; University of Freiburg, Germany), brokers of technology to museums (Foundation of the Hellenic World), and end users (Foundation of the Hellenic World, Greece; Deutsches Museum Bonn, Germany; Byzantine and Christian Museum of Athens, Greece).

Links:
Project URL:
http://www.ics.forth.gr/tourbot

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ServiceBots – Mobile Robots in Co-operative Environments

by Liliane Peters, Michael Pauly and Klaus Beck

The challenge in the control and behavior of a team of autonomous robots in indoor environments is mainly in the high uncertainty existing in the environment. The type of uncertainty can be classified as sensor dependent, information dependent, and communication dependent. The objective of the Robots in Buildings team of the Institute for Autonomous intelligent Systems at GMD focuses on the development of reliable, effective and scalable service architecture for autonomous service robots able to service in structured indoor or restricted outdoor environments. The demonstrators are industrial robot platforms that are enhanced with a service system approach. The proposed solution is platform independent and can be directly transferred to industrial environments.

The complexity of service environments is quite high and very different from building to building. Structural elements like corridors, offices, or halls, are different. Corridors can have a various width, length and illumination types. The number of offices and their shapes depend not only on the year the building was constructed, but also on the type of company using it. In addition to this, the corridors and connections between floors have all different doors, elevators, staircases, etc. To comply with the complexity in these 'work environments' calls for the autonomous system to be able to navigate collision free through all the floors, separated by doors and elevators as well as to adapt, foresee and react to dynamic changes in the environment, like the occlusion or partial occlusion of corridors by objects or employees co-working in the same environment.

To solve this dilemma between the required high complexity of the mobile service robots and the economic constraints related to efficiency, costs, etc., we propose a new approach to service robots operating in structured indoor environments. This approach is based on the particular 'robot intelligence' needed for each part of the 'work environment'. In our understanding robot intelligence means the capability of a computer-based mobile system to navigate reliable between two points within the environment independent of the complexity and the steady changes of the environment The approach proposes the distribution of the needed 'intelligence' capability between the ServiceBots (mobile systems) and other systems like software agents (SoftBots) or embedded systems (FixBots) co-existing within the same environment. Thus any navigation task can be solved through the co-operative work of a number of 'Bots'. As a result each ServiceBot needs only a 'medium intelligence', but needs prime communicative capabilities with its peers.

A 'medium intelligent' robot is able to navigate without co-operative support in parts of the work environment with average complexity. When the complexity of the environment increases, some additional FixBots or SoftBots will support the navigation process. The ServiceBots , FixBots, and SoftBots form a cluster of fixed and mobile autonomous intelligent systems operating within a given 'work environment'. The major link between all these 'Bots is the IT backbone (LAN) of the building. As the LAN is also the major communication medium for humans in modern enterprises, the users or the supporting team of the service system can request services ask for information, monitor, etc. from any computer (fixed or mobile) within the work environment. Due to security reasons the access of users is limited to all the persons having a registered user account in the test environment

The number of elements of the co-operative service team are calculated as follows: The number of ServiceBots is dependent on the number of requested tasks per day and hour. The number and the type of FixBots is defined by the complexity of the environment. The number of Softbots is dependent on the degree of reliability of services requested. The higher the reliability and the longer the service time the higher the number of monitoring agents insuring the requested quality of service

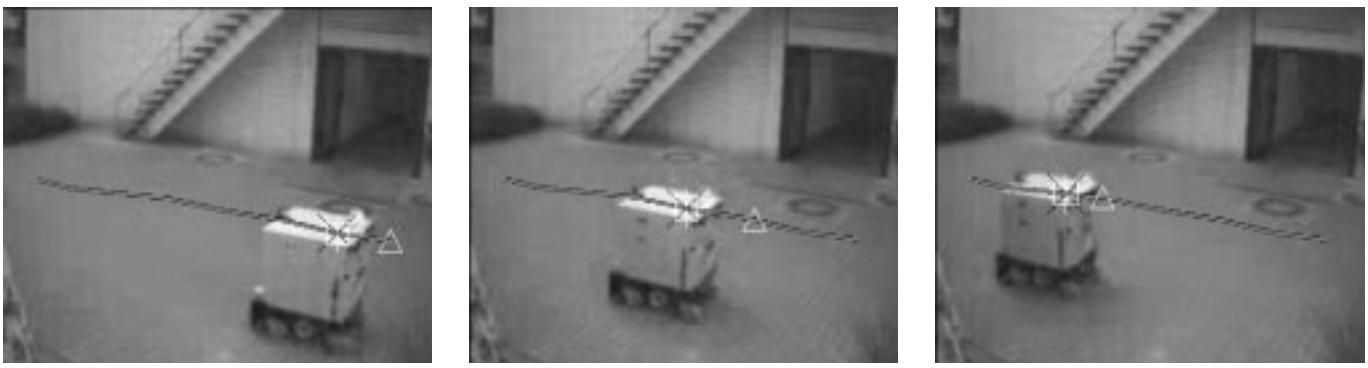

Figure 1: The ServiceBot 'Kalle' navigating in an outdoor 'complex' environment.

Figure 2: The ServiceBot 'Kalle' navigating in an outdoor 'complex' environment.

GMD-Robobench

The GMD-Robobench is our experimental environment and test bed. It consists of two buildings which are connected by a glazed corridor and a lane in the backyard connecting the two buildings. Each of these buildings has three floors which can be reached by lift. Each floor is subdivided by several fire doors. A wireless based Ethernet network (IEEE 802.11) connects the ServiceBots or mobile humans to the fixed LAN in the GMD-Robobench environment. The FixBots servicing the ServiceBots are electronic driven doors accessed via a door-server, elevators accessed by an elevator server ,and some Web cameras. All FixBots are managed by a Resource Manager. The Problem Manager of the service system reports via e-mail any incident encountered during the service of any ServiceBot and can be used to monitor or support the service system remotely.

Navigation in Complex Environment through Co-operation

In the following two example of co-operative navigation are presented. The first complex environment is a glazed corridor between two buildings. The complexity is higher than the average as:

- there is a staircase connecting the floors which can not be seen with the available sensors on the robot
- the entrance to the elevator is very narrow (for the dimension of the robot).

Each ServiceBot has only 2 wheel encoders and 2 laser sensors (one for each driving site – front and back) with an error up to 10 cm. With the given sensorial capabilities the robot is not able to insure the needed robustness of navigation. An additional web-camera installed in the area combined with a SoftBot can support the robot to improve the self localization process. Thus the support of the FixBot has to insure that the navigation through the elevator door is accurate and that by no mean the ServiceBot drives into the stair-case area. The service offered by the FixBot is to inform on request how large the deviation error from the ideal path of the ServiceBot is. It is up to the ServiceBot to correct its path or to ignore the information. If there is a mismatch between the real position of the robot and its own localization system, the ServiceBot will re-calibrate its own co-ordinate system.

The second sequence presents the navigation path between the entrance of two buildings. Here the complexity of the environment is even higher than in the first case. The robot navigates on a virtual path only based on the wheel-encoder information. The laser sensor information supports only the local collision avoidance. To increase the robustness of the navigation for this environment a web camera with another softbot is situated in the environment. The FixBot monitors the navigation path of the robot checks if it fits the virtual one and suggests a correction if needed. As in the first case it is up to the ServiceBot to use the given information. The tracking of the ServiceBot –as there are several operating in the same environment – is started and stopped on request. The ServiceBot can leave or enter a building by requesting the support of the door-opening server. For this request of service the mobile system has to identify itself due to security and availability check reasons. This information can be sent to the FixBot too and start the monitoring process. If several possible navigation paths exist in the outdoor environment, these are identified by giving the destination entrance door to the FixBot. The tracking is stopped the moment the robot opens the entrance door to the next building.

Conclusion

Through the distribution of tasks between robots and the environment and the open standardized communication system, the service system can be scaled. The number of robots working in an environment can be increased or decreased without changing the service structure of the system. Heterogeneous robots can operate in the same environment as long as they use the same communication channel. The service system can easily be redesigned to another environment just by redistributing the FixBots or adding some SoftBots. Last but not least through the reduced number of sensors available on the 'medium intelligent robot' the proposed service system becomes affordable for many application in the area of: health care, administrative buildings and even industrial manufacturing lines, while guarantying an agreed level of quality of service.

Links:
The ROB group: http://ais.gmd.de/ROB/

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AI-based Modelling and Optimisation of Coupled Production Processes

by Zsolt János Viharos and László Monostori

Reliable process models are extremely important in different fields of computer integrated manufacturing. One of the main goals of the project is to generate multipurpose models that are applicable for a set of assignments and can satisfy the various accuracy requirements at the same time. As to the application phase, novel techniques are needed to find the unknown (input) parameters of the model in certain situations. The modelling and optimisation of process chains are of special importance. These issues are treated and solutions for them are given in a Ph.D. work completed these days at SZTAKI.

Difficulties in modelling manufacturing processes are manifold considering the great number of different machining operations, the multidimensional, nonlinear, stochastic nature of machining, partially known relations between parameters, lack of reliable data, etc. A number of reasons necessitate the required models: design, optimisation, control and simulation of processes and design of equipment. On the base of the applied knowledge, fundamental, heuristic and empirical models can be distinguished.

Artificial neural networks (ANNs) are general, multivariable, nonlinear estimators. This soft computing technique can offer viable solutions especially for problems where abilities for real-time functioning, uncertainty handling, sensor integration, and learning are essential features. Successful applications in manufacturing were reported on in the literature. The assignments to be performed determined the I/O configurations of the models, ie which parameters are to be considered as inputs and which ones as outputs. This predetermination, however, results in models which do not necessarily produce the best mapping between the considered quantities.

A novel approach for generating multipurpose models of machining operations has been developed which combines machine learning and search techniques. Because of the general nature of the multipurpose models, almost in every application, only some of the input parameters are known, and the task is to determine the unknown parameters while satisfying some constraints. For this purpose, a simulated annealing search technique has been developed.

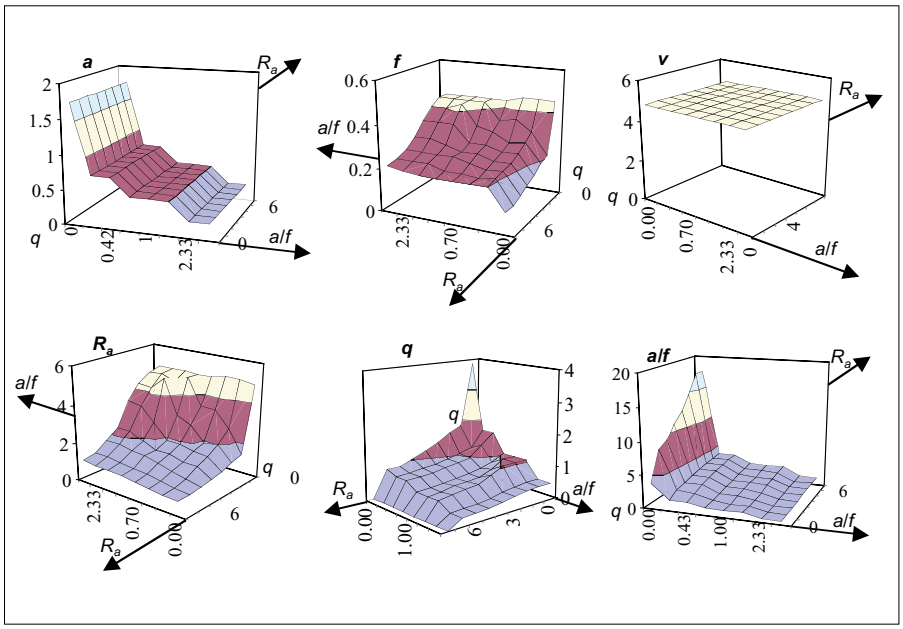

Figure1: Parameters resulted by the threefold optimisation of the plate turning.

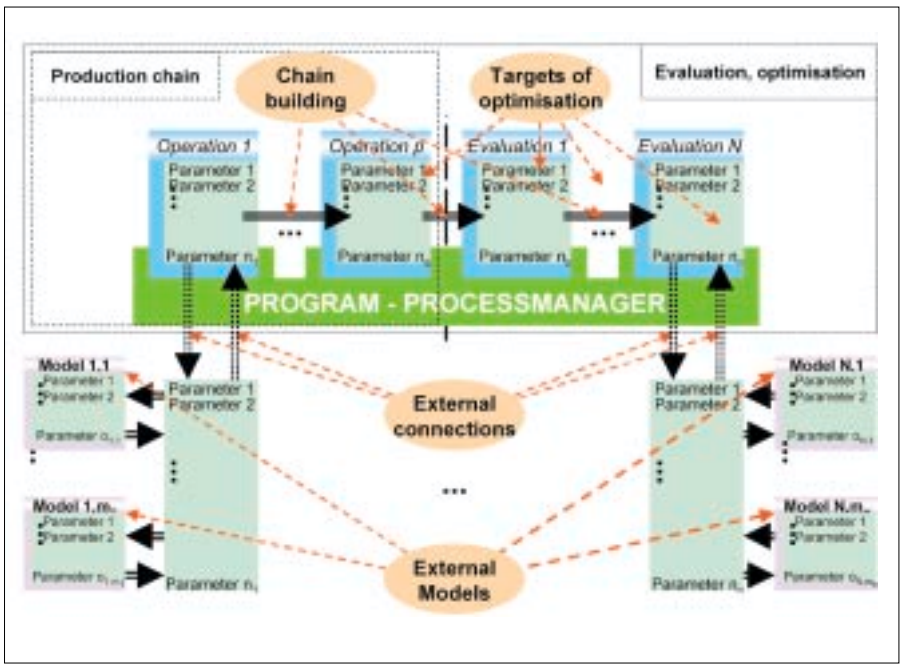

Figure 2: Hybrid modelling and optimisation of process chains by ProcessManager

Figure 1 illustrates the application of the developed software package ProcessManager for the threefold optimisation of the viewpoints of the customer (minimisation of the surface roughness), the owner of the company (profit/productivity maximisation) and the production engineer (maximisation of process stability through the a/f ratio). Ratios of the weighting factors of the three variables to be optimised are represented along the axes.

Special emphasis was laid on the optimisation of manufacturing processes and process chains. A block-oriented framework for hybrid modelling and optimisation of coupled processes has been developed where the individual process models can be of different types, ie having the form of ANNs, expert systems or equations (see Figure 2).

The ProcessManager incorporates:
- definition of the elements of the chain
- determination of the process models in a hybrid way, by integrating analytical equations, expert knowledge and example-based learning
- connection of the single models into a process chain by coupling input-output model parameters not limited to models of successive processes in the chain
- definition of eligible intervals or limits for the process parameters and monitoring indices
- Definition of a cost function to be optimised, etc.

It is expected that the developed package would be a valuable tool for the modelling, monitoring and optimisation of manufacturing processes and process chains. Taking the globalisation issues and the increasing role of virtual enterprises into account, the distributed version of the system is expected to show further benefits. This project is partially supported by the Hungarian Scientific Research Fund, Grant Nos. F026326 and T026486.

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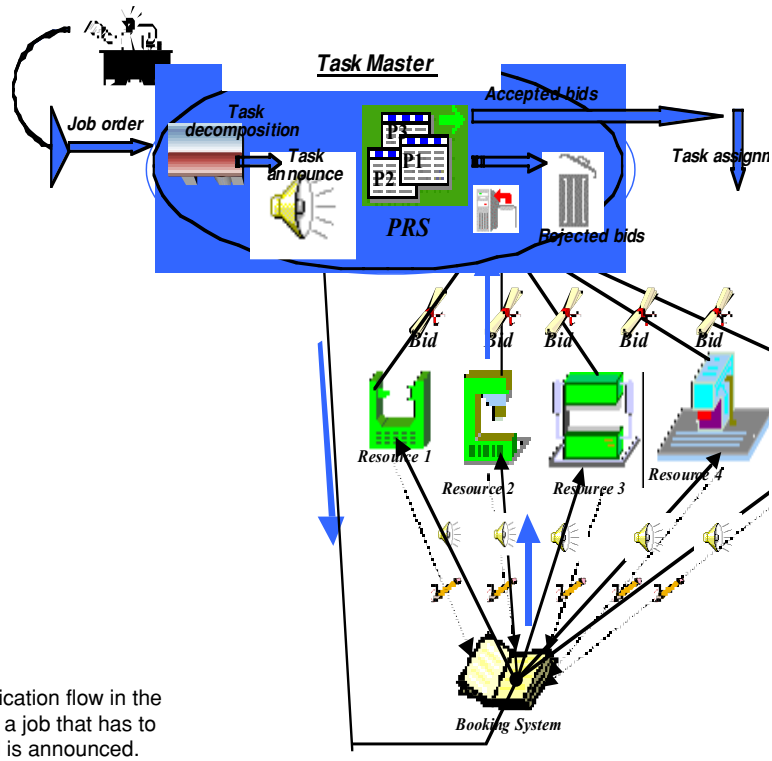
Environmental and Life Cycle Issues in Agent-based Manufacturing

by Elizabeth Ilie Zudor and László Monostori

The goal of manufacturers, regardless of industry, is to efficiently get the products to the market, right and fast. Nowadays, on the one hand, companies have become customer-order-driven, ie they must be able to manufacture a high variety of customer-specific products, with short delivery times and low costs. On the other hand, to the technological criteria such as efficiency, productivity, profitability, other aspects concerning health, environmental impacts, resource and energy conservation, waste management and social impacts have been added. The fundamental goal of the research that started one year ago at SZTAKI, was to treat the efficiency and the environmental impacts of production in an integrated way.

Growing complexity is one of the most significant characteristics of today's manufacturing which is manifested not only in manufacturing systems, but also the products to be manufactured, in the processes, and the company structures. The systems operate in a changing environment rife with uncertainty. Difficulties arise from unexpected tasks and events, non-linearities, and a multitude of interactions while attempting to control various activities in dynamic shop floors.

Holonic manufacturing systems (HMSs), as one of the new paradigms of manufacturing, consist of autonomous, intelligent, flexible, distributed, co-operative agents or holons. Holonic systems were found to deliver better performance in a wider range of situations than their more conventional counterparts. One of the most promising features of the holonic approach is that it represents a transition between fully hierarchical and heterarchical systems.



The communication flow in the system when a job that has to be performed is announced.

An environmentally benign approach to agent-based production control has been developed, which complies with the principles of HMSs. In the model the Task Master (TM) is responsible for job orders, including job decomposition into tasks, task announcement and assignment (see Figure). All the resources on the shop floor are expected to report their abilities (the tasks that they are able to perform) into the Booking System (BS). When a job order enters the system, the TM checks the BS and sends task announcements to the appropriate resources.

A multi-level system of rules named Priority Rules System (PRS) has been introduced to decide which resource is to fulfil the given task. In the proposed approach, not only the cost problems, but also the environmental impacts of processes and operations are considered during a resource allocation process relying on market principles. With the help of the SIMPLE++ production and logistics simulation package, the communication between agents on a shop floor was simulated. The mathematical model, which takes the PRS into consideration, was transposed in the SimTalk programming language. Simulation results illustrate the positive interference of life cycle assessment techniques of products and production facilities, on the one hand, and of agent-based approaches applicable within their life cycles, on the other.

In the near future, the existence of the product holons after the effective production till the end of life of products and the incorporation of waste management holons will be investigated. A more detailed elaboration of the proposed ideas is also addressed, and a more thorough series of experiments is foreseen. This project is partially supported by the Hungarian Scientific Research Fund, Grant No. T026486.

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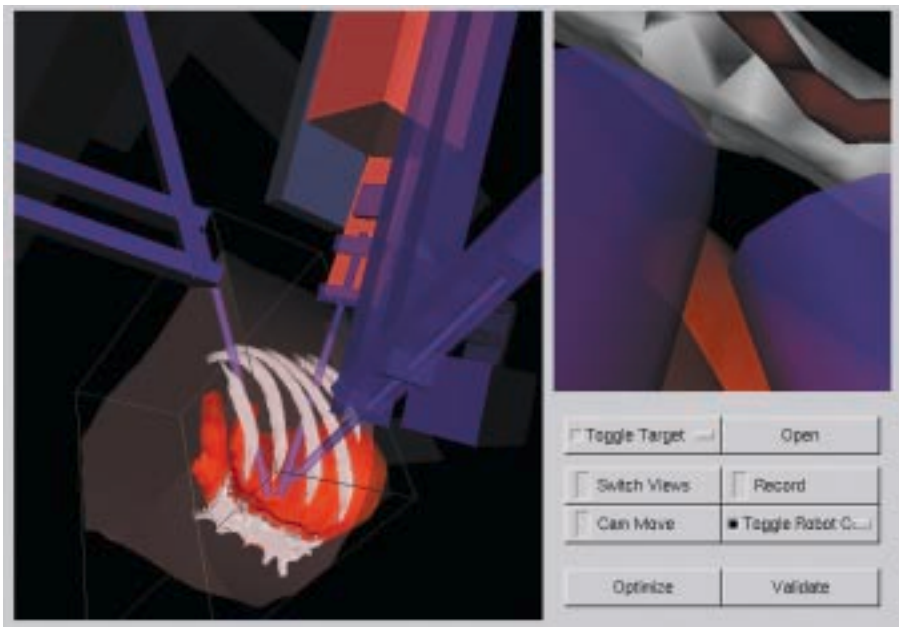
Robotics in Surgery

by Eve Coste-Manière

Surgery now uses robotic and image processing systems in order to interactively assist the medical team, both in planning the surgical intervention, and in its execution. The objective of this new technique is to enhance the quality of surgical procedures by minimizing their side effects (smaller incisions, lesser trauma, more precision,...), thus increasing patient benefit while decreasing the surgical cost. These techniques are being successfully introduced in several areas of surgery: neurosurgery, orthopaedics, micro-surgery, cardiovascular and general surgery etc.

Three main steps can be pointed out in a general robotic surgery intervention: data acquisition and subsequent planning, intra operative assistance, and post-operative patient control. In the pre-operative phase, a patient dependent model of the rigid (eg bones), and de-formable (eg the heart) anatomical entities involved in the surgical act have to be built. For this, several medical imagery techniques (MRI, Scanner, Ultrasonics, etc.) are used, where the anatomical structures are detected, located and modelled. In the same time, the mechanical model of the robotic system is fused in an overall geometric model. This will be used to describe and simulate the different potential problems that may occur during the intervention.

The results obtained in the planning phase are then calibrated and put in correspondence with patient in intra-operative situation. As a consequence, the robotic system is able to provide interactive assistance/guidance, and to constrain the movements of the surgeon in order to perform, with the desired precision, the possibly pre-defined procedure (eg neuro-surgical biopsy). In some cases, the robot may have an autonomous behaviour in order to realize



The software designed in the Chir team for the planning and simulation of surgical interventions. Upper right: the endoscopic view, left: the external positionning the robot in the thoracic cage.

The Chir Team at INRIA Sophia Antipolis integrates vision and robotic algortithms around the Da Vinci (TM Intuitive Surgical, Inc) system in collaboration with Professor Carpentier's team (Hopital Broussais) in heart surgery.

a dedicated and fixed part of the procedure (eg thighbone drilling for artificial hip installation).

As for tele-operated robots, the surgeon through a master console benefits from an enhanced (sometimes 3D) vision of the organs. In addition, augmented reality would allow the overlay, in real-time, of the pre-operative data of the patient during the intervention. The surgeon movements may be reduced to increase precision, and smoothed to avoid hand tremor by virtue of a decoupled master/slave unit.

INRIA Sophia Antipolis (Chir Robotics Medical Team) is directing its efforts towards this specific application field. In particular, a recent French National Research Grant 'Telemedecine' realized in collaboration with Pr. Alain Carpentier's heart surgery team, has been initiated and is now in progress. Fundamental research in key areas of robotics surgery are being studied: the modelling of de-formable organs (eg the heart), planning and simulation of robotics procedures (eg using the Da Vinci robotic system), safe & real-time integration with augmented reality. Our major concern is having a safe and robust software, especially in what concerns software integration of various disciplines. Several efforts in computer science have been devoted to develop modular and safe control mechanisms of software components used in robotic systems. This is the case of the Orccad/Maestro initiative at Inria, which is a software integration environment for the design and validation of complex robotic tasks. The fundamental properties required on such software systems can be validated beforehand, using formal verification of their logical behaviour, thus enforcing system safety.

The project's second priority is the demonstration of the validity of the developed research and tools through experimentation (eg in coronary artery bypass in heart surgery), and through industrial transfers towards specialized partners.

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The Design of the MIPS Micro-Robot for Endoscopy Applications

by Jean-Pierre Merlet

The SAGA research team at INRIA Sophia Antipolis develops a micro-robot to be used in medical and industrial inspection applications as, for example, in minimally invasive surgery.

Endoscopy is an important tool for industrial inspection and minimally invasive surgery which enable to get images from remote locations within an industrial plant or a human body. An endoscope is basically a flexible beam in which the orientation of the last ten centimetres may be controlled by pulling wires at the free-end of the endoscope (see figure 1). This type of control has two main drawbacks: first, a change in the orientation of the tip of the endoscope imply also a translation of this tip, which may not always be possible if the diameter of the pipe is too small and second an accurate positioning of the tip is not possible due to the friction in the wire guide and potential energy storage in the wire that act like springs. Hence most endoscope are used only for diagnostic purposes but not for direct operations.

A possible way to correct these drawbacks will be to add at the tip a micro-robot that

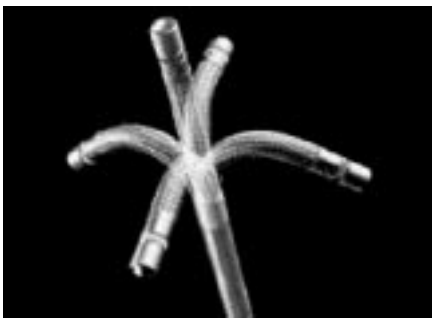

Figure1: The motion of the tip of the endoscope.

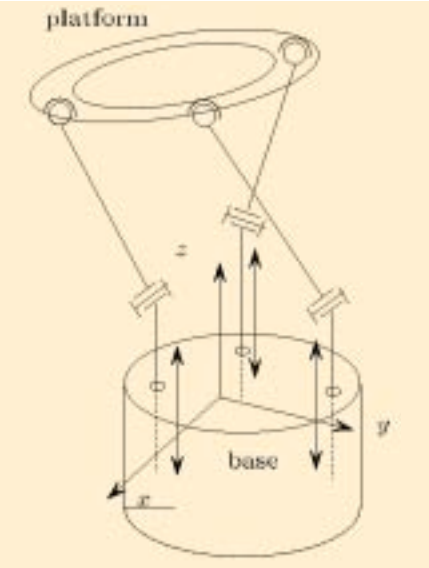

Figure 2: The mechanical architecture of the micro-robot.

Figure 3: The preliminary prototype of MIPS.

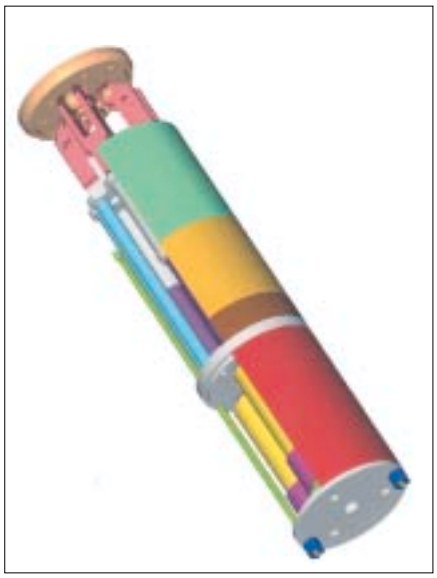

Figure 4: A CAD model of the new prototype.

will offer a local accurate mobility. After discussion with surgeons from INSERM we have decided to design such a micro-robot with the aim at using it for intestinal minimally invasive surgery. A consensus on the requirements for this robot has been established with the surgeons: its diameter should be approximatively 1cm (which is the diameter of the endoscope used for this type of surgery), it should have three degrees of freedom (one translation of about 3mm and two rotations of about 30 degrees) and its accuracy should be less than 1/10 of mm. But the most difficult requirement to fulfil was the force requirement: although in the operating mode the robot will have to produce a small force (equivalent to a load of about 15 grammes) to cut human tissue, it should be able to sustain the very large forces that are produced when inserting the endoscope. Fortunately a specific mechanical architecture, the parallel robot, fit the previous requirements: the chosen mechanical principle is shown in figure 2.

The end-effector of this robot is connected to its base by three legs which are attached to the end-effector by ball-and-socket joint. The other extremity of the leg is attached to a revolute joint and linear actuator enable to change the height of these joints. By changing the three heights it is possible to translate the end-effector along the vertical direction and to rotate it around the two horizontal axis.

A preliminary prototype of 1cm diameter has been designed for testing the feasibility of this project (see figure 3).

A joint French-Israeli project with the laboratory LMARC from Besancon and the Technion from Haifa has been established for developing such micro-robot within the framework of the 'Factory of the Future' project.

The Design Problems

Various problems have to be addressed before moving on a pre-industrial version of MIPS. First we have to deal with technological issues such as finding the appropriate actuators and sensors. After investigating various possibilities we have decided to use three micro-electrical motors of 1.9mm of diameter from MicroMotor, whose rotation motion will be converted into a linear motion with a screw, and three LVDT sensor of 1.5mm of diameter from MicroStrain (that limit the stroke of the linear actuator to 6 mm). We have then to figure out what should be the dimensions of the various components of the robot so that the surgeons requirements will be fulfilled. This problem is known as the 'optimal design' problem and is usually quite complex. It involves analysing and solving a large number of systems of equations, a problem which is the kernel of the SAGA project. For MIPS we have developed various tools based on exact or approximate computation that enable to determine the best design.

The New MIPS

As the best robot geometry has been determined we have decided to build a new prototype of which a CAD model can be seen in figure 4.

When the linear actuators are fully retracted this prototype looks like a cylinder of diameter 7mm. This prototype will be available at fall 2000 for preliminary tests and control algorithms will be developed before the end of this year.

Conclusion

After completing the tests for the control of the new prototype we intend to use the motor current measurement to evaluate the forces and torques exerted by the end-effector. This will enable the surgeon to get a force-feedback from the robot, that will complement the visual feedback provided by the endoscope. A third medical version of the prototype will be then built and proposed for clinical tests.

Links:
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Stability Issues in the Control of Anthropomorphic Biped Robots

by Bernard Espiau

An anthropomorphic robot, called BIP2000, has been designed by the Laboratoire de Mécanique des Solides de Poitiers and INRIA Rhône-Alpes. Shape and performances of the robot are close to the human ones. The robot has 15 active joints and environmental sensors, and its control architecture is based on advanced concepts of safe real-time programming. It will be demonstrated at the World Expo 2000 in Hannover. This paper presents an overview of the control problems which underlies the design of this class of systems.

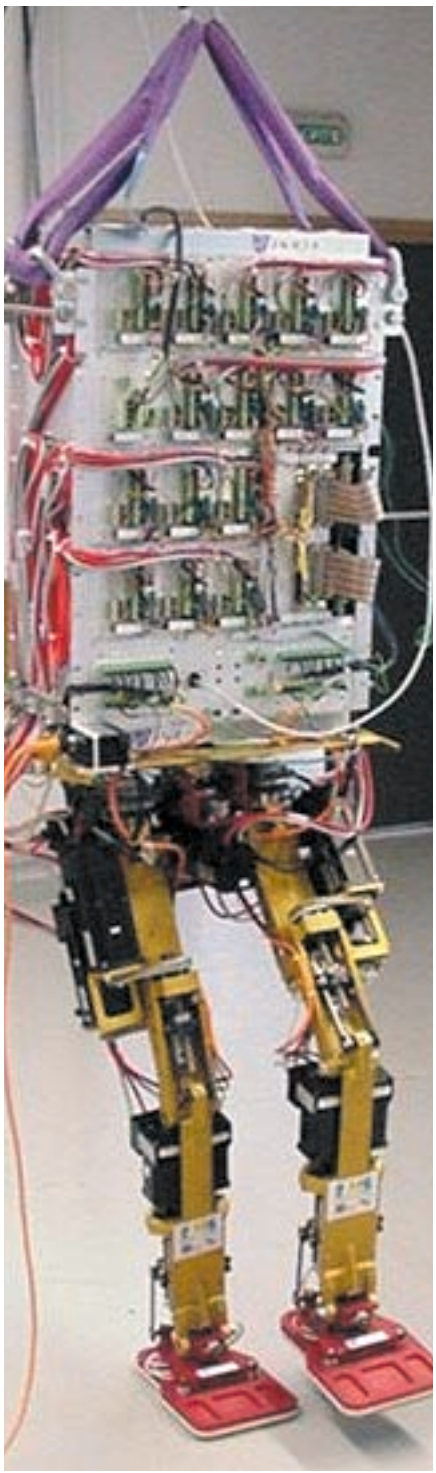
The ability of legged machines to pass obstacles or to move on uneven terrain in a low-invasive way is in general better than that of wheeled robots. This gives rise to outdoor applications as various as agriculture and field robotics, demining, exploration, forest exploitation. When considering structured environments, legged systems, and particularly biped ones, look well-suited for climbing stairs, walking through corridors or moving and acting in rooms designed for human occupancy. Like Honda did for his P2 robot, this tends to privilegiate the choice of designing robots in an anthropomorphic way, as soon as they are intended to be general-purpose, for example in human assistance. Biped robots share many problems with the other classes of mobile robots: perception and understanding of the environment, friendly interaction with humans, autonomous decision making, grasping and manipulation. Forgetting these aspects, we focus here on what is specific to biped robots: the analysis and the control of their motion.

The interest of biped locomotion is that it combines high capacities of mobility with a small convex hull of contact points. Besides, since the system is naturally unstable, control methods have to be very efficient and safety aspects are mandatory, any fall being liable to result in a fatal failure. This needs to revisit the classical concept of stability with a point of view different from the classical one used in automatic control.

Whatever the objective assigned to a biped robot, its dynamics is characterized by the existence of variable constraints resulting from its interaction with the ground. A common way of modelling that is to consider the robot as a chain of rigid bodies in tree form in rigid interaction with the ground through unilateral linkages and Amontons-Coulomb friction. Non-penetrating constraints result in normal ones of the form $\phi_n(q) \geq 0$; if we exclude the case where the robot is slipping, tangential constraints write as $\phi_t(q)$. Here q stands for the parametrization of the whole configuration space of the robot when free in the 3D space. Denoting as Γ the actuation forces and as λ Lagrange multipliers, the dynamics of a biped robot can write:

$$M(q)\ddot{q} + N(q,\dot{q}) = T\Gamma + \frac{\partial \phi}{\partial q}^T \lambda$$

Furthermore, the unilaterality imply the semi-positivity of normal contact forces and the existence of friction induces bounds on the tangential forces. Both of them can be expressed as inequality constraints on the Lagrange multipliers, $A(\lambda) > 0$.



The anthropomorphic robot BIP2000.

The normal forward motion of a biped robot is a cyclic succession of phases characterized by the variable dimension of involved contact constraints and by transitions between successive phases. The number of constraints is maximal in double support with the two feet flat, and may vanish in the extremal case of the flying phase in running. According to the considered case and to the rank of T (always less than the dimension of the configuration space), and owing to the contact forces in the RHS of the above dynamics, the system can be seen as either underactuated, fully actuated or overactuated. Furthermore, transitions between phases may correspond to impacts which result in abrupt changes in some state variables.

In addition to these problems of hybrid dynamics, and even within a single phase (ie without changing the set of active constraints), the control problem is difficult. In a classical robot, the

constraints are bilateral. Therefore, it is in general possible to reduce the configuration space of the system in order to get T the identity and to suppress inequality constraints. Passive control techniques, like computed torque or enhanced PD control are then sufficient to ensure the tracking of a trajectory in the q-space or in any other space diffeomorphic to it. Stability is then understood in the Lyapunov sense, and corresponds for example to asymptotical vanishing of the tracking error.

In the case of biped robots, the goal is rarely to accurately follow a joint space trajectory. When the robot is walking, he has to progress in the desired direction whithout falling; when the robot stays in the same place while performing some task, it should also maintain his static equilibrium (again avoiding to fall) despite the needed motions of his links.

Let us imagine a robot standing at a stationary position, ie having his joint variables regulated at a given value. If we slightly disturb this equilibrium, the robot can be driven back to its goal position by a classical joint position control in closed loop. If the disturbance is large enough, this is not sufficient and the robot will avoid to fall only by stepping forward, i.e, changing his reference trajectory. This illustrates the fact that, to be 'stable' the system has also to be able to generate the reaction forces and moments which are needed for preserving the constraints. In that sense, the Lagrange multipliers can be seen as particular inputs of the system. This shows also the interest of having force/torque sensors in the feet or the ankle in order to get the required information.

Finally, this problem can be mathematically expressed properly using the concept of viability. Without details, the basic idea is to stabilize a set instead of a trajectory in some given output space. This can be for example realized by parametrizing a set of optimal trajectories, ie extending the state space. Expressing the on-line problem in terms of linearly constrained minimization then leads to the need to solve at each time a Quadratic Programming problem. The use of generalized predictive control is also a possible alternative.

Links:
http://www.inrialpes.fr/bip/

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Rigid Body Dynamics Algorithm for Parallel Computers

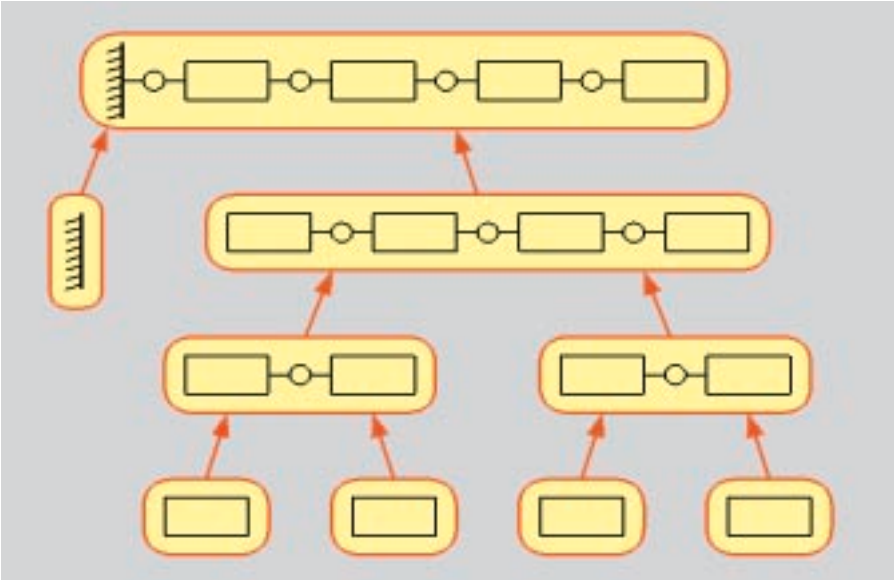
by Roy Featherstone

A new algorithm has been developed by the author for efficient calculation of the dynamics of rigid-body systems on a parallel computer. It achieves the theoretical minimum complexity, and it is applicable to most rigid-body systems.

The equations that describe the motions of rigid-body systems have been known for centuries, but efficient algorithms for evaluating those equations are a relatively recent invention. In the 1970s and 1980s, researchers in the robotics community developed a number of highly-efficient recursive algorithms to calculate the dynamics of robot mechanisms, treating them as rigid-body systems. Although the initial aim was to calculate robot dynamics, the new algorithms were applicable to rigid-body systems in general, and quickly found applications outside the robotics community.

These algorithms were originally intended to be run on a serial computer, and they are still today the best available algorithms for serial computation of rigid-body dynamics. However, the intrinsically-serial nature of their recursive computations has made it difficult to devise comparably efficient algorithms for parallel computers. In particular, algorithm designers have sought for many years the 'holy grail' of an algorithm that would run in O(log(n)) time on a computer with O(n) processors, n being the number of bodies in the system. The problem was first solved in 1995 by Fijany et al. for a restricted class of rigid-body systems; but there is now a new algorithm, developed by the author, that is applicable to a much larger class of systems and achieves the theoretical minimum possible complexity. It is also the fastest algorithm in many situations.

This new algorithm uses a divide-and-conquer paradigm, and its operation is illustrated in figure 1. Starting with a collection of individual rigid bodies (rectangles), the equation of motion of each body is evaluated. As each body is independent of the others at this stage, all of the equations can be evaluated in parallel. The next step is to connect them together in pairs, typically using joints (small circles) but other types of



The construction of a rigid-body system from its component bodies by recursive pairwise assembly. The new divide-and-conquer algorithm constructs the equations of motion in the same manner.

A rigid-body system with 1024 bodies and fractal tree connectivity, used to test the correctness and accuracy of dynamics calculation algorithms.

kinematic constraint can also be accomodated. This creates a collection of two-body subsystems. A special formula is used to evaluate the equations of motion of these subsystems from the equations already evaluated at the previous stage. Since these subsystems are still independent of each other, the evaluations can all be done in parallel. This process repeats until a subsystem is obtained that contains all of the bodies in the original rigid-body system, plus all of the inter-body connections except for the connections to a fixed reference body. These connections are added last, and the computation is complete.

The algorithm can be thought of as assembling the desired rigid-body system from its component parts, and the order of assembly is the 'assembly tree' shown in the figure. Roughly speaking, the execution time on a parallel computer is proportional to the depth of the tree, and the total number of computations is proportional to the number of nodes in the tree.

The new algorithm is appropriate whenever it is desired to calculate the dynamics of a large system of rigid bodies on a parallel computer that supports fine-grained divide-and-conquer algorithms. It can handle any system with tree connectivity and most systems with closed loops. The main exceptions are closed-loop systems with area-filling or volume-filling regular grid patterns of connectivity. Potential applications include redundant and hyperredundant robot mechanisms, multi-rigid-body approximations to elastic systems, complex mechanical devices, and rigid-body approximations of protein and polymer molecules. It has been tested on large kinematic trees, like the 1024-body fractal tree shown below, but not yet on closed-loop systems.

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doFSR - Optical High-speed Packet Switched Networking

by Kari Seppänen, Ulf Betlehem, Risto Mutanen, and Juha Zidbeck

Exponentially increasing Internet protocol (IP) traffic and new quality of service sensitive applications require cost efficient solutions throughout the network. WDM technology has provided solutions for transport networks at the backbone level, and similar solutions are emerging for metropolitan area networks (MAN). One important issue is how the network is controlled and how its resources are shared. A network system that is scalable from local switching networks to wide area networks (WAN) has been developed at VTT Information Technolgy, based on their proven frame synchronised ring (FSR) concept. It does not depend on a particular transport network, but it is adaptable from parallel optical links to dense WDM systems.

The original FSR is a ring-structured switching network where adjacent nodes are connected together by unidirectional point-to-point links. At the beginning it was applied as a parallel backplane bus that had separate control signals and data bus carrying fixed length frames. The medium access control (MAC) is decentralised and it guarantees fair resource allocation between the nodes. Multiple rings can be connected together to create larger and more complex network configurations. Later, a serialised FSR, in which all control and data signals are transferred using a single serial link, has been developed.

The FSR frame can be tailored to match the particular application used. It is composed of a header, payload and optional trailer fields. The header field includes source and destination addresses. The latter one is not encoded but there is one bit reserved for each node enabling efficient multicast support. Members of a multicast connection could be added and removed dynamically. Thus handovers required by mobile traffic are also efficiently supported.

The occupied frames are destination released: compared to multidrop or source release ring the FSR has double capacity on the average. In a FSR system consisting two counter-rotating rings, capacity of a single ring is doubled again, as the frames have to travel shorter distance. This means that the aggregate capacity in such system is 8 times of the capacity of a single internodal link.

Distributed Optical FSR

The doFSR is a serialised FSR with high-speed optical links between nodes. The basic setup consists of two counter-rotating rings, but bus capacity can be scaled up by using multiple WDM channels or parallel fiber links. A large doFSR system can be composed of dozens of pairs of parallel counter-rotating rings. The doFSR adapts itself automatically into a large variety of internodal distances, so it scales from local area networks (LAN) to wide area networks (WAN).

Different kinds of nodes and subnetworks can be connected to a doFSR network. A simple node may have only a single line card which is attached to a doFSR network through a DWDM add-drop multiplexer. A large central office (CO) type node have multiple line cards and all DWDM channels are terminated. As use of WDM components is not cost effective at short ranges, parallel optical links can be applied instead. At very short distances signals can be transmitted in electrical

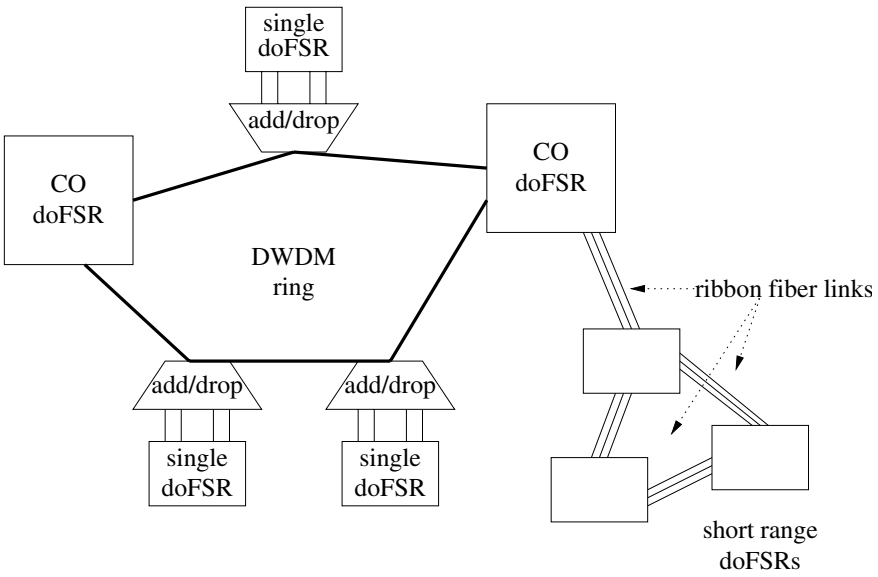

Figure 1: An example of heterogenous doFSR network architecture.

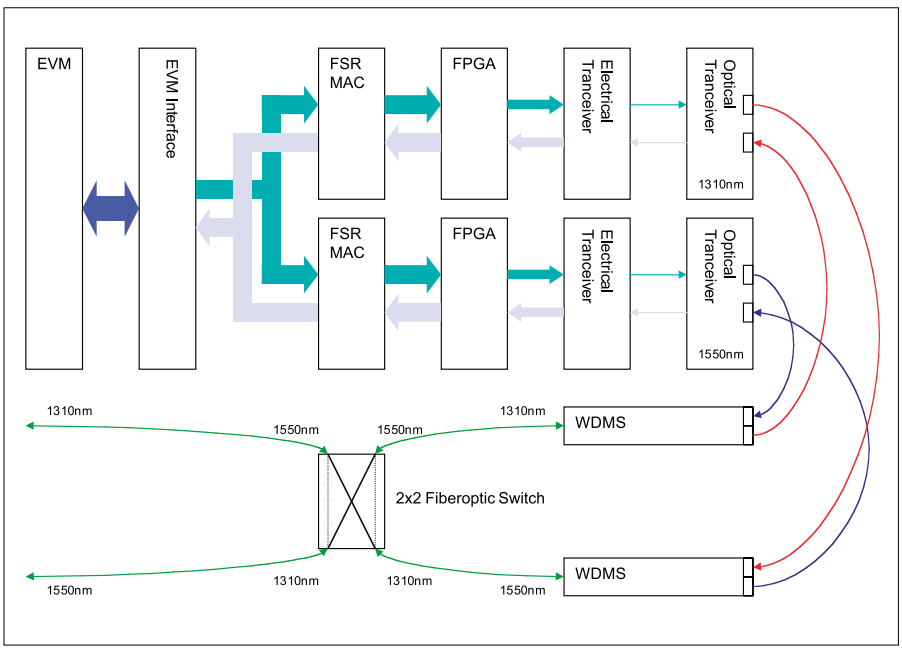

Figure 2: The structure of the prototype system.

domain using, eg, parallel low voltage differential signals (LVDS) links.

Each doFSR line card is attached to one clockwise and to one counter-clockwise rotating lightpath. All doFSR nodes have protection switches to ensure system operation in case of node failure. In nodes with multiple line cards each slot can be equipped with own protection switch to enable hot swap operation. Adaptation to a changed network configuration after failures is automatic.

Prototype System

The prototype implementation demonstrates the doFSR concept with one pair of counter rotating rings in single fiber using coarse WDM components. The prototype was built as a daughterboard for a 3rd party DSP-card, which provides a convenient platform for testing and further development. Transmission clocks are synchronised to a single clock source using local PLL controlled crystal oscillators to minimise jitter. Serialisation control, word-alignment and synchronisation are implemented using high-speed programmable logic devices. The nodes contain two switching FSR buses that can be used independently of each other. Flexible design supports automatic network reconfiguration when nodes are added or removed.

We have developed a Linux PCI network driver with bus-mastering capabilities for efficient data transfers. The DSP board utilises DMA-channels, which minimises overhead and allows the CPU to control the header manipulation. The prototypes have been tested with realistic IP traffic using fiber lengths from a couple of meters to several kilometers.

Distributed IP Router

A distributed IP router will be the first application for doFSR. It will transfer datagrams directly without intermediate layers, effectively acting as a decentralised IP-switch. In this way the workload of IP routing operations can be shared between doFSR nodes at the edge of the network. As internodal distances can be rather long, many hops between routers taking place in legacy router networks can be avoided.

Conclusions

We have developed doFSR, an efficient ring structured network based on a proven concept. Extremely scalable design makes it an ideal solution for applications ranging from distributed computing environments to edge networking Furthermore, a doFSR based IP network can be a cost efficient high performance alternative for access, feeder and backbone networks.

Links:
doFSR home page: http://www.vtt.fi/tte/rd/optical-networking/doFSR/

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E-Grid – Toward the Creation of a European Grid Community

by Domenico Laforenza

The popularity of the Internet and the availability of powerful computers and high-speed networks as low-cost commodity components are changing the way we use computers today. It is now possible to cluster or couple a wide variety of resources including supercomputers, storage systems, data sources, and special classes of devices distributed geographically, and use them as a single unified resource, thus forming what is popularly known as a computational grid. Two important international open forums, Grid and E-Grid, have been created in order to promote and develop Grid Computing technologies and applications.

The initial aim of Grid Computing activities was to link supercomputing sites; current objectives go far beyond this. According to Larry Smarr, NCSA Director, a Grid is a seamless, integrated computational and collaborative environment. Through the computational grid, scientists will be able to access virtually unlimited computing and distributed data resources. The grid will provide a group collaboration environment. Using a Web browser, users will be able to view and select grid resources and services in a virtual infinite machine room. The implications are enormous. The vision is to offer dependable, consistent, pervasive, and inexpensive access to high-end resources.

It is clear that many applications can benefit from the grid infrastructure, including collaborative engineering, data exploration, high throughput computing, and of course distributed supercomputing. However, building a grid implies the development and deployment of a number of services, including those for resource discovery, scheduling configuration management, security, and payment mechanisms in an open environment.

International Grid Forums

There are many grid projects underway worldwide. The Grid Forum is a mainly US community-initiated forum of individual researchers and practitioners working on distributed computing, or 'grid' technologies. It focuses on the development and documentation of 'best practices', implementation guidelines, and standards with an emphasis on rough consensus and running code. Grid Forum efforts are also aimed at the development of a broadly based Integrated Grid Architecture that can serve to guide the research, development, and deployment activities of the emerging Grid communities. The definition of this architecture will advance the Grid agenda through the implementation of fundamental basic services and by sharing code among different applications with common requirements. Wide-area distributed computing, or "grid" technologies, provide the foundation for a number of large-scale efforts utilizing the global Internet to build distributed computing and communication infrastructures. As common Grid services and interoperable components emerge, the undertaking of such large-scale efforts will be greatly facilitated and the resulting systems will better support interoperation.

The European Grid Forum: E-Grid

The main objective of E-Grid is to create an open forum to improve the conditions for Grid-related research in Europe. The community includes people from European research institutes, universities and companies working in the field of wide area computing and computational grids. E-Grid is a medium for information exchange as well as a place where researchers, supercomputing centers, and other European GRID-oriented research institutions or companies can find partners for future or current projects. E-Grid is similar in intentions to the successful US initiative but reflects the particular situation in Europe. It will gather information about all Grid-related projects in Europe and ensure that individual projects are aware of and can integrate with similar efforts. E-Grid intends to establish a high profile and will support the Grid Idea, stimulating projects and collaboration.. A long-term goal is to build a European Grid. The first informal E-Grid meeting took place in Portland, Oregon, USA, during the Supercomputing'99 conference. About 30+ representatives from different European and American institutions participated. During the meeting it was decided to organize the 1st E-Grid Workshop in April'2000, in conjunction with ISThmus'2000 in Poznan, Poland. During the April E-Grid Workshop, hosted by the Poznan Supercomputing and Networking Center, the following working groups were created:

- **Testbeds and Applications**
  chair: Ed Seidel, Max-Planck-Institut für Gravitationsphysik, Albert-Einstein-Institut, Golm, Germany (eseidel@aei-potsdam.mpg.de)
- **Resource Management**
  chair: Jörn Gehring, Paderborn Center for Parallel Computing, Paderborn, Germany (joern@uni-paderborn.de)
- **Programming Models**
  chair: Thierry Priol, IRISA/INRIA, Rennes, France (Thierry.Priol@irisa.fr)
- **Data Management**
  chair: Andre Merzky, Konrad Zuse Zentrum, Berlin (merzky@zib.de)
- **Performance Analysis**
  chair: Péter Kacsuk, MTA SZTAKI Research Institute, Budapest, Hungary (kacsuk@sztaki.hu).

The 2nd E-Grid meeting will take place during the EuroPar conference in Munich from 29 August to 1 September 2000, (http://wwwbode.informatik.tu-muenchen.de/~europar/). The University of Lecce, Italy has been proposed as hosts of the 3rd E-Grid Workshop in winter 2000.

Links:
The Grid Forum: http://www.gridforum.org
E-Grid: http://www.egrid.org

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Fast Graph Clustering Algorithm by Flow Simulation

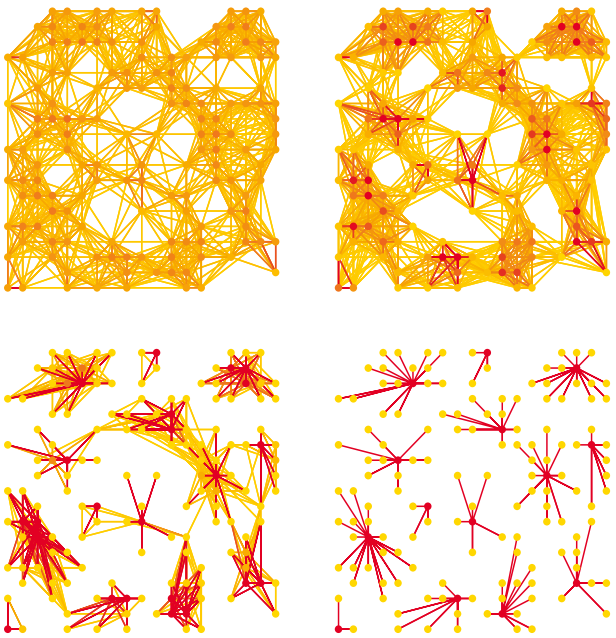
by Henk Nieland

Cluster analysis is a very general method of explorative data analysis applied in fields like biology, pattern recognition, linguistics, psychology and sociology. The aim is to recognize 'natural' groups within a class of entities. A fast algorithm was developed at CWI to disclose cluster structure in data represented as graphs. This Markov Cluster algorithm (MCL) is based on random walks on a graph, uses simple algebraic operations on its associated stochastic matrix, and does not require a priori knowledge about an underlying cluster structure.

The ability to distinguish close groups of entities, or clusters, is inherent in all living beings. This power of observation is in fact as important for survival as is food. Also consciously we frequently apply the method of clustering. It goes back to Greek antiquity, when Aristotle attempted to classify all living organisms. Cluster analysis on medical data in order to gain insight into a still not understood disease is a typical modern application.

In several cases data can be represented as a graph, consisting of a collection of nodes with their interconnections (edges). The World Wide Web is here an appealing example. CWI researcher Stijn van Dongen has invented a fast algorithm for automatic graph clustering. It is fast because it only uses very simple algebraic operations. This Markov Cluster algorithm (MCL) utilizes the notion of random walk for the retrieval of cluster structure in a graph. In a random walk at each node the direction to be followed is given by chance. Imagine a vast collection of random walks, all starting from the same point. Walkers will in general follow different paths. An observer floating high above them will see a flow: the crowd slowly swirles and disperses, much as if a drop of ink is spilled into a water-filled tray.

The aim of a cluster method is to dissect a graph into regions with many edges inside, and with only a few edges between regions. Once inside such a region, a random walker has little chance to get out. The idea behind MCL is very simple. Simulate many random walks (or flow) within the whole graph, and strengthen flow where it is already strong, and weaken it where it is weak. By repeating the process an underlying cluster structure will gradually become visible. The process ends up with a number of regions with strong internal flow (clusters), separated by 'dry' boundaries with hardly any flow.



Successive stages of flow simulation by the MCL process. The degree of redness of a node indicates the amount of incoming flow. In the last picture, the red nodes attract all flow (loops are not shown). The degree of redness of a bond between two nodes indicates the maximum of the total amount of flow in both directions.Thus, a red bond between a red node and a yellow node indicates that all flow is going in the direction of the red node. From the sequence of pictures it can be seen that flow between different dense regions of nodes which are sparsely connected eventually evaporates, showing cluster structure present in the original input graph.

Mathematically flow is simulated by algebraic operations on the stochastic (Markov) matrix associated with the graph. Flow can be expanded by computing powers of this matrix. This operation allows flow to connect different regions of the graph, but will not exhibit underlying cluster structure. An 'inflation' operator (technically: the entry-wise Hadamard-Schur product combined with diagonal scaling) is responsible for both strengthening and weakening the flow.

The MCL method has also been applied to problems in pattern recognition. Here the pixels of a digitalized image are seen as the nodes of a graph, and are interconnected if their grey values differ only a little. The method was tested for fast recognition of sharp transitions in an image.

In several cluster problems, for example in the medical and social sciences, the data are described in a 'vector' model instead of a graph. A single item is characterized by a set of numbers, which can be seen as a vector in a multi-dimensional space. Vectors are close according to some distance measure. At first sight this concept is rather different from that of a graph. Although developed for graphs, the MCL method is also applicable to problems which are naturally better described in a vector model.

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Fuzzy Neural Networks for Geomagnetic Storm Prediction

by Gabriela Andrejková, Henrich Tóth and Karel Kudela

Dynamical neural networks are used for geomagnetic storm predictions. A research team at J-P Safárik University in Kosice studies fuzzy neural network models which for such type of predictions look to be useful too.

Strong disturbances of the geomagnetic field, the geomagnetic storms initiated from the interplanetary space, along with the related enhanced energetic particle emissions have many consequences both on space and on the ground activities. Energetic particles are causing damage in space and the aircraft electronics leading to eventual failures of the systems; radiation hazard for the astronauts is increasing; the state of the ionosphere is changed and telecommunication systems are affected; geomagnetically induced currents can disturb the pipelines etc. Thus the prediction of the events, when suddenly (during few hours) the horizontal component of the geomagnetic field is depressed are of practical importance. Many schemes of the prediction are using 'prehistory', ie time series of interplanetary magnetic field and of solar wind plasma records monitored on the satellites outside the Earth magnetosphere.

Neural Networks are used for prediction of events (eg function fitting) and we could find many results about using multilayer feed-forward networks with error backpropagation learning strategy. The multilayer networks (see figure 1) belongs to the class of supervised networks, ie they learn from known answers.

From our point of view, 'neuro-fuzzy' means the employment of learning strategies derived from the domain of neural network theory to support the development of fuzzy systems. The learning capability of neural networks made them a prime target for combination with fuzzy systems in order to automate or support the process of developing a fuzzy system. Modern neuro-fuzzy systems (NFSs) are usually represented as multilayer feedforward systems, but it is possible to use the other network architecture, which means that the systems can have different properties:

- NFS is a fuzzy system that is trained by a learning algorithm (usually derived from the neural network theory). NFS can be described as a special feedforward NN.
- NFS approximates an (unknown) *n*-dimensional function that is partially given by the training data. The fuzzy rules encoded within the system represent vague samples.
- NFS can always be interpreted as a system of fuzzy rules. The form of the rule depends on the actual classifier.

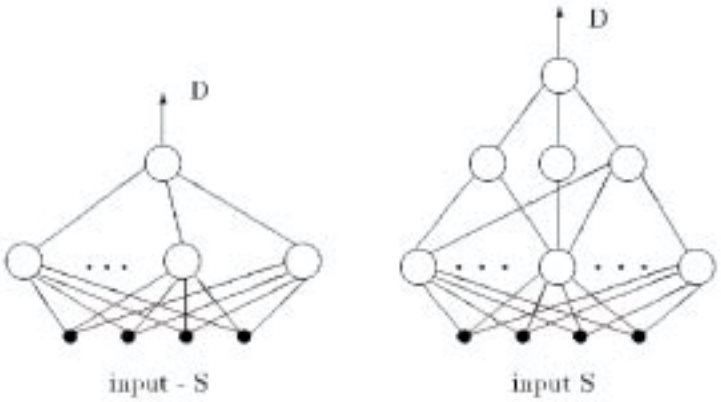

Figure 1: Examples of multilayer neural networks.

The neuro-fuzzy classifier (NFC) is a modified neuro-fuzzy system that finds a solution of the classification problem. The main difference between the NFS and NFC is in the structure of IF – THEN rules.

Neuro-fuzzy Learning from the Data

The algorithm creates the rules for the training data and the structure of the fuzzy neural network. The algorithm can be used to initialize the network.

The main problem is to construct the knowledge base of fuzzy rules for the given data space. Figure 2 gives an example of a fuzzy neural network for the knowledge base.

The prediction of geomagnetic storms is made on the basis of parameters. To prepare the training and testing samples we used the data from years 1980-1984 and 1989-1998 available from the NASA

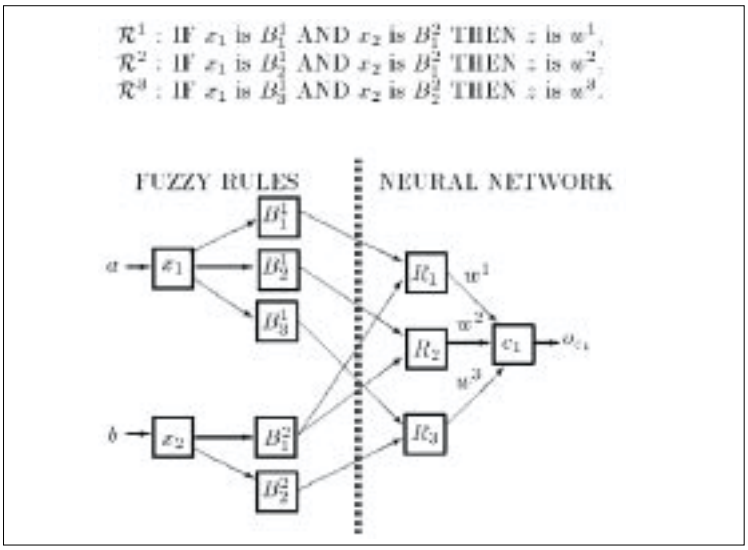

Figure 2: An example of a fuzzy neural network.

(http://nssdc.gsfc.nasa.gov) because we had the continued values of parameters which are measured at each hour and relatively few measured values were missing. The data from the years 1980, 1981 and 1991 were used as the training samples, while the remaining examples were used for the testing.

Discussion and Conclusion

Several years of hourly records were examined. The years 1980, 1981 and 1991 with rather large number of geomagnetic storms were taken as training samples, while years 1982-1984, 1989-1990 and 1992-1998 as testing ones. FNN approach demonstrated to be useful in the schemes of preditions of geomagnetic storms.

The schemes developed will be used for systematical checking of relevance of other physical parameters (eg, cosmic ray time series measured by ground based global network of neutron monitors) for the preditions of geomagnetic storms.

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Software Reuse in Geographical Information Systems Domain

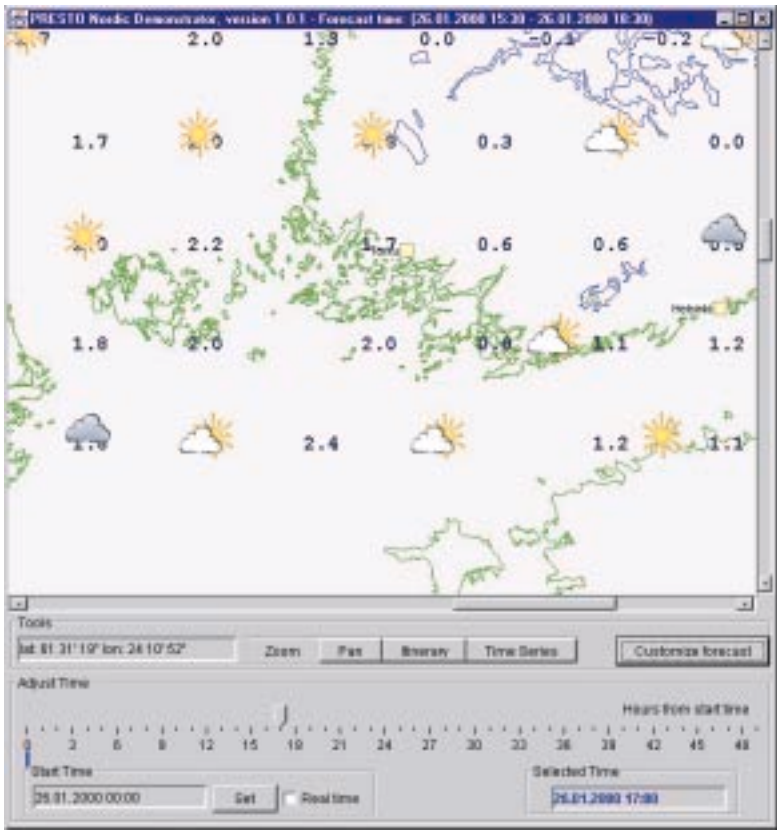
by Jyrki Haajanen, Robin Berglund, Ville Kotovirta, and Markus Laakso

The JGISFrame framework developed by VTT Information Technology enables fast composition of end-user software for Geographical Information Systems (GIS).

VTT's research in the domain dates back to the early 1990's. In 1999 VTT had several GIS projects active simultaneously and the potential synergy was obvious. It was decided to build a software framework encapsulating previous experience to support this set of projects. As a result, the development of JGISFrame started at June 1999, and first applications based on it were ready by the end of the year. The development of the framework still continues as new GIS projects are carried out at VTT Information Technology.

A parallel iterative development process was applied in the development of JGISFrame. A base version of the framework was developed quickly and a set of projects was applying it in their end-user software. Feedback from the applying projects including improvement ideas and arising problems was immediately available to the framework developers. The resulting solutions and changes in the JGISFrame were negotiated in close operation with the developers in the applying projects. Each of the developers of the JGISFrame was also involved in one or more of these. This gave a valuable multi-project scope to the detailed implementation of the framework and increased confidence in it among the application developers.

The purpose of the JGISFrame is to allow fast development of Java-based thick-client end-user GIS software. The thick-client approach is selected because we have mobile customers operating at sea or on the road with limited communication facilities. In the thin-client approach the server contains the application logic and generates views on the data, which are then passed to the client for visualization. If the user requests another view on the same data the server generates it and passes it to the client software. As a result the communications



PRESTO Nordic Demonstrator is one of the applications based on the JGISFrame.

load increases due to successive requests of the same data. A thick-client can contain the application logic for creating different views based on the data that is delivered only once, thus eliminating the successive requests for different views.

The architecture of the framework is based on the Model-View-Controller pattern. This provides separation of the data model and views to it in the application. Furthermore, it is easier to construct multiple views to the same set of data. The idea of the JGISFrame is to provide a set of components with predefined relations that implement the basic features of an end-user application. This basic model is then broadened and specialised with the inheritance mechanism, that allows maximal reuse of code. Other well-proven design patterns are also extensively applied in the JGISFrame. The framework is self-extendable – almost any feature implemented in an application can be included in the framework as it is or with slight modification and reused in the future projects.

The model in the framework provides an abstraction of a single point of GIS-data and their compounds. These basic constructs can be specialised for developer needs by use of inheritance mechanism. Virtually any GIS data can be presented with these basic constructs. Point and vector data can be represented with points and their compounds respectively and raster data can be associated with a bounding box of points. The JGISFrame provides a default local storage for the resulting data types. Query attributes can be spatial, temporal, or both. If the application has very specific needs, a custom implementation of storage can also be provided.

The JGISFrame currently contains 263 classes totalling more than 28 kilolines of source code (KLOC) with comments and blank lines excluded. Applications implemented with the framework contain 4 - 16 KLOC. The ratio of framework code to the deployed code in the applications is 65 - 90 %.

The framework approach is very productive. Within 10 months we have developed two operative applications and one prototype application based on JGISFrame, and one operative application is currently under development. More projects will follow in the near future. The costs of the development of the framework were considerably less than the opportunity cost of implementing similar functionality in each of the applying projects separately.

This summer we will launch a new project developing a ligh version of the JGISFrame for GIS-clients on portable mobile platforms, such as cellular phones and palm computers. Possible technologies to be used are WAP, Epoc, Windows CE, and Linux.

Links:
http://www.vtt.fi/tte/pub/tte1/mobilemarine/JGISFrame

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TOWER: Theatre of Work Enabling Relationships

by Wolfgang Prinz and Uta Pankoke-Babatz

The TOWER project aims to bring the wealth of clues and information that create awareness and cohesion in collocated teams to the world of virtual teams. TOWER will develop a 'Theatre of Work', a 3D-representation of teams and their work, which will enhance distributed teams with group awareness and spontaneous communication capabilities. Thus TOWER will facilitate a new way of working across time and distance.

In a collocated team, members typically learn from a wide range of cues about the activities of the other members, about the progress in the common task and about subtle changes in group structures and the organisation of the shared task environment. Most of the group awareness is achieved without specific effort. Work is a theatre of communication and activity, a balance of 'players', roles, artefacts, space, time, logic, physics, geography, power, social behaviour, trust, self interest, and group interest. The characteristic of communication in such a place is its richness and fluidity, woven into an intricate web.

With TOWER we will create a Theatre of Work for electronic co-operation that echoes the characteristics of the powerful fluidity found in face-to-face interaction. TOWER will support group awareness and chance encounters through a 3D environment which is the heart of the Theatre of Work. Users and their current actions on shared objects while suing a groupware application are represented by avatars and their symbolic actions. An avatar acts out the symbolic meaning of the users everyday actions on their behalf in the space of the Theatre of Work. Avatars of users who work in a similar context appear spatially close in the 3D environment. Movements of an avatar are driven by its user's action in his work environment. Thus a user must not perform any extra navigation in the 3D world, instead, the TOWER system does the walking – and the acting according to the users actions.

This idea will be extended into asynchronous communication showing a symbolic representation of an asynchronous communication occurring over time. Past events may be recorded

Figure 1: Ambient display with a prototype realisation of the Theatre of Work in the background.

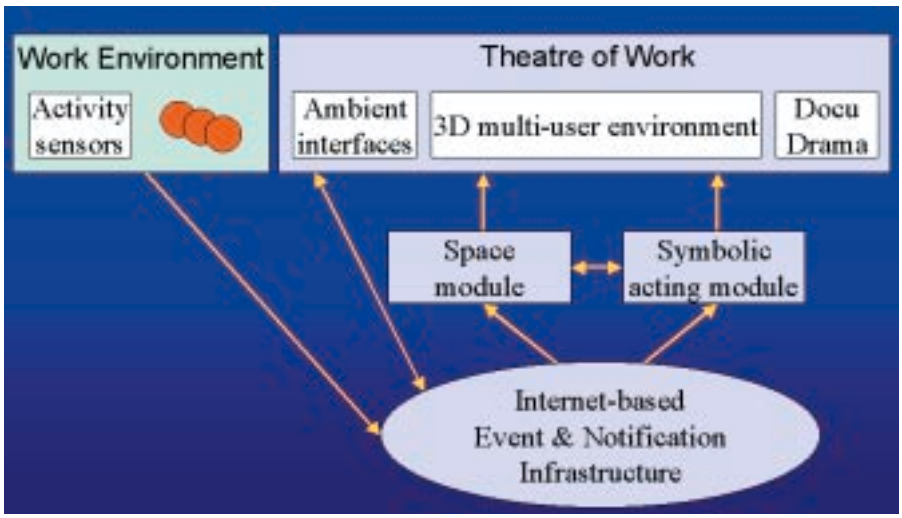

Figure 2: Illustration of the TOWER architecture.

and compiled to tell the stories or narratives of past actions. These stories will help users to catch up to the current work situation after temporal absences and in asynchronous work settings.

TOWER will develop a co-operation support infrastructure which consists of the following components (see Figure 1):

- a number of different activity sensors that capture and recognise user activities in a real and virtual work environment and that submit appropriate events
- an Internet-based event & notification infrastructure that receives events and forwards these events to interested and authorised users
- a space module that dynamically creates 3D spaces from virtual information environments, eg shared workspaces, or groupware systems and that adopts existing spaces to the actual usage and work behavior of the users that populate these spaces
- a symbolic acting module that transforms event notifications about user actions into symbolic actions, ie animated gestures of the avatars that represent users and their activities in the environment
- an already existing 3D multi-user environment that interoperates with the symbolic acting and space module for visualisation and interaction
- the 3D visualisation is complemented by ambient interfaces that will be integrated into the physical workplace to provide activity visualisation methods beyond the standard desktop
- a DocuDrama component that transforms sequences of event notifications and history information into a narrative of the past co-operative activities

These mechanisms will provide new innovative ways of integrating real and virtual workplaces. The real workplace will be extended into the virtual or electronic workplace, and the virtual workplace will be extended into the real one. This will lead to new ways to integrate social and task oriented awareness information.

TOWER will be developed as a construction set which may be used to augment existing groupware systems with awareness information. With this approach, users may benefit from the awareness information provided in the Theatre of Work, without extra effort, in particular they may continue working with the tools and systems they are familiar with. A major objective of TOWER is to find the right balance between the needs to disclose individual activities and the protection of privacy.

The evaluation of TOWER in real work settings and the improvements based on practical experiences are essential to the project. The TOWER project conceives, implements, evaluates, and evolves the infrastructure in three consecutive cycles. Evaluation of the prototypes of the systems will be based on trials in different application areas such as research project work and support of distributed teams at an oil company. Feedback yielded from this use will constantly inform and progress the design of subsequent system versions.

The TOWER project has started in January 2000 and will run until in summer 2002. This activity is funded in part though the IST-program (IST-10846). The partners of the project are: blaxxun international AG, British Telecommunications plc, GMD institute FIT, The Bartlett School of Architecture at UCL, and Statoil's Research Centre.

Links:
http://orgwis.gmd.de/projects/tower/

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Vision System for a Light-tube Production Line

by Tamás Lédeczi and György Ákos

A multi-camera real time visual inspection system was developed by Cortex Technical R&D Ltd. for measuring the hot formed ends of glass tubes used in the fabrication of fluorescent (Ne) light sources. The system uses the DSP based proprietary UltraGrab card developed by Cortex Ltd. for fast data acquisition, enabling the measurement and sorting of glass tubes at a maximum rate of 250 pieces/min.

Cortex Technical R&D Ltd

Cortex Technical R&D Ltd. was founded in 1990, following the restructuring and opening-up of the Hungarian economy. The core of the company consists of a five person team: four engineers and one physicist. The company can be considered as a spin-off from SZTAKI, and formed from the Computer Vision and Robotics Laboratory of the Institute. During the academic period a lot of theoretical and practical research and development work had been carried out in the field of digital signal processing, especially in image processing. Based on this special accumulated knowledge the group was able to start a private business and transfer this knowledge to real industrial applications.

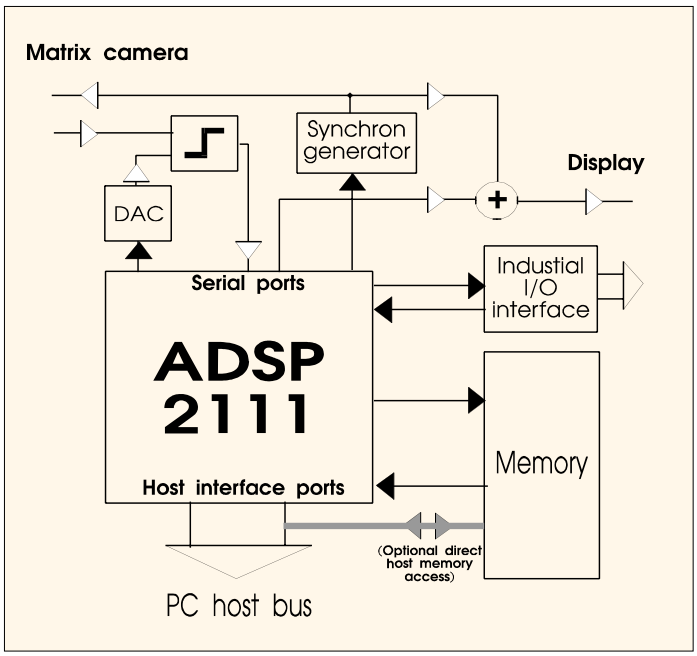

Figure 1: The layout of the UltraGrab card.

The UltraGrab PC Card

The binary frame grabber and image processor PC-board has been primarily designed for real-time industrial applications. It is based on the Analog Devices ADSP-21XX Digital Signal Processor (DSP). The maximum image size is 800 x 576 pixels, the limit set by standard PAL video cameras. The board is also applicable for NTSC standard, in which case the resolution is somewhat lower.

An interesting feature of the board is that there is almost no extra digital hardware for image acquisition and display, but these functions are realised on the DSP itself using its on-chip resources. This solution not only results in a fairly compact and low-cost board, but also a very flexible system, since image size, format, timing etc. are completely under software control. For example, it is possible to have multiple windows on the image and grab images to the windows independently. To help making vision systems even more compact, the board also includes 2+2 bits of optocoupled inputs and outputs, which can be directly connected to most industrial controllers. The inputs can be associated with a DSP interrupt, thus even very strict synchronisation requirements can be met.

Communication towards the PC host is performed via the DSP's Host Interface Port (HIP). Communication is initiated by the PC, but for alerting the host the DSP can take control over one of the PC interrupt lines. If greater information throughput is required, the host can also have direct access to the DSP`s external data memory.

For creating vision systems with the UltraGrab board, two different software approaches can be taken. In the first scheme the UltraGrab is a stand-alone measurement system, where the PC only provides power, initialisation and optional registration or supervision of the measurements. This is ideal for the simpler applications, or when several DSP boards are plugged in a single PC. For complex systems, however, it might get clumsy to program all the measurement control into the DSP. In this case, the DSP program only includes the lower-level, computationally demanding measurement routines, while these routines are invoked and parameterised by a higher level program run by the host. In this case, DSP programming can be minimised or completely omitted.

The Vision System

One of the vision systems employing the UltraGrab card is used at a glass plant of the General-Electric-Tungsram company at Vác, Hungary to check the hot-formed ends of glass tubes used for fluorescent lighting for a given prescribed shape with fairly narrow tolerances. The system also measures the length of the glass tubes.

The task is to measure whether the inevitable size differences do not exceed the allowed limits, to check whether the tube end is not broken or cracked, and to reject faulty parts. Since tubes arrive at a maximum rate of 250 pieces/min, human inspectors employed so far were unable to perform a stable quality checking, and they could only roughly estimate the parameters to be measured.

The system does not require any mechanism to stop the tubes during inspection. This solution proved to be robust and needs practically no maintenance. Tubes move continuously along their way during inspection and the parallel acquisition of the images is taken on the fly.

To realize thorough inspection, each end of every tube needs to be checked from four views using eight CCD cameras (6 matrix and 2 line scan cameras). Figure 2 outlines the arrangement of the 6 matrix cameras. The processing core contains an industrial PC equipped with the DSP based UltraGrab frame grabber and image processing boards. All the image processing tasks are carried out by the DSP boards, the PC acts only as a host device, providing Microsoft Windows based user interface, statistics, calibration utilities, system level control and detailed diagnostics on the state and settings of the end forming machine.

Figure 3 shows a typical measurement. The evaluation of the data shows a cracked collar and the measuring lines of the important dimensions of the tube collar can bee seen.

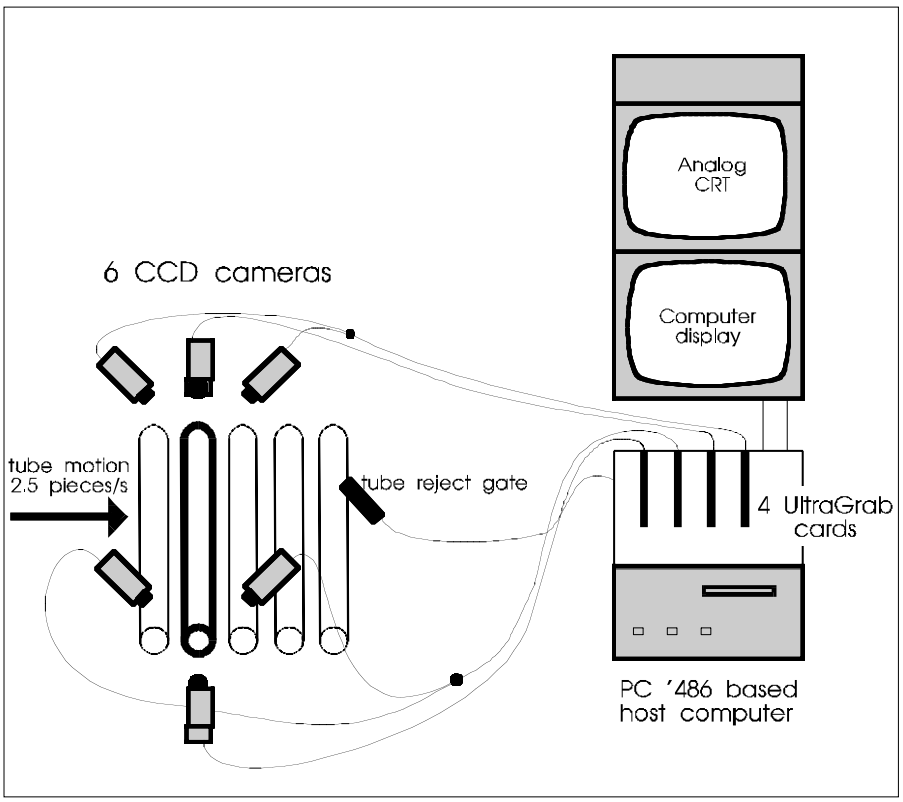

Figure 2: The vision system for testing light tubes.

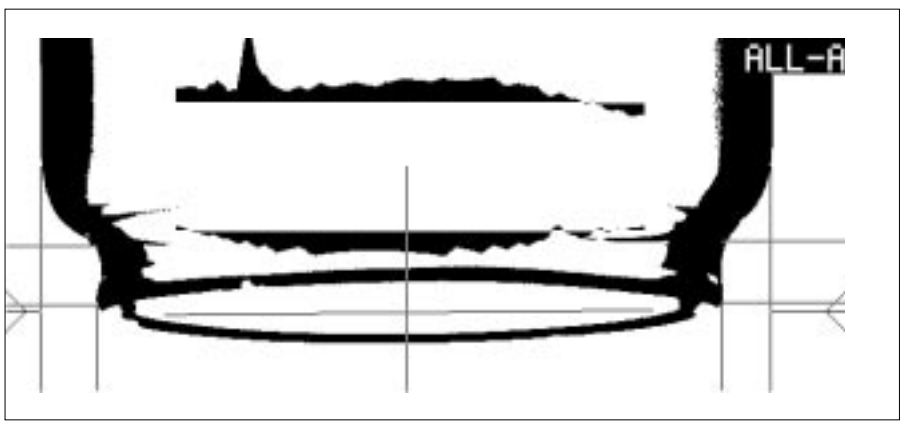

Figure 3: Processed image of the glass tube collar.

The measurements are carried out with 0.1 mm (0.004 inches) accuracy. This requires compensation for all possible secondary and ternary factors that might distort measurements (eg even an ideal end ring, appearing as ellipse on the image, is distorted by several factors, many of them varying with the actual position and wall thickness of the tube), while at the same time the measurement has to be robust enough to maintain tolerance of noise and non-optimal setting of the imaging system.

Conclusion

In the example described above, the DSP based UltraGrab frame grabber developed by Cortex Ltd., has been used for performing the fast and reliable measurement, check and sorting of glass tubes according to their shape during manufacturing. Similar systems have been developed for the following tasks:

- vision system for starter drive quality inspection
- laser scanning and diffraction gauges for contactless measurement of the outer diameter of objects ranging from 10 μm tungsten wire to 50 mm glass tubes
- combined laser scanning and line scan system for measuring the diameter, length and end-tilt of glass tubes used in the manufacture of compact light tubes
- combined laser scanning, laser scatter and line scan system for measuring the diameter and bow of glass tubes, and for detecting imperfections (knots and stones) within the lead glass.

Present work concentrates on developing a wall thickness gauge for arbitrary shaped glass objects.

Links:
Cortext web site: http://www.cortex.hu

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New Version of BSCW Groupware System Released

by Wolfgang Appelt

A new version of GMD's BSCW (Basic Support for Co-operative Work) Shared Workspace System has been released. BSCW is an efficient tool for computer supported co-operation via the Web, developed by GMD's Institute for Applied Information Technology (FIT) .

Version 3.4 of the BSCW system has been released in May. BSCW is particularly useful for geographically dispersed groups working in a heterogeneous system environment. The system is implemented as an extension to normal Web servers such as the Apache Web Server or the Microsoft NT Internet Information Server and runs on various Unix systems (including Linux), Windows NT and Windows 2000 systems. Today there exist more than 500 BSCW servers world-wide with an estimated user community of well over 100,000.

The new release includes a number of features that have been developed in the CESAR project funded by the European Union's Telematics Applications Programme. Highlights of the new release are, for example:

- there exists now an indexed based full text search which allows queries in documents stored on BSCW servers in all commonly used document formats.
- users can specify in much more detail than in the previous versions in which way they want to be informed about events in their workspaces
- users can receive notifications about events in their workspaces on their mobile phones via WAP
- in addition to email distribution, documents in BSCW workspaces can now also be directly sent via fax
- user data can also be retrieved from LDAP servers which can save multiple maintenance of user data
- for BSCW system administrators it is now also possible to register users and allocate them to particular work spaces via a script interface which is particularly useful when dealing with large user groups
- by code enhancements the performance of the system could be increased by about 40% for typical BSCW applications.

The BSCW interface.

The system can be used at GMD's public BSCW server at http://bscw.gmd.de/ and the new release of the software can also be downloaded from there so that interested parties may install their own BSCW servers. Licences may be obtained from OrbiTeam Software GmbH (http://www.orbiteam.de), a GMD spin-off company which has been founded in 1998 to ensure professional support, customer requested modifications and enhancements, and long-term maintenance and development of the system.

Links:
BSCW home page: http://bscw.gmd.de/

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Firmitas – Structural Monitoring of Ancient Buildings

by Maurizio Brocato

The availability of appropriate information is paramount for the conservation of our cultural heritage and for the repair of ancient buildings, especially when structural restoration is needed.

Figure 1: 'Salone del Maggior Consiglio', Duke's Palace, Genoa.

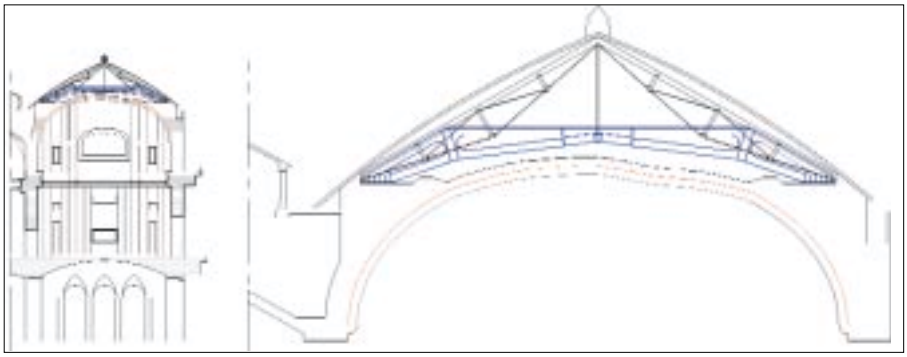

Figure 2: Cross-section of the west wing of the Palace and of the vault .

In situ observations give hints on the main causes of health degradation. Sometimes historical analyses provide architects with fundamental, though qualitative, answers on the origin and evolution of the observed structural problems. Measurements are usually taken soon before and/or during work to investigate the strengths and weaknesses of an ancient structure, but a record of the structure's life, with the necessary data stored in a well-structured data base, is most often unavailable. There is currently a real need for a scientific and technical initiative aimed at the design and organization of data acquisition and storage systems for historical buildings and monuments. This activity would be a valuable contribution – per se – for studies on the history of ancient buildings and provide an important tool for architects in the future.

The Firmitas project aims at the development of a set of procedures and knowhow for monitoring the structural health of ancient buildings. This is a multidisciplinary activity calling not only on architecture, history, civil and electronic engineering, but also on more fundamental scientific disciplines such as physics, mechanics, mathematics, and computer science.

In addition to the standard approach to the problem of structural health monitoring (sensing and processing information on the effects of loads and temperature), less well known issues are tackled, such as the study and monitoring of bio-mechanical interactions and the reduction of damage and collapse risks through implementation of mechanical control systems.

Thanks to the financial support of the European Social Fund (through the Italian Ministry for the Universities and Scientific and Technical Research) and of the Province of Messina, a group of nine graduate students is currently working on this project at IEI-CNR in Pisa. The activity of the group is organized into four sectors: architectural and historical analysis, mechanics of materials and structures, numerical computations, data acquisition and process. Two 'pilot' examples have been chosen to focus on concrete issues: the vault of the 'Salone del Maggior Consiglio' in the Palazzo Ducale in Genoa, and the Monastery of San Placido Calonerò in Messina.

The first structure dates from 1778 and, due to construction problems, which were already evident at the time of building, has had to be restored many times since then. The vault spans a surface of 17 by 35 meters and suffers from a localised distortion of curvature (see figures). A system of health monitoring is currently in operation. With the permission of the Ente Palazzo Ducale, and thanks to information provided by them and by the Superintendency for Cultural Wealth of Genova, we are now investigating possible extensions to the existing monitoring system, in particular through an improved analysis that also takes hygro-thermal effects and damage to the masonry into consideration.

The Monastery of San Placido Calonerò, built during the Norman period in Sicily, is situated on the hills above the town of Messina. The Province of Messina has encouraged us to design a health monitoring system for the monument. The main structural problems are caused by differential foundation displacements and loss of resistance due to moisture. There have been many architectural modifications, including the rebuilding of parts, in the past, and the compatibility between old and new materials within the structure needs to be verified. As the seismic risk of the site is very high, tools for the evaluation of the possible consequences of earthquakes and a data base on the local magnification or attenuation of seismic waves must also be designed.

Links:
FIRMITAS: http://www.iei.pi.cnr.it/~firmitas

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INRIA led Worldwide Calculation for Biggest Public-key Cryptography Crack

by Catherine Girard

Researchers at INRIA announced on 13 April the solution to the most difficult public key cryptographic challenge ever solved after a huge calculation on close to 10,000 computers throughout the Internet. The challenge, called ECC2K-108, was set by Canadian cryptographic company Certicom in 1997 to encourage researchers to test the security of cryptography based on elliptic curves.

This extraordinary achievement demonstrates the high level of security that elliptic-curve cryptography (ECC) can offer with much shorter keys than RSA. It also highlights the relative weakness of some curves with special properties and confirms that for optimal security one should pick random curves with no special characteristics.

Organization of the Project

Robert Harley and three INRIA colleagues, Damien Doligez, Daniel de Rauglaudre and Xavier Leroy, found the 109-bit cryptographic key after four months of computation distributed on 9500 computers with the help of 1300 volunteers in 40 countries. Two thirds of the computation were done on Unix workstations and one third on Windows PCs. On a single 450 MHz machine the computation would have taken 500 years.

The project, called ECDL, was organized into teams which used open-source software developed by Harley to calculate more than two million billion points on a particular type of elliptic curve, called a Koblitz curve by Certicom. Among these points, the teams discovered 'distinguished' points and sent them to an AlphaServer at INRIA where a Web site allowed participants to follow the computation's progress in real-time. After two million distinguished points had been collected, a final phase of processing was able to extract the solution. The participants also stayed in constant communication via the Web site and a good-humoured competition quickly developed among them.

Of the US$10,000 prize money offered by Certicom, $8,000 will be donated to the Apache Software Foundation to support development of the Apache open-source Web server software package. The remaining $2,000 will go to two participants who found crucial distinguished points used in computing the solution.

Implications

Arjen Lenstra, vice president at Citibank's Corporate Technology Office in New York and a participant in the project, noted "The amount of computation we did is more than what is needed to crack a secret-key system like DES and enough to crack a public-key system like RSA of at least 600 bits".

Robert Harley remarked "Even so, it was only about one tenth of what should normally be required for a 109-bit curve. That's because Certicom chose a particular curve with some useful properties but we used those same properties to speed up our algorithm. This underlines the danger in adopting particular curves and the need to pick random ones with no special characteristics. I'm concerned about Koblitz curves and complex-multiplication curves, which some people advocate using in order to avoid the point-counting problem".

François Morain, Professor of Computer Science at École Polytechnique, explained: "To use a curve for ECC one first has to calculate the number of points on it, which is quite a difficult task. To improve security one should use arbitrary curves picked at random and change them frequently, but currently most cryptosystems use fixed curves chosen to have particular properties which make it easy to compute the cardinality. These very properties could one day endanger them, as happened with super-singular curves. There have been dramatic improvements in point-counting algorithms and good implementations are now becoming available. Recent progress should soon undermine any remaining argument in favour of special curves".

Conclusion

For INRIA researchers, such experiments are very important: they enable theoretical assessments of the security of cryptosystems to be confirmed by experiment. In this way a large-scale test of their resistance to attack is achieved, which helps to improve their security just as crash-tests by automobile manufacturers contribute to the safety of cars.

Links:
The ECDL project:
http://cristal.inria.fr/~harley/ecdl/
The Certicom ECC Challenge:
http://www.certicom.com/research/ecc_challenge.html

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WWW9 attracted over 1400 Participants to Amsterdam

by Ivan Herman

The 9th World Wide Web conference hosted by CWI in Amsterdam attracted more than 1400 participants (55% Europeans, almost 40% from USA/Canada). 20 companies and organizations (including ERCIM, but also Sun, IBM, ACM, Philips, the Internet Society of the Netherlands, or UPC) were involved through some form of sponsorship, an exhibition booth, or as co-organizer. 30% of the participants came from academic institutions (universities, research centres, museums or galleries), over 50 reviewed academic papers were presented (280 submissions).

Such dry statistical facts do not tell about the exciting atmosphere during the week of 15-19 May, when the 9th World Wide Web conference was held in Amsterdam. These conferences have traveled all over the world, from Santa Clara, in California, through various European cities to Brisbane, in Australia. They have become the primary meeting places of Web experts worldwide, where the latest technologies are presented and discussed. Amsterdam was no exception.

Internet Access Room.

Booths of ERCIM and CWI.

The WWW conferences are not trade shows; they are typically attended by techies, with only few 'suits' around. This determines the nature of the conference programmes, too. At WWW9, the technical paper sessions were complemented by a series of Web & Industry sessions (featuring such companies as General Motors, Elsevier, or Nokia), where industrials presented their visions for the future and the technical challenges they face in realizing these; panels over XML protocols, WAP and its connection with the Web, graphics techniques on the Web (such as Web3D, SVG, or WebCGM), or Web internationalisation generated passionate debates; 90 posters triggered further technical discussions around a high diversity of topics. There were five keynote speakers, coming from such companies as Ericsson, Philips or Psion. A series of tutorials and workshops preceded the 'core' conference; a so-called Developers' Day, which gave speakers the opportunity to dive into the most intricate details of their work, closed the event.

The evolution of the mobile Web was one of the main topics that spread throughout the conference. The term 'mobile' is very general: it refers to mobile phones with WAP facilities, but also to PDA-s like Psions or Palms, or to applications used, for example, in the automobile industry. This new phenomenon raises a number of new challenges, from protocol level to application. There were tutorials and developers' day sessions on the subject; the opening and the closing keynotes (Egbert-Jan Sol, Ericsson, and Charles Davies, Psion, respectively) both gave a thorough overview from their perspective. It was a nice coincidence that this conference took place in Europe this time; the Old Continent has a considerable advantage over the US in the mobile Web area, it was therefore quite appropriate that this topic dominated a conference held in Amsterdam.

The World Wide Web conferences have a traditional contact with the World Wide Web Consortium; indeed, the conference is the most important annual public appearance of W3C, where the newest developments are presented. In Amsterdam the W3C track sessions which included presentations on new topics and specifications like SVG, P3P, XML Schemas, or the Web Accessibility Initiative, were extremely popular and well attended.

Of course, the Web has also become a social phenomenon. One new aspect of the Amsterdam conference was that social issues were brought to the fore, too. The keynote address of Lawrence Lessig (Harvard Law School), talking about the issues of government control on the Web, or about trademark and patent problems, was certainly one of the highlights of the conference. A separate, parallel track was entirely devoted to cultural activities and the Web. Virtual museums and galleries, Web-based architectural models, metadata and property right problems, etc., all raise new challenges to the technical community.

For all those who could not make it to Amsterdam, the proceedings of the technical papers are available (published by Elsevier, Amsterdam) and, of course, accessible on the Web (http://www9.org). In the coming weeks the presentation materials of the keynote speakers will be put on the web site, too, so that everybody can have an impression of the conference. The next conference in the series will be in Hong Kong, May 2001.

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Interactive Learning Environments for Children

by Constantine Stephanidis

The one-day Workshop on 'Interactive Learning Environments for Children' took place at the Training and Conference Center of the National Bank of Greece S.A., in Athens, Greece, on March 3rd 2000. The Workshop was organised by the ERCIM Working Group on 'User Interfaces for All' in the context of the i3 Spring Days 2000, with Prof. Constantine Stephanidis as the Workshop Chair.

The Workshop aimed to consolidate recent work and to stimulate further discussion, on the state of the art in user interfaces that are intended for use by children, as well as to facilitate the exchange of knowledge and experience between researchers and practitioners in the fields of Universal Access and Design for All, and the i3 community. The success of the Workshop confirmed the expectations that there are many common research themes between the field of User Interfaces for All and the i3 community, and initiated a lively and fruitful exchange.

Following a peer review process, the proceedings have included three main categories of articles accepted for presentation at the Workshop: 6 long papers, 5 short papers, and 1 position paper. The proceedings of the Workshop are electronically available via the Web site of the ERCIM Working Group 'User Interfaces for All' at the URL address: http://ics.forth.gr/proj/at-hci/UI4ALL/i3SD2000/proceedings.html.

The Workshop attracted considerable interest from an international audience, with more than 50 participants from countries around the world. The paper presentations and discussions during the workshop covered a variety of topics, including: theoretical and technical frameworks for meeting children's needs; the design and evaluation of Interactive Learning Environments; Virtual Reality Learning Environments; standard and adaptive multimedia interfaces for disabled children; computer games for blind children; and distance learning environments.

The participants had the opportunity to discuss and exchange ideas for future co-operation between the two research communities. As a first step towards more close collaboration, the i3 community was invited to participate in the 6th ERCIM Workshop on 'User Interfaces for All' that will take place in Florence, Italy, 25-26 October 2000 (Local Organiser: Dr. Pier Luigi Emiliani, Director of CNR-IROE).

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6th ERCIM Environmental Modelling Workshop

by Brian Read

CLRC-RAL hosted the sixth workshop of the ERCIM Working Group devoted to Environmental Modelling 23-24 March 2000. It took place at the historic Cosener's House by the River Thames in Abingdon. Seventeen researchers from eight institutes participated. The nine presentations addressed the topic of the application of information systems in environmental modelling.

Achim Sydow from GMD Institute for Computer Architecture and Software Technology, chair of the working group, welcomed everyone and thanked Keith Jeffery for RAL's hospitality. Bob Hopgood (CLRC) opened the workshop with an invited talk. He spoke with customary authority on the status of web technology, concentrating on the relevance of XML and its role in the better management, presentation and transfer of data.

Three presentations on IT techniques followed: Jean-Paul Berroir and François Llirbat (INRIA) discussed workflow techniques for processing environmental

Environmental Modelling workshop participants.

data, Manolis Vavalis (FORTH) proposed the use of agents in a distributed environmental system, while Brian Read (CLRC-RAL) reviewed data exchange formats and the potential of XML for scientific data.

Turning to applications, Bertram Walter (GMD-FIRST) described his success with modelling the scattering of sunlight in the atmosphere. The demanding calculations allowed realistic visualisation of phenomena such as sunsets and rainbows. Roberto San José (UPM) presented recent developments by the Madrid group for their air quality forecast model, studying the value of vertical meteorological data input.

The second day of the workshop took up the theme of weather and climate modelling with reports of more local activity. Povl Frich from the UK Meteorological Office gave an overview of the problems in managing large and disparate datasets, contrasting the needs of commercial weather forecasting with those of researchers. The UGAMP (Universities Global Atmospheric Modelling Project) team were represented by Paul Berrisford (Reading University) who describing how they were tackling the problems of managing the large (200GB to 2TB) datasets produced by their gridded models.

A rather different kind of modelling was presented by Simon Lambert (CLRC-RAL). He described his work with Gordon Ringland on a 'Management Flight Simulator'. This decision support system has been applied to the better management of flood control in Bordeaux and of drinking water supply distribution.

Overall it was an enjoyable Workshop, being a mix of old and new topics to interest Group members. The opportunity was taken immediately before the workshop for a working meeting on current tasks of the DECAIR project. This is an EC R&D collaboration initiated by the working group. The workshop concluded with acceptance of an invitation to hold the next one at Las Palmas in September. It will be a joint workshop with the ERCIM Database Research Group.

Links:
Environmental Modelling Working Group:
http://www.first.gmd.de/applications/em.html
Decair Project home page:
http://www-air.inria.fr/decair/

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Events sponsored by ERCIM

ERCIM sponsors up to eleven conferences, workshops and summer schools per year. The funding is in the order of 2000 Euro. Conditions and an online application form are availalble at http://www.ercim.org/activity/sponsored.html. Upcoming events sponsored by ERCIM:

- **EUROGRAPHICS 2000,** ***Interlaken, Switzerland, 20-25 August 2000*** ***http://www.eg.org/eg2000/***
- **MFCS 2000 – 25th International Symposium on Mathematical Foundations of Computer Science** ***Bratislava, 28 August-1 September 2000*** ***http://www.mfcs.sk/***
- **4th European Conference on Research and Advanced Technology in Digital Libraries** ***Lisbon, 18-20 September 2000*** ***http://www.bn.pt/org/agenda/ecdl2000/***
- **QofIS'2000 – Quality of future Internet Services** ***Berlin, 25-26 September 2000*** ***http://www.fokus.gmd.de/events/qofis2000/***
- **FORTE/PSTV 2000 – Formal Description Techniques for Distributed Systems and Communication Protocols** ***Pisa, Italy, 10-13 October 2000*** ***http://forte-pstv-2000.cpr.it/***
- **Sofsem 2000 – Current Trends in Theory and Practice of Informatics** ***Prague, 25 November-2 December 2000*** ***http://www.sofsem.cz/***
- **International Joint Conference on Automated Reasoning – IJCAR** ***Siena, Italy, 18-23 June 2001;*** ***http://www.sofsem.cz/***
- **MFCS'2001 – 26th Symposium on Mathematical Foundations in Computer Science ,** ***Marianske Lazne, Czech Republic, 27-31 August 2001*** ***http://math.cas.cz/~mfcs2001/***

CALL FOR PARTICIPATION

SCI Summer School 2000

Trinity College Dublin, Ireland, 2-4 October 2000

The Scalable Coherent Interface (SCI) IEEE Std 1596-1992 is one of the enabling interconnect technologies for high performance computing. The SCI Summer School is an intensive 3-day event involving 50% tutorial and 50% laboratory sessions with a strong collegiate ethos. It is targeted at both newcomers to SCI as well as those experienced in the field, with the objective to increase both the breadth and depth of their working knowledge of SCI.

Programme:

- Base SCI Technology (Dolphin Interconnect Solutions)
- SCI Hardware Support Tools (SCILAB Technology & Trinity College Dublin)
- SCALI Technology (Scali)
- SMI & SCI-MPICH Software (RWTH-Aachen)
- SMiLE Shared Memory Programming (Technische Universität München)
- Embedded SCI Solutions (Dolphin Interconnect Solutions)

Further information:
SCI Summer School 2000 website:
http://www.cs.tcd.ie/Michael.Manzke/SCI_Summer_School_2000/sci_scho.htm

CALL FOR PAPERS

ECAL 2001 – 6th European Conference on Artificial Life

Prague, Czech Republic, 10-14 September 2001

Artificial Life is an interdisciplinary scientific and engineering enterprise aimed at understanding life-as-it-is and life-as-it-could- be, and at synthesizing life-like systems and phenomena on the basis of chemical, electronic, software, and other artificial media and situated in corresponding environments. ECAL as one among the leading periodical professional meetings encourages contributions on theoretical and experimental results and approaches in Artificial Life. Moreover, ECAL 2001 encourages also contributions on influences of biological and chemical phenomena to development of our general view of computers and computing.

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Milena Zeithamlová, Action M Agency, Prague, Jiři Iványek, Laboratory of Intelligent Systems, University of Economics, Prague, Jozef Kelemen, Institute of Computer Science, Silesian University, Opava, Roman Neruda, Institute of Computer Science, Academy of Sciences of the Czech Republic, Prague

Submissions and Proceedings
Proceedings of the ECAL 2001 will be published by Springer-Verlag as a volume of the LNCS/LNAI series. Submissions should be no longer than 10 pages in the Springer-Verlag LNCS/LNAI format with abstract of about 100 words. Style files (LaTeX and MS Word) and formatting instructions are awailable at the Springer-Verlag electronic address http://www.springer.de/comp/lncs/authors.html. Authors should make all possible efforts to state the relevance of their contribution to the field of Artificial Life and explain the implications of their results. Electronic (or paper in 3 copies) submissions shall be submitted to: Jozef Kelemen, ECAL 2001 PC Chair, Institute of Computer Science, Silesian University, Bezručovo nám. 13, 746 01 Opava, Czech Republic, E-mail: ecalprog@fpf.slu.cz

Workshops, Tutorials and Presentations
September 9-10 will be reserved for workshops and tutorials. During the conference, software and hardware presentations will be possible. For more information contact the PC Chair before 28 February 2001.

Important Dates
- Submission: 28 February 2001
- Notification on acceptance or rejection: 30 April 2001
- Camera ready copy (in electronic form): 31 May 2001

Further information
http://www.cs.cas.cz/ecal2001/
E-mail. actionm@cuni.cz

CALL FOR PAPERS

EMMCVPR 2001 – Third International Workshop on Energy Minimization Methods in Computer Vision and Pattern Recognition

Sophia Antipolis, France, 3-5 September 2001

Minimization problems and optimization methods permeate computer vision (CV), pattern recognition (PR), and many other fields of machine intelligence. This is because many approaches to CV&PR involve optimization tasks, and, at a more basic level, several problems can be cast as the minimization of some basic quantity (often called an energy).

Instances of (energy) minimization problems arise in Bayesian decision making, Markov random fields, relaxation labeling, neural networks, variational formulations, support vector machines, regularization, to mention only a few (not necessarily mutually exclusive) areas/frameworks of CV&PR, with roots in disciplines such as statistics, (statistical) physics, and psychophysics.

The aim of this workshop, which is the third of a series, is to bring together people with research interests in this interdisciplinary topic. Although the subject is traditionally well represented in major international conferences on CV&PR, this workshop provides a forum where researchers can report their recent work and engage in more informal discussions. As with the previous editions (1997 and 1999), the proceedings will be published by Springer Verlag in the Lecture Notes on Computer Science (LNCS) series. The submission instructions can be found in the web page of the workshop at http://red.lx.it.pt/~emmcvpr

The scientific program of EMMCVPR-2001 will include the presentation of invited talks and contributed research papers. The workshop, which is sponsored (approval is pending) by the International Association for Pattern Recognition (IAPR), will be organized by the Sophia-Antipolis research unit of INRIA.

Important Dates:
- Paper submission deadline: 3 February 2001
- Notification of acceptance: 30 April 2001
- Camera-ready paper due: 31 May 2001

Further information:
http://red.lx.it.pt/~emmcvpr

CALL FOR PARTICIPATION

Welcome to ACM SIGCOMM 2000!

ACM SIGCOMM 2000, the leading scientific conference in computer communications is held in Stockholm, 28 August - 1 September 2000.

ACM SIGCOMM 2000 is the annual conference of the Special Interest Group on Data Communication (SIGCOMM), a vital special interest group of the Association for Computing Machinery (ACM).

Further information:
http://www.acm.org/sigcomm/sigcomm2000/

CALL FOR PAPERS

SSSC'01 – 1st IFAC Symposium on System Structure and Control

Prague, 27-31 August 2001

The aim of the Symposium is to enable experts working on the system structure and control design to discuss new trends and ideas, establish fruitful contacts, and promote interactions between their fields of interest. The Symposium will consist of invited and contributed sessions, plenary talks, poster sessions, panel discussions, and Workshop on Max-plus Algebras and their applications to discrete-event systems, theoretical computer science, and optimization.

The history of the Symposium goes back to 1989 when the 1st IFAC Workshop on System Structure & Control was organised. It turned out that the idea of bringing the researchers interested in the system structural features and control was fruitful, and therefore the 2nd Workshop (Prague, 1992) and the 1st and 2nd IFAC Conference on System Structure & Control (Nantes, 1995 and 1998) followed. Recently this series of workshops and conferences has reached the status of regularly organised symposia sponsored by IFAC.

The Symposium is organised by the Institute of Information and Automation, Academy of Sciences, and the Faculty of Electrical Engineering, Czech Technical University in Prague.

Deadlines

- Submission of papers and sessions: 31 October 2000
- Notification of acceptance: 31 January 2001
- Receipt of papers in camera-ready form: 31 March 2001

Further information:
http://www.sssc01.cz/

CALL FOR PAPERS

6th ERCIM Workshop on 'User Interfaces for All' – Special Theme: 'Information Society for All'

Florence, Italy, 25-26 October 2000

The 6th ERCIM Workshop on 'User Interfaces for All' builds upon the results of the five previous Workshops held at Heraklion in 1995; Prague, Czech Republic in 1996; Obernai, France in 1997; Stockholm, Sweden in 1998; and Dagstuhl, Germany in 1999.

The vision of User Interfaces for All advocates the proactive realisation of the design for all principle in the field of Human-Computer Interaction, and involves the development of user interfaces to interactive applications and telematic services, which provide universal access and quality in use to potentially all users. This user population includes people with different cultural, educational, training and employment background, novice and experienced computer users, the very young and the elderly, and people with different types of disabilities, in various interaction contexts and scenarios of use.

The emphasis of this year's event is on "Information Society for All" and invites contributions on a broad range of topics, including technological, applications and policy developments aiming to advance the notion of an all-inclusive Information Society accessible and acceptable by the widest possible end user population.

Areas of Interest

Areas of interest, for which papers are solicited, include, but are not limited to, the following:

- adaptable and adaptive interaction, user modelling
- intelligent user interfaces, guided or co-operative interaction, intelligent agents
- Computer-Supported Collaborative Work
- multilinguality, internationalisation / localisation of interactive applications
- novel interaction techniques, multimedia/ multimodal interfaces
- virtual and augmented reality
- dialogue design methodologies and approaches
- interface design assistance tools
- interface architectures and development tools, interoperability
- formal methods and languages for interaction specification and verification
- ergonomics, human factors and usability issues
- evaluation techniques and tools
- sociological and economical issues
- novel approaches to information access and retrieval in large information spaces
- cognitive Factors in Design
- User-Centred Design
- interface metaphors
- intuitive, seamless interfaces
- interfaces to wearable and ubiquitous systems
- information visualisation
- support measures (eg standardisation) for user interfaces for all
- accessibility of information environments.

This year's special theme is 'Information Society for All', and a special session will be devoted to the issue of 'Universal Access in Healthcare Telematics'. In this context, areas of interest include, but are not limited to:

- organising healthcare collections for universal access
- reference models for universally accessible medical records
- advanced interaction techniques for Healthcare professionals
- Virtual Hospital
- personalisation and adaptation in Healthcare Telematics
- social aspects of universal access to medical records
- security, privacy and IPR
- universal access principles and the organisation of Regional Healthcare Networks.

Important Dates

- 11 September 2000: Deadline for electronic submission of all papers
- 2 October 2000: Conditional notification of acceptance (confirmation will be given upon registration)
- 9 October 2000: Deadline for registration
- 16 October 2000: Deadline for electronic submission of camera-ready papers.

Further information:
http://www.ics.forth.gr/proj/at-hci/UI4ALL/UI4ALL-2000/call.html

ERCIM NEWS

ERCIM News is the in-house magazine of ERCIM. Published quarterly, the newsletter reports on joint actions of the ercim partners, and aims to reflect the contribution made by ercim to the European Community in Information Technology. Through short articles and news items, it provides a forum for the exchange of information between the institutes and also with the wider scientific community. ERCIM News has a circulation of 7000 copies.

ERCIM News online edition is available at http://www.ercim.org/publication/ERCIM_News/

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CALL FOR PARTICIPATION

ESSIR'2000 – European Summer School in Information Retrieval

Varenna, Italy, 11-15 September 2000

ESSIR'2000 is the third European Summer School in Information Retrieval. The first one was organised by the University of Padova and was held in Bressanone in 1990. The second ESSIR was organised by the University of Glasgow in 1995. This third ESSIR is jointly organised by the University of Padova, the University of Strathclyde and CNR Milan.

The school will give participants a grounding in the core subjects of IR – architectures, algorithms, formal theoretical models of IR, and evaluation – as well as covering some of the current 'hot' topics such as digital libraries, retrieving from multimedia document collections, and retrieving over wide area networks such as the Internet and the Web.

The target audience of the Summer School are advanced undergraduate students, PhD students, postdocs and academic and industrial researchers and developers. The courses of the Summer School will be held from Monday to Friday and the programme will include plenary sessions, demonstrations and panels.

Grants

A small number of grants will be available thanks to CEPIS funding. Full-time students can apply for these grants on a competitive base. Grant recipients will not be required to pay registration fees and will receive a flat contribution to travel, accommodation and subsistence expenses. The conditions and amount of the grant will be available on the Web-site from mid June.

Further information:
ESSI'2000 website: http://www.itim.mi.cnr.it/Eventi/essir2000/index.htm

CALL FOR PAPERS

International Conference on Shape Modelling and Applications

Genova, Italy, 7-11 May 2001

Reasoning about shape is a common way of describing and representing objects in engineering, architecture, medicine, biology, physics and in daily life. Modelling shapes is part of both cognitive and creative processes and from the outset models of physical shapes have satisfied the desire to see the result of a project in advance. The programme will consist of two days of tutorials and three days of paper sessions. Special sessions will be organized on relevant topics. The Conference is organized by the Istituto per la Matematica Applicata of CNR in co-operation with ACM SIGGRAPH (pending) and EUROGRAPHICS.

It is expected that the Conference Proceedings will be published by IEEE Computer Society Press.

Topics

The conference will address all areas of shape modelling, including:
- Shape Modelling: Abstraction, Analysis and Transformation
- Computational Basis for Shape Modelling
- Topological Modelling of Shapes
- Shape Recognition
- Surface Modelling and Reconstruction
- Geometric Modelling
- Shape Rendering
- Volume and Multidimensional Modelling
- Interactive Shape Modelling

Important Dates

- Paper submission deadline: 15 October 2000
- Notification of acceptance: 15 December 2000
- Camera-ready paper due: 25 January 2001.

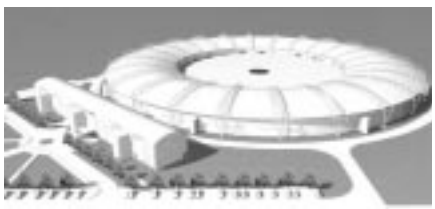
Further information:
Conference website:
http://SMI2001.ima.ge.cnr.it/

Ulf Lindqvist from VTT has been awarded with the Graphic Arts Developer's prize by the The Research Foundation of the Graphic Arts Industry.

Ulf Lindquist.

The prize is a recognition for his national and international research work as well as his major role as a developer of the research-industry interface. Ulf Lindqvist has been appointed research professor for media technology at VTT Information Technology from 1 June 2000.

The United Kingdom is replacing its pioneering synchrotron source, the SRS at CLRC Daresbury Laboratory with a brand new machine to be operational in 2006. Funded by the Wellcome Trust and the UK and French Governments the new synchrotron will serve an academic and industrial research community of several thousand researchers across a broad range of



An artist's impression of how the new synchrotron might look. The main ring will have a circumference of between 400 and 500 metres depending on the final specification and design.

scientific disciplines. A synchrotron is essentially an accelerator for electrons where strong magnets are used to guide the electrons around a circular path. As the electrons reach speeds close to the speed of light and have their direction changed, they emit a continuous spectrum of light of wavelengths from infrared to X-rays. This light is fed to experimental areas where researchers can select the range of wavelengths they need for a particular experiment. For example, X-rays are chosen to determine the complex structure of proteins, whilst ultraviolet light is used to study how these huge molecules fold. The SRS at CLRC Daresbury Laboratory was the World's first dedicated X-ray synchrotron source. The new machine will be a third generation instrument, specifically designed to use insertion devices.

SZTAKI established a new computer laboratory with 58 clustered processors, providing supercomputing power. The state-of-the-art, user-friendly graphical software environment (P-GRADE) for supercomputer programs have been developed by the Parallel and Distributed Systems Laboratory, headed by Péter Kacsuk. The new laboratory will serve as a training environment as well. The cluster will be available for our partners through internet and it it will provide access to other supercomputers and clusters.

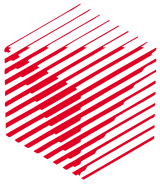
CNR-GMD Workshop – Within the context of the bilateral agreement for collaboration between CNR and GMD, a workshop was held on 9-10 March 2000 in Berlin. The aim of the annual CNR-GMD workshops has

Prof. Luca Simoncini (Director, CNR-CNUCE) and Prof. Piero Maestrini (Director, CNR-IEI) at the annual CNR-GMD Workshop in Berlin

been for participants to present and review the current progress of the joint projects underway between the two institutions and to discuss plans for future activities. The research areas currently involved include digital libraries, application of information technology in the cultural heritage sector, the development of systems to support mobile communications, and the implementation of sophisticated systems for various types of traffic control. New topics proposed for cooperation between the two institutions are model-based design of context-dependent applications, complex data reasoning, and formal test cases derivation for UML statechart diagrams specifications.

SZTAKI was recognised as a Centre-of-Excellence by the European Commission, Directorate General Research, - International co-operation, after our proposal had been favourably evaluated by the Commission services with the help of independent experts. Contract negotiations are in progress. SZTAKI wishes to thank all those partner institutions and colleagues within ERCIM, who helped to achieve this prestigious title. By using ERCIM NEWS, and our updated Web services, SZTAKI will regularly inform ERCIM members of all the promotional and dissemination activities that will reflect our work and help partners to join our activities.

GMD: Worldwide the first CAVE-like installation with olfactoric display. GMD's Virtual Environment Research Division extended it's software framework for virtual environments AVANGO by an olfactoric display, which was presented at Cebit 2000 in Hannover. The virtual presentation of a theme parc designed by the Austrian artist Andre Heller in co-operation with GMD, RMH and Vertigo Systems for the city of Bochum is presented as a full sensory experience, addressing the visual, the audible the tactile senses and the sense of smell. GMD has installed and tested this olfactory display in its cave-like installation called CyberStage in Birlinghoven, near Bonn, Germany. Scent controllers are used to create a new level of immersion. The scent systems allows ambient scents as well as scents bound to objects and events. The olfactory display is not polluting the virtual reality installation. All scents are almost completly gone after 20 seconds. The system is very promissing for virtual training in hazardous environments, for product design and evaluation, for education, arts and entertainment. GMD and its partners RMH and Vertigo Systems will exploit the olfactory display immediately in event based installations, so called Cyberstage productions.



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