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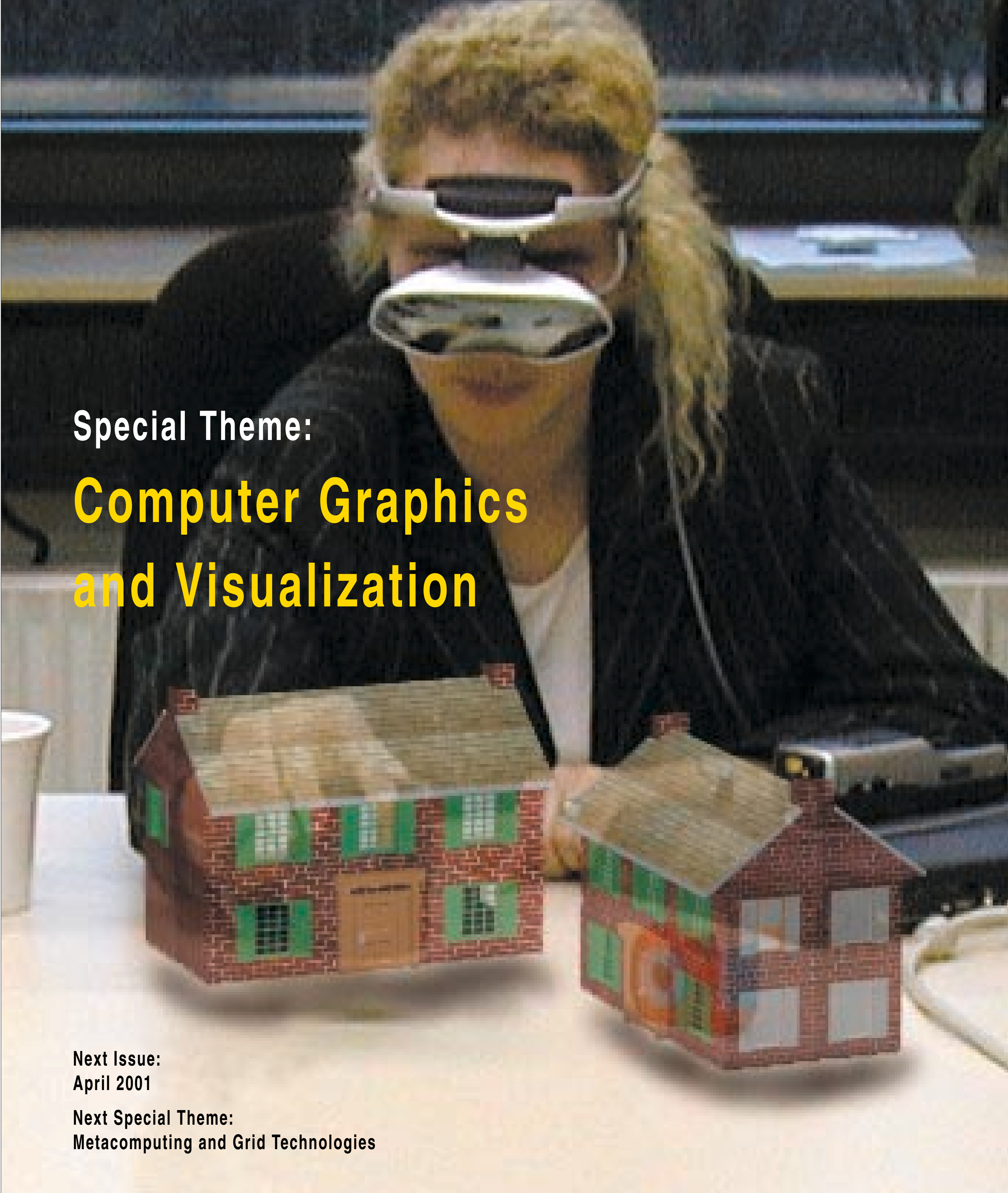

Special Theme:

Computer Graphics and Visualization

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April 2001

Next Special Theme:
Metacomputing and Grid Technologies

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Cover image: Round table scenario with virtual objects, see article on page 42

Elly Plooij-van Gorsel,
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European scientists should have access to national programmes in other member states. This is needed with a view to greater coherence in European research policy. Although no concrete target figures have been agreed, the political will to achieve this has been voiced by the ministers of research and technology policy in the member states, the European Commission and the European Parliament. But more is required for the transition to the knowledge economy to be successfully achieved.

At present, it cannot be said that a uniform European research policy exists. Research policy of the member states and of the Union are conducted alongside one another, without constituting a coherent whole. Apart from the fragmentation of efforts, isolation and compartmentalisation in national research systems, European member states invest significantly less in research than the United States and Japan. These two factors mean that the Union has simply come to lag further behind the United States in recent years.

As a result, the European research climate is declining rapidly. Research in Europe clearly needs a fresh boost.

If the European Union is to invest in greater competitiveness and employment, a broader and more innovative approach is required than has been the case to date. European member states should abandon their techno-nationalism and make greater efforts to achieve a European Union, at the research and technology level as well.

The forthcoming enlargement of the Union makes this all the more necessary. The Framework Programme for Research and Technology Development is a very useful instrument in fostering international collaboration, but is has been found that this programme alone is insufficient to improve the collective European research endeavours. More is required to actually arrive at a European internal market for research.

The move made by Euro-Commissioner Busquin to create a single European Research Area is something I very much welcome, speaking as rapporteur on the subject on behalf of the European Parliament. In the Guidelines for EU research activities (2000-2006), the Commission focuses primarily on optimising the infrastructure, by such means as linking up Centres of Excellence in a network and establishing virtual centres. ERCIM is a good example. But a European Research Area requires more than simple measures at the infrastructure level. Infrastructures do not innovate, nor do electronic networks, although they must be in place. A European research area can only come about if in addition to an advanced infrastructure there is also a European identity and a European creativity. That means that member states must come to see each other much more as partners rather than competitors. Opening up one another's national programmes is a step in the right direction.

But more is called for. Innovations have led to society changing from an industrial society into a knowledge society. It is clear that in future further development of this knowledge society lies in prospect. That requires ongoing investment in education, training, but also investment paving the way for scientific breakthroughs. The rapid technological progress in the ICT sector is a major catalyst in this respect.

Better coordination between the development of new technologies and applications in the market is called for. Europe does not have any problem in converting Euros into research; what is troublesome is converting research into Euros. Marketing, or adding knowledge to a product, appears to be more successful in the United States than in Europe. Increasing knowledge is not an objective in itself. Converting that knowledge into innovation and industrial success is what we need to aim at. This is what creates employment and prosperity. I would like to make my contribution from the European context and I am looking forward to any comments you may wish to make.

Elly Plooij-van Gorsel

Philippe Baptiste Winner of the 2000 Cor Baayen Award

The annual ERCIM Cor Baayen Award was presented to Philippe Baptiste during a ceremony in Dublin on 9 November 2000. The award is given every year to the most promising young researcher in computer science and applied mathematics having completed the PhD-thesis in one of the 'ERCIM countries'.

The winner of the award, Philippe Baptiste is today conducting research at the French National Center for Scientific Research (CNRS) located at the University of Technology of Compiègne, France.

Philippe is 28 years old and has received his PhD at the University of Technology of Compiègne in 1998 while he was working for the research department of Bouygues, a diversified industrial group leading activities in telecommunications, television, public utilities management, building/civil works, roads, etc. He has taken part into the development of optimization applications and of constraint programming libraries dedicated to the resolution of scheduling problems. Philippe has also been working on complexity theory. He has fixed the complexity status of several scheduling problems that had been opened for several years. His work has been published in several international journals and he's a member of the editorial board of the Journal of Scheduling. See also his article 'Combining Operations Research and Constraint Programming to Solve Real-Life Scheduling Problems' on page 53.

Philippe is also winner of the 2000 Prix Robert Faure, an award given every 3 years to a French speaking researcher under 35 by the French Operations Research Society.

Cor Baayen Award 2001

The Cor Baayen Award for the most promising researcher in computer science and applied mathematics was created in 1995 to honour the first ERCIM President. The Cor Baayen award is open to any young researcher having completed the PhD-thesis in one of the 'ERCIM countries', currently: Czech Republic, Finland, France, Germany, Greece, Hungary, Italy, Slovakia, Sweden, Switzerland, The Netherlands and the UK. The award consists of a cheque for 5000 Euro together with an award certificate. The selected fellow will be invited to the ERCIM meetings in autumn.

Rules for Nomination

Nominations for each country are made by the corresponding ERCIM Executive Committee member (also referred to as 'national contact'). Those who wish that a particular candidate be nominated should therefore contact the ERCIM Executive Committee member for their country (a list with all national contacts can be found at http://www.ercim.org/contacts/execom/).

Nominees must have carried out their work in one of the 'ERCIM countries'. On the date of the nomination, nominees must have been awarded their PhD (or equivalent) during the last two years.

Each ERCIM institute is allowed to nominate up to two persons from its country. A person can only be nominated once for the Cor Baayen Award. The selection of the Cor Baayen award is the responsibility of the ERCIM Executive Committee.

How to nominate

For proposing a nomination to your national contact, fill out the Cor Baayen Award Nomination Form available at the ERCIM website.

Deadlines

- 30 April 2001: nominations are to be received by the national contacts.
- 15 May 2001: national contacts to send their selected two nominations to the coordinator.

Further information can be obtained from your national contact or from the ERCIM Cor-Baayen Award coordinator Lubos Brim.

Links:
The ERCIM Cor Baayen Award:
http://www.ercim.org/activity/cor-baayen.html
National contacts:
http://www.ercim.org/contacts/execom/

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Co-ordinator fot the Cor-Baayen Award
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ERCIM President Gerard van Oortmerssen presents the 2000 ERCIM Cor Baayen award to Philippe Baptiste.

Strategic Workshops – Shaping future EU-NSF collaborations in Information Technologies

'Bionics', 'Future Information Processing Technologies' and 'Semantic Web' are three of five strategic emerging domains for a series of joint EU-NSF workshops. These three areas have been selected from over 350 different topics proposed by the European scientific community following the call for ideas for strategic workshops to be organized by ERCIM under the auspices of the European Commission and the US National Science Foundation.

The European Commission (programme IST-FET) and the US National Science Foundation (CISE-NSF division) will organize a series of strategic research workshops to identify key research challenges and opportunities in Information Technologies. On the European side, ERCIM solicited ideas for high-level workshops from the European IT scientific community. From the more than 350 suggestions, the Strategic Workshop Review Committee selected the following topics for joint future research initiatives:

- long-term/high risk nature of the research involved, justifying risk sharing at international level
- high potential payoffs both in the EU and the US that make up for the long-term/high risk nature of research
- existence of sufficient scientific and technological bases in both the US and the EU to entail balanced research efforts

ERCIM will organize a first series of workshops on the three selected topics in 2001. The respective programme committees will be nominated by the Strategic Workshop Review Committee. Participation is by invitation only, each workshop will be attended by a total of 20 participants from both Europe and the US.

The workshops are intended to facilitate brakethroughs in innovative domains, stimulate research activities and scientific discussions of mutual interest.

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

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INRIA is growing at an Unprecedented Pace and is starting a Recruiting Drive on a European Scale

Last July, the French government decided to allocate 425 extra positions to INRIA between now and 2003 as a means of bolstering the public research effort in information science and technology. INRIA will grow by more than 50% in three years — a unique opportunity to begin an ambitious policy and an unprecedented recruiting drive.

The Institute's strategy is based on the close combination of scientific achievement and technology transfer. In order to meet its objectives, the Institute intends to take up five major scientific challenges:

- mastering the digital infrastructure by knowing how to code, compute and communicate over the Internet and over heterogeneous networks
- designing new applications that make use of the Web and multimedia databases
- knowing how to produce reliable software
- designing and mastering automatic control for complex systems
- combining simulation and virtual reality.

Through these five challenges and in closely coordinated interaction with other scientific disciplines, INRIA will focus its efforts on some major fields of applications, primarily telecommunications, multimedia, health and biology.

As early as 2001, the staff will grow by 180 personnel while the Institute's funding will follow suit with an increase of 60 million francs or 9.17 million euros.

115 civil service positions will be open to French and foreign candidates: young scientists, senior researchers, engineers and technicians. There will also be between 50 and 60 one- to three-year contracts for recent graduates as well as academic or industrial experts. INRIA proposes also 200 opportunities: to prepare your PhD in one of its 100 research project teams or to make post-doctoral stays of 12 to 18 months in one of its 100 scientific teams to develop a research project.

The whole recruiting drive, job openings and the projected time line for the initiative are available on INRIA's website.

Further information:
http://www.inria.fr/

Graphics and Visualization: Breaking New Frontiers

by Carol O'Sullivan and Roberto Scopigno

From the early graphical applications such as flight simulators, to today's stunning special effects in movies, computer graphics have had a significant impact upon the way computers have been used to represent and visualize the world. There are many big problems left to be solved, some of which are reflected in the following pages of this issue.

The two core issues in the past in computer graphics and visualization, have been Modelling, ie capturing and representing the geometry and topology of virtual objects, and Rendering, which is the process of producing a realistic image from such models. Although amazing advances have been made in both these domains, research is still extremely active as the quest for true realism, and not just photorealism, continues. Increasingly, extremely large 3D datasets or models are required and the level of accuracy, and hence the complexity, of such models is growing dramatically. The article by Francois Sillion and Cyril Soler discusses a new application of the radiosity rendering technique which allows accurate simulations of very large plant models. Another reason for this explosion in model size is the improvement of the devices for the rapid acquisition of 3D digital models eg the non-invasive scanning devices widely used in medical imaging and in industrial inspection, or the optical 3D scanning devices which can be used to acquire the surface properties of real objects. The contribution by Holly Rushmeier describes ongoing research into 3D scanning systems at IBM Watson Research.

Visualization might also seem a rather consolidated field. Many techniques have been proposed in the last ten years for managing different data (surfaces, volumes, scattered points, vector fields, etc). Users have access to a wide range of visualization modalities which allow sophisticated and differentiated insights of the data to be obtained. Consequently, visualization is a crucial communication and analysis tool in the design and simulation of many new products or systems. In the field of medicine, visualization has the potential to radically change the way that health is administered, and significant progress has been made to date. Andreas Koenig and Eduard Groeller from the Technical University of Vienna have contributed an overview of their group's work in this important field. Even if visualization technology has reached a rather mature state, research in the field is still very active with the aim of: extending the potentialities of the visualization techniques, developing new approaches for interacting with and navigating the data, and improving efficiency. The search for more space- and time-efficient solutions is still a basic goal, because the impressive performance improvement of computing systems is counterbalanced by the increasing scale and complexity of the problems to be managed.

The advent of low-cost 3D graphics systems based on the PC architecture makes high-quality, real-time Interactive Graphics a ubiquitous and affordable resource. A powerful 3D graphics platform is now on the desk of anyone, from the scientist to the student. New games console hardware provides un-precented support for real-time animation and rendering at a relatively low cost, bringing cutting-edge 3D graphics into millions of homes around the world. Many of the advances in this area are based on the results of pioneering graphics research. A big challenge in the future, is to capture this technology, and to use it for other purposes, such as desktop VR for education, art and entertainment. For this to happen, real-time graphical systems need to achieve levels of realistic image synthesis only achieved in the past with very computationally expensive rendering techniques such as path-tracing and radiosity. The animation of objects needs to be based on physical models, and entities in the world should be endowed with behaviours so that they can interact convincingly with the user. The performance/cost ratio may have improved considerably, but such computational power is still not possible on low-end platforms. Therefore, techniques which use multiresolution models, and levels of detail for all aspects of simulation, are becoming increasingly important.

New frontiers for visualization and interactive 3D graphics are opened by the rise of Virtual Reality environments (CAVEs, workbenches, data walls) which can greatly enhance the way that users analyze data or objects, or navigate a virtual world. Large tiled displays will be available at a low cost in the near future, and applications requiring cooperative analysis of data or navigation could benefit from these devices. Augmented reality allows graphical images to be superimposed on a real scene, either by projecting them onto real objects such as walls, or by viewing such virtual object with see-through glasses. An exciting future development will be the incorporation of real people into a virtual world, as in the blue-c project described by Markus Gross and Oliver Staadt in this issue.

Europe is a primary player in the domain of Graphics and Visualization. This is proved by the many research projects active on these topics in European laboratories, and ERCIM institutions support many of these research initiatives. The contributions collected for this Special Issue give only a partial view of the many research projects active in this domain. Nevertheless, the spectrum of applications and topics covered by the contributions is notably wide: basic modelling techniques (classical techniques, level of detail techniques, 3D scanning), rendering techniques (texture-based graphics, image-based modelling of BRDF), classical animation and non-photorealistic rendering, physically-based simulation, virtual reality and haptic interfaces, augmented reality, 3D medical imaging, molecular modelling, information visualization, visualization for simulation and training, and more. It is clear that this will remain a significant area of activity for ERCIM institutes well into the future, and we hope that you gain as much enjoyment from reading about these vibrant and exciting research activities as we have while coordinating this special issue.

CONTENTS

3D Scanning for Computer Graphics

by Holly Rushmeier

Three dimensional scanning has recently become a very active area in computer graphics. The requirements for computer graphics are different from those of traditional scanning applications. At IBM Watson Research we are developing scanning systems for producing virtual objects that can be rendered with high visual quality.

The capture of 3D representations of objects has been an area of research for decades in computer vision, robotics and metrology. Traditional uses for digital objects include industrial inspection, autonomous robot navigation and object recognition. Each of these areas has different requirements and different approaches for data acquisition and processing. For inspection applications, metric accuracy is critical, and scanners with great precision have been developed. Autonomous navigation applications, such as the use of robots in hazardous environments, need to be very robust and justify the use of expensive scanning equipment. Object recognition may use both the shape and surface properties, but only to the extent they are needed to compute a unique signature for the object.

Unlike traditional applications, the end product of scanning for computer graphics is a model that can be used to render a realistic image of the object under novel conditions, ie in a location or under lighting conditions that exist only in computer simulation. The emphasis is on visual, rather than metric accuracy. A systematic error in the shape may be less important than errors in the color or apparent shininess of the object. This translates into a greater concern for estimating the spatial variation of the spectral bidirectional reflectance of a surface, and less concern for precision range measurements.

Applications for computer graphics rendering of scanned objects include virtual museums, e-commerce and games. In virtual museums, institutions can allow visitors to interact with virtual copies of objects that are physically too delicate to touch, or possibly even to keep on display. In e-commerce, a vendor may offer a potential consumer the capability to view an object in a variety of customized configurations. In games, scanned objects can be used to populate visually rich synthetic environments. These applications, while affecting a wide population, can only justify a modest expenditure on individual scanners, dictating the use of commodity components in their construction. Also, these applications require interactive display of the digital objects. This requirement dictates that the output of the scanning processing pipeline must be a form that can be rendered in real time.

Scanning Michelangelo's Florentine Pieta.

At IBM Watson Research, we have focused on the development of scanning systems that acquire surface properties as well as shape, use commodity digital cameras, and produce texture-mapped triangle meshes that can be efficiently rendered by graphics hardware. Our first system was built around a commercial shape scanner that used projected light stripes and multi-baseline stereo. We enhanced the scan with a novel photometric system that acquired surface normals and albedo at a spatial resolution 4 times the base geometry. We developed a processing pipeline for the acquired data that included new algorithms for meshing point clouds, for computing consistent normals from photometric data, and for the alignment and integration of surface texture maps.

Our first major project using our scanning system was creating a digital model of Michelangelo's Florentine Pieta`. The sculpture was scanned on site in the Museum of the Opera del Duomo in Florence. The resulting model was used by art historian Jack Wasserman to study issues such as how the work appeared after damage (now repaired) inflicted by the artist, and how it would have appeared in its originally intended site in a niche above the artists tomb.

Many European research groups are pursuing the development of inexpensive scanners for computer graphics. Cultural heritage is a leading application for many of these projects. For example, the Visual Computer Group at CNR Pisa, Italy, has developed a scanner based on a digital camera and video projector. They have recently used this scanner to capture a model of a bronze Minerva in Florence. The VISICS group at the Katholieke Universitat Leuven, Belgium has developed numerous capture techniques, including a method for generating texture-mapped models from uncalibrated video streams. This method was used in reconstructing the site of ancient Sagalassos in Turkey.

At IBM Research we are continuing to develop new scanning systems. We are exploring the use of alternative shape capture systems based on digital cameras. We are exploring the trade-offs between shape and texture resolution. We are also improving the processing pipeline to reduce user intervention to make scanning accessible to a wide range of consumers.

Links:
IBM Visual and Geometric Computing group:
http://www.research.ibm.com/vgc

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Subdivision Surfaces in Geometric Modelling

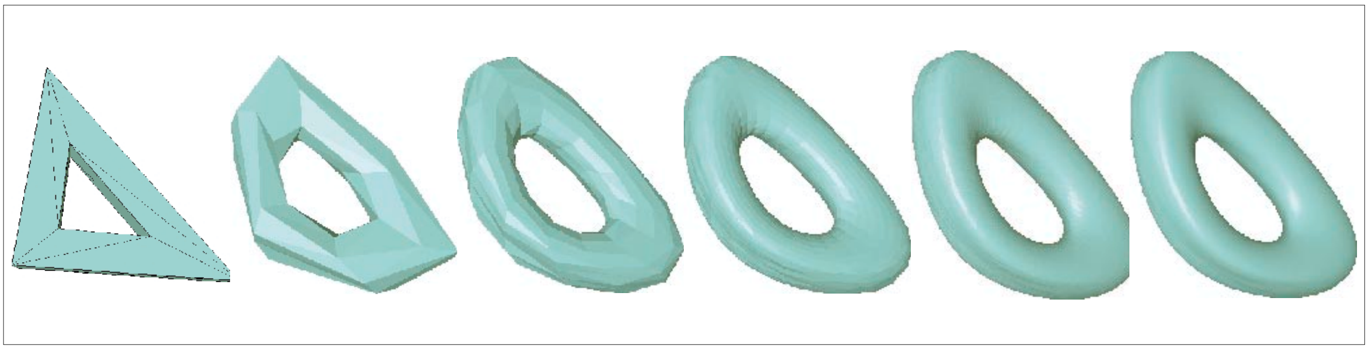
by Pavel Chalmoviansky

Scientists at Comenius University, Bratislava, are developing techniques for efficient and robust manipulation of the geometric properties of shapes, a task that has been particularly problematic in the past.

Construction using subdivision surfaces is a technique in geometric modelling which combines both computational simplicity and ease of control. Although there are some unsolved problems, this appears to be a growing trend in recent years. After the era of mainly parametric, implicit and functional modelling, there is now a method which offers more flexible (than in the case of implicit surfaces) and more intuitive (than in the case of integral or rational surfaces) control and modelling of the final shape. Moreover, the final surface can be easily represented as a multiresolution model.

The first subdivision method was developed more than 20 years ago, but the method achieved more popularity only in the 90's. During these years the mathematical foundations were laid and several problems (eg of continuity and parameterisation) were solved. However, success was only achieved with static subdivision methods.

The principle is to refine the structure of the surface representation up to a state with which we are content. We start with cell complex K(0) and function p(0) on the vertices of K(0). The refinement or subdivision has two phases: We construct K(i+1) from K(i) and p(i+1) from p(i). The rules are usually local and simple, hence the new complex and the new function can be easily computed. In the figure below, the whole process of the subdivision can be seen. Usually several iterations are enough for high accurate results.



Subdivision process.

There are several known schemes of this type published by Loop, Catmull-Clark, Doo-Sabin, Kobbelt and others. All of them work on an almost regular cell complex with triangular or quadrilateral faces. Final surfaces can interpolate the values of p(i) at vertices and one can also mark special edges which play the role of boundaries during the construction and thus other rules are applied upon them. There are also so-called combined schemes which take special care at the boundaries of the surface. The schemes produce surfaces of lower degree (if they are polynomials) and lower order of continuity. This is however not enough for some applications and further schemes are sought.

The main open problems are to be found when we consider the manipulation of these objects. As the number of cells increases exponentially, it would not be possible to maintain a high number of objects at their full representation. Adaptive methods represent objects using several layers. The more layers one displays, the more details one can see. The cell that will be cancelled in a layer can be computed according to variational calculus. More efficient methods are still required. Modelling inside CAD systems in this area produces more problems: during the intersection of two surfaces we create objects that are not primarily products of the subdivision scheme. The solution for this situation should be compatible with the whole modelling system. Mainly in CAD systems, high order continuity surfaces are required. The known methods suffer from huge numbers of vertices involved in the computation of the next iteration.

A wide range of unsolved questions arise if we consider also irregular cell complexes. The set of solutions is very sparse here. Subdivision surfaces were also used in real applications. In 1997 the first animation using only subdivision surfaces was made by Pixar - Geri's Game, and Toy Story II also used them.

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A System for Out-of-Core Simplification of Huge Meshes

by Paolo Cignoni and Roberto Scopigno

Recent evolution in graphics technology has been impressive, and the management of very complex models is now possible on inexpensive platforms. We present the results of a project aimed at the design and implementation of a library for the out-of-core management of huge 3D meshes. One of the main goals is to support high quality simplification of huge meshes.

The performance of graphics subsystems has improved enormously in the last couple of years, but unfortunately the complexity of 3D scenes and graphics applications has also increased greatly. A very critical aspect in interactive 3D graphics is the complexity, in terms of number of triangles, of the meshes to be managed. Huge meshes can be easily produced in many applications: by fitting isosurfaces on large volume datasets, by converting surfaces into triangulated meshes, by 3D scanning real objects. All 3D scanners perform a regular sampling on the surface of an object, returning triangle meshes of complexity directly proportional to the scanner's sampling resolution and the object surface area. For example, the size of the S. Matthew 3D model, recently produced by the Digital Michelangelo Project, is around 370M triangles. Obviously, these complex meshes introduce severe overheads in transmission, rendering, processing and storage. Mesh simplification and level-of-detail (LOD) management can in many cases efficiently reduce these overheads but only very large and costly systems can manage meshes characterized by such a huge size: RAM size is often a severe bottleneck.

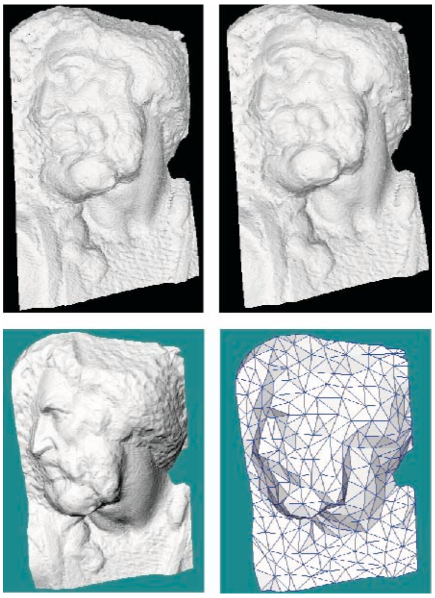

Figure 1: An image from the simplified digital S. Matthew mesh: a portion of the high resolution mesh is top-left (4M triangles), a simplified intermediate LOD is top-right (48K tr.); a drastically simplified mesh (500 tr.) is shown bottom-right, with shape detail preserved by a resampled texture in bottom-left image.

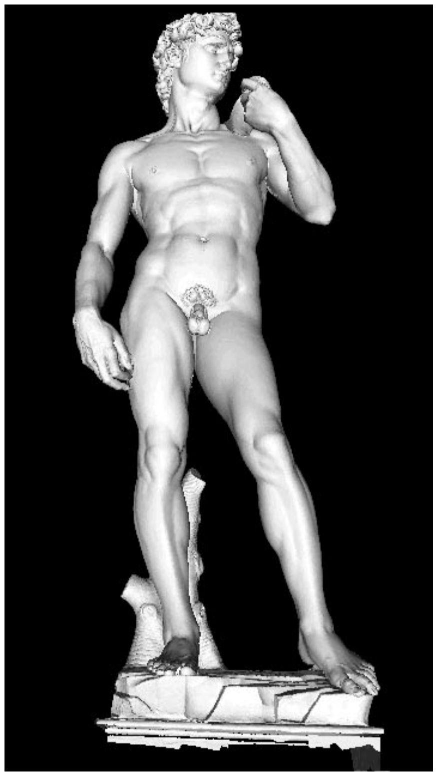

Figure 2: Images from a simplified digital David mesh (only 215 K triangles).

The management of complex geometric datasets is a very active research area. A number of sophisticated technologies have been developed to simplify the geometry while maintaining accuracy and preserving any attributes contained (eg colour or pictorial data), and to use LOD techniques to speedup rendering.

We have recently studied a problem which arises while 3D scanning large artefacts: how can simplification technology be extended to manage datasets that do not fit the main memory of most computers? Our aim is to design an Out Of Core (OOC) mesh simplifier. Here below we describe the architecture of a new OOC simplifier, which adopts a simplification approach based on edge collapse.

Management and Simplification of Huge Meshes

We briefly introduce a system which supports huge mesh management (including mesh editing, visualization, simplification and detail preservation) on PC-based platforms. The system uses a innovative hierarchical data structure, called Octree-based External Memory Mesh (OEMM), to maintain the data on external memory, to load only selected sections dynamically in main memory, and to preserve data consistency during local updates.

Our goal has been the management of really huge meshes on a PC-based platform with limited memory. No existing systems support this functionality. The hierarchical OEMM data structure is at the base of our mesh management and simplification system. The OEMM structure supports dynamic 'on request' loading of portions of the current dataset from secondary memory, for the browsing or updating of geometrical and topological information. This data structure can be constructed starting from a generic raw triangle-based mesh representation. The following modules can be built on the top of this data structure:

- a mesh editing library that allows the user to perform simple editing actions (such as 3D scanning and rapid prototyping). These include topological check of the mesh, detection of non-manifold components, detection of

holes and automatic or user assisted hole-triangulation, elimination on request of complex vertices and faces, elimination on request of small components, etc
- a mesh simplification library, which performs out-of-core simplification adopting the quadric error metric approach (see Figures 1 and 2)
- a detail preserving library, which resamples bump- or rgb-texture to encode the high frequency detail lost during simplification (see Figure 2)
- a visualization module and GUI components

Our system supports management and simplification of up to O (10^9) triangles meshes. The time overhead due to the external memory management is affordable.

The only other approach which supports out-of-core simplification of huge meshes is the out-of-core clustering solution recently proposed by Lindstrom at Siggraph 2000. This solution is very easy to implement but, unfortunately, it has the drawbacks of the clustering approach: the simplified mesh quality is much lower than the quality of simplified meshes produced with the edge collapse approach, simplification is not adaptive to surface shape and many topological degenerated situations are introduced. We have compared the results produced by OOC Clustering and our OEMM edge collapse simplifier on the same dataset (the David mesh of the Digital Michelangelo Project) and the improvement of shape accuracy supported by our solution was significant.

This project has been developed with the financial support of the Progetto Finalizzato 'Beni Culturali' of the Italian National Research Council and the Project 'RIS+' of the Tuscany Regional Government. Scanned data are courtesy of the Digital Michelangelo Project, Stanford University (USA).

Links:
Visual Computing Group CNR-PISA:
http://vcg.iei.pi.cnr.it

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A Graphical System for Internal Density Modelling by Coons Bodies

by Silvester Czanner and Roman Durikovic

The rise of solid modelling as a principal medium for mechanical product description can be traced to the requirement of informational completeness of geometric representations. Unfortunately, traditional geometry-based systems do not contain the important information neededfor some engineering designs. Many unambiguous solid representation techniques like primitive instancing, cell decomposition, constructive solid geometry have one limitation, they cannot offer ways of representing internal behavior.

In the mechanical industry it is very important to know not only the description of the surface, but also about the interior and the density of the object. Therefore, there was a need for a system which makes it possible to model the interior density of the 3D parameter solids.

A Project between the Software Department of the University of Aizu and the Department of Computer Graphics and Image processing of the Comenius University exists to support and develop a new methodology for representing an internal structure of density of 3D objects. The main goal of the project is to develop a graphical system for modelling and visualizing the interior structures and density of 3D objects. It allows a developer to make modifications into internal structure of 3D object in a natural and intuitive way.

The system can also modify and composite 3D objects (basic elements) to an arbitrary 3D shape. The elements used are so called parametric solids. We are using three types of parametric solids, namely Coons body 0, 1 and 2. The bodies are defined as an extension into four-dimensional space of well-known Coons patches in B-splines form.

Each of the three Coons bodies have different abilities to control the interior structure. The simplest and most limited is Coons body 0 where only the shape of quadrilateral can be changed. Coons body 1 allows the user to control the interior by modification the control points along the edge curves of a parametric solid. The most general is the Coons body 2, having the ability to modify shape and interior by all control points within the boundary surfaces of a parametric solid.

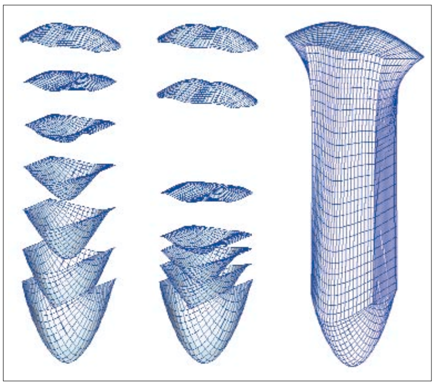

Figure 1: Nail as Coons body 2 with two different interior density distributions applied as initial conditions for two FEM simulations of internal tension.

To understand the interior structure of 3D objects several visualization methods are used. The easiest way to visualize a parametric solid is to display it as a set of isoparametric surfaces. Another option is to visualize a shaded object together with projected parametric curves corresponding to constants u, v and w. The most difficult option is to show the interior changes in time as metamorphoses between two Coons bodies.

The most useful elements are Coons bodies 2. Since, any of them is a B-spline

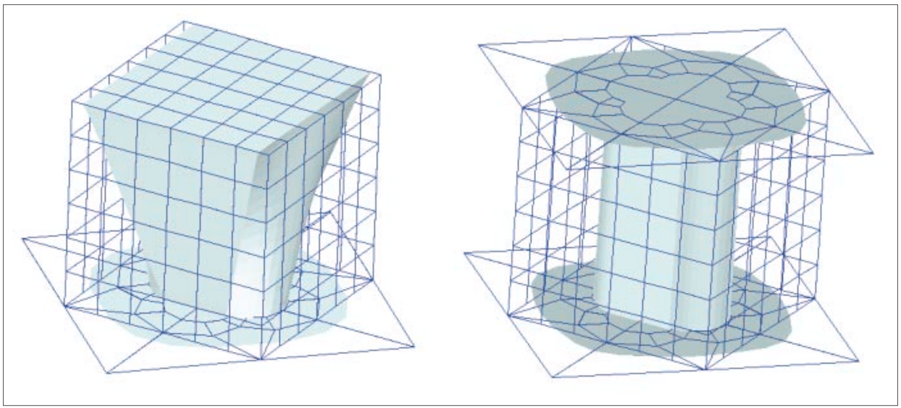

Figure 2: Modelling a spool as Coons body 2 starting from a cube.

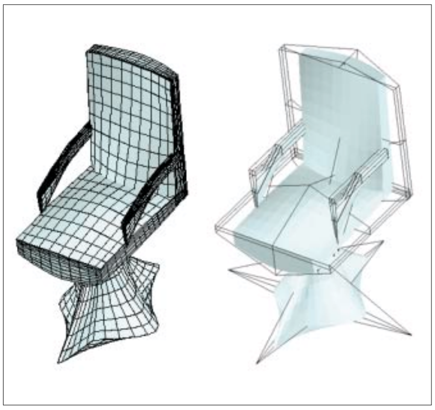

Figure 3: Shape represented with five Coons bodies 2..

volume, the shape continuity is simply controlled in a similar way as it is for B-splines. The system can create more complicated shapes such as a composition of several Coons body elements.

Implementation is done under the Linux Red Hat 6.2 operating system and the objects are stored in a scientific format SILO.

The authors see the advantage of this graphical system in the ability to define the boundary and internal initial conditions prior to numerical simulations. Parametric solids can be effectively applied on finite elements with irregular or trimmed boundaries to avoid difficult problems in model design for Fine Elements Methods.

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Multiresolution Modelling of Surface and Volume Data

by Leila De Floriani, Paola Magillo and Enrico Puppo

Multiresolution models have become very popular during the last few years to manage the increasing complexity of surface and volume data visualization. This topic is the subject of several research projects carried out by the geometric modelling and computer graphics group at the Department of Computer and Information Sciences of the University of Genova. Major applications concern terrain modelling in the context of Geographical Information Systems, 3D object modelling, and volume visualization.

The resolution of a geometric model is related to the number of primitives used to represent the details of a shape. Resolution has an impact both on the accuracy of the representation (thus, on the similarity of the model to the real object) and on the size of the data structures (thus, on computational efficiency).

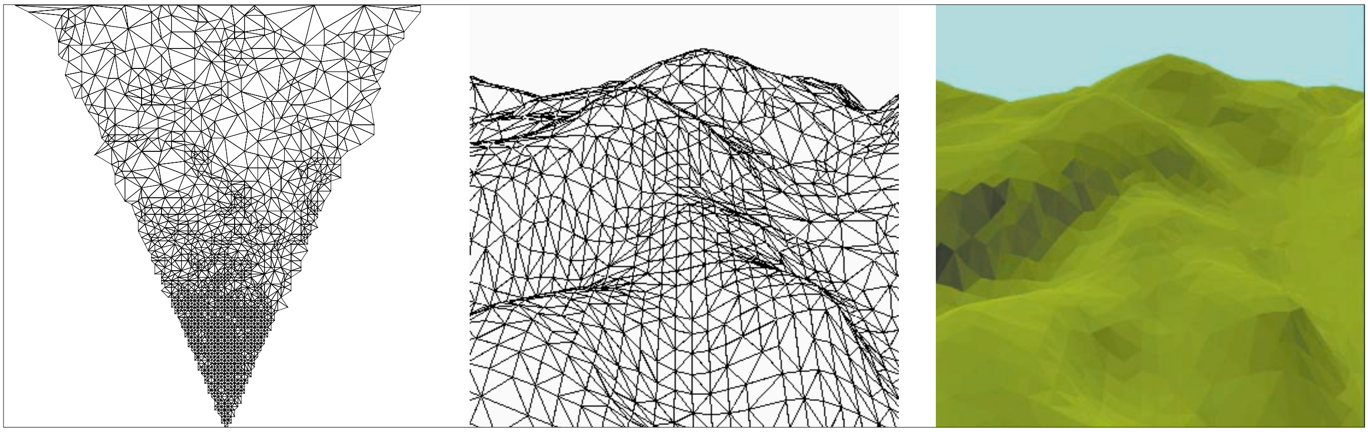
Modern tools both for acquisition of geometry from real world, and for computer-aided design, can provide models at very high resolution. These models are very accurate but often too large to be effectively used in rendering, especially at an interactive rate. Multiresolution refers to the possibility of representing a spatial object at different resolutions, trying to balance the opposing issues of having sufficient accuracy and small size.

The key idea is that usually high resolution is not needed everywhere; the level of resolution can be variable in space and time. For instance, a three-dimensional scene can be rendered using a resolution which is higher near the viewpoint, since many details are required only close to the observer; in an interactive visualization program with a moving viewpoint, the resolution should be adapted dynamically.

Variable resolution is crucial, eg, for real-time visualization in virtual reality (aircrafts, ships, buildings...), scientific data visualization (three-dimensional fields such as temperature, pressure...), geographic information systems (terrain), medicine (volume data from TAC, SPECT...).

Since the production of a model at a specified (variable) resolution is computationally expensive, a multiresolution model is built off-line as a comprehensive structure which organises several pre-computed resolutions and supports a fast on-line combination of different resolutions into a single model, according to user parameters.

The DISI research group has developed the Multi-Tesselation (MT) model, a general multiresolution model for spatial data that does not depend on:
- the dimension of the data (it can model surfaces in space, solid objects, volume data, scalar fields in any dimension...)
- the process used to generate the resolutions that contribute to the model



Using a variable resolution in the view frustum for terrain rendering allows high quality images with reduced computational effort. Here, resolution (ie size of triangles) decreases with distance from the viewpoint (see top view), while the size of projected triangles is constant through the whole image (see perspective view).

(unlike many other models which must be built only with a certain algorithm)
- the criteria used to extract representations at variable resolution from the MT (the user can constrain either the granularity or the accuracy on a local basis by providing reference entities such as areas of interest, viewpoints...).

The MT model can be specialised for specific types of data, construction processes and/or operations, leading to very efficient implementations in those specific cases.

We have recently released a software library implementing the MT model (see http://www.disi.unige.it/person/MagilloP/MT/), which is intended as a general tool for supporting variable resolution in geometric applications.

MT has been used as a basis for: VARIANT, a prototype system for terrain modelling, which supports variable resolution; and TAn2, a system for scientific visualization developed in collaboration with the Visual Computing Group at CNR in Pisa (Italy), which can render huge three-dimensional data sets thanks to a multiresolution approach.

Links:
Geometric Modelling and Computer Graphics group, University of Genova:
http://www.disi.unige.it/research/Geometric_modeling/

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New CAD Tools for Aesthetic Design

by Chiara Catalano, Bianca Falcidieno, Franca Giannini, Maria Meirana and Marina Monti

The definition of tools to support design intent representation and management during product development is a key issue for new CAD systems. In the context of product styling development, the design intent is represented by the shape of the resulting product and can be schematized by the defining character curves and by the behavior of the reflection of light over the surface. In order to provide tools for the direct manipulation of the shape through character curves, in the FIORES project the form feature concept has been extended to the aesthetic design domain. Algorithms for surface modification through target shadow line specification have also been implemented.

In a competitive world wide market, where product life time is being reduced, quality and cost are not necessarily the only important key elements for success: the aesthetic aspect is also becoming fundamental in customers' decisions. Furthermore, the availability of new materials and production tools makes the fabrication of very complex shapes possible, thus permitting a greater freedom in design.

Computer-aided tools have been developed to support styling, providing high quality rendering and animation facilities for the purposes of simulation and evaluation, thus reducing the number of physical prototypes and cutting design costs.

Unfortunately, current CAD/CAS systems do not support the fast generation of alternative shapes starting from existing models. It is sometimes very difficult to change a small detail and can cost more than re-creating the entire model.This is due to the fact that the modelling activity is based on low level geometric elements (eg NURBS/B-Splines control points and nodes) completely unrelated to the design intent of the stylist.

In order to overcome these limitations, new modelling tools are being developed. The Brite-Euram Project FIORES (Formalization and Integration of an Optimized Reverse Engineering Styling Workflow) focused on this problem. The two main aspects regarding styling considered by the project are identification of free form features for

Figure 1: An example of a car having very evident character lines.

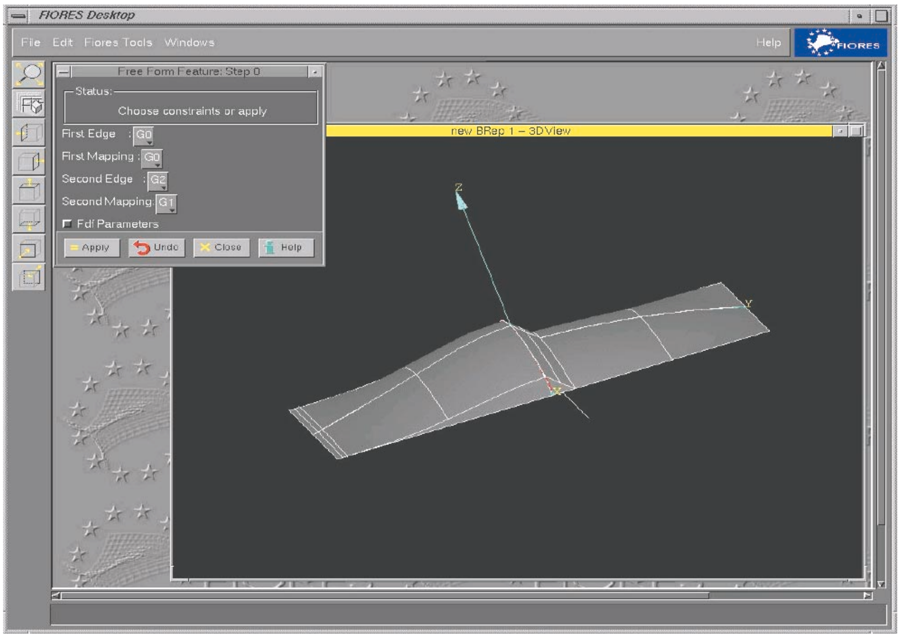

Figure 2: A snapshot of the step-like feature implemented in the FIORES prototype system by Dassault Systemes and University of Kaiserslautern.

shape modification, and engineering in reverse techniques for surface refinement.

Free Form Features

Feature technology is employed to speed up the model creation process and permit the reuse of existing models. Features are well known and common in mechanical design and their application to styling has required an analysis of the various elements characterizing the product shape.

We have identified two relevant categories of form features:

- Structural features, consisting of key lines for the overall shape definition. Examples of structural features are contours, object profiles and sections, or structural character lines having an overall aesthetic impact.
- Detail features, consisting of local shapes added to the object surface for aesthetic and functional reasons and to enhance the visual effects of character lines.

We have mainly focused on detail features and have proposed a formal definition of feature types on the basis of detail features obtained by modifying a given free form surface locally.

This classification is based on the topological and morphological characteristics associated with the deformation functions used to create the features. Two main classes of features have been identified: those corresponding to elastic deformations and those regarding elimination of surface regions. A feature taxonomy has been specified on the basis of these two classes. It is aimed at allowing the identification of a useful set of intuitive parameters (possibly with aesthetic value) and conditions, which can be hard-coded, to define meaningful deformation with predictable behavior. A feature class has been implemented to demonstrate the feasibility of this approach.

Engineering in Reverse

This approach aims at shortening the frustrating loop reiterating surface modification and aesthetic evaluation of the product model. Many industrial products, such as cars, are evaluated in terms of certain evaluation lines that give the expert designer an idea of the aesthetic quality of the object. These lines range from section curves and reflection lines to special curvature lines. The designer then modifies the object surfaces to make the derived evaluation lines look good.

With the engineering in reverse (EiR) approach adopted by FIORES and implemented by Matra Datavision together with UDK Utveckling and Formtech, the modification loop can be avoided: the designer can directly specify a preferable target evaluation line, and insert additional constraints (such as the modifiable area). The system will return a surface with the given evaluation line. An optimization approach is used to compute the best solution, ie the solution that according to a given criterion is as close as possible to the desired target.

Links:
FIORES web page: http://www.fiores.com

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Figure 3: A surface with ‘bad’ highlights.

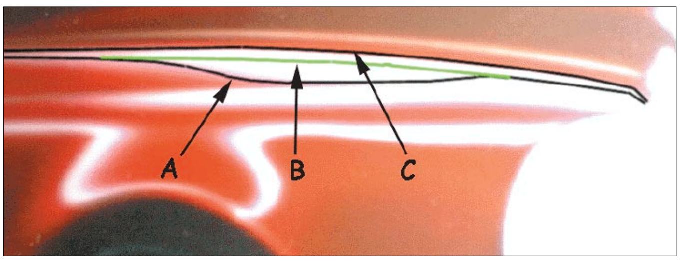


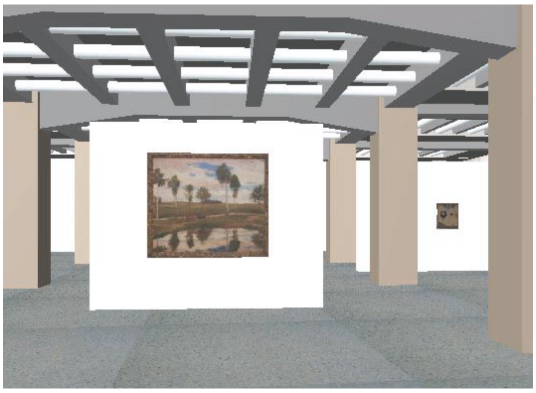
Figure 4: Specification of the target highlight (B) for correcting the wrong one (A) and the one (C) resulting from the application of the engineering in reverse method.

Image-Based Acquisition of Virtual Gallery Model

by Michal Haindl and Pavel Slavík

The purpose of this Virtual Reality project was to build a virtual gallery model from real image data measurements utilising results from the VIRTUOUS project. The resulted virtual model of the Department of Modern Art of the National Gallery in Prague is intended to serve as the core of the web based National Gallery information system.

Customary manual creation of virtual reality models of real world scenes is tedious and error-prone work as the scene complexity increases and any automation can substantially reduce the laboriousness and consequently the cost of the whole process. Visual sensors offer the ideal source of data for such a task especially when range and vision sensors are already common and their mutual registration can be done using either standard photogrammetric techniques or an appropriate sensor setup.



Part of the exhibition in the Department of Modern Art.

To make virtual worlds realistic detailed scene models must be built. Satisfactory models require not only complex 3D shapes accorded with the captured scene, but also lifelike colour and texture. Textures provide useful cues to a subject navigating in such a VR environment, and they also aid in the accurate detailed reconstruction of the environment. This increases significantly the realism of the synthetic generated scene.

Our pilot system for the virtual model acquisition currently restricted to planar-faced scene objects was used to build the gallery model. The core part of this VR modelling system is a fast range image segmentation algorithm for planar-faced scene objects. The Department of Modern Art, housing a collection of images, drawings and statues from the period of 20th century, is located in a functionalistic building in Prague, where the planar-faced object restriction is quite acceptable. The segmentor combines a discontinuity detection step and the subsequent line based region growing guided by these detected discontinuities. Range segmentation results subsequently supervise the following - geometry inference and texture analysis steps.

The gallery model is composed from mutually connected partial submodels (halls, corridors, etc.) containing mostly planar-faced objects. However although even if a single planar face is correctly found, its corresponding range pixels values are too noisy to be of direct use for the face model construction. Such a model would have many small noise-generated faces which have to be eliminated. Noise filtering is done through the least-square fitting of a plane to a detected face perimeter pixels and only the rectified face pixels are subsequently used for a virtual model face geometry inference.

Thematic maps from the range segmentor serve also as the region maps for the registered colour textured images. If a detected face has sufficient area for a reliable texture model inference then this model is inferred from the corresponding projected colour textured image area, otherwise the face is classified as too small for individual texturing and the texture model can be assigned interactively if required. Textures are modelled using our fast multi-grid Markov random field based model and combined with model geometry information.

Resulting gallery model is quite complex hence it has to be completed with a virtual environment navigation system. Otherwise its user can be easily lost in the labyrinth of gallery virtual corridors. Our solution to this problem is an automatic path generation that defines a trajectory of the virtual walk through. The path parameters (entry and exit points, obstacle avoidance - eg, usage of a staircase for handicapped visitors, etc.) are defined by the user. The process of the path finding is in principle finding a path in a underlying graph describing the virtual scene and constrained by requested art works to be seen on the way.

The virtual model of the Department of Modern Art of the National Gallery in Prague was semi-automatically created in the VRML2 language so it can be easily placed on the web server with sufficient resources. The model recently describes interior public exhibition areas of the gallery building together with the exhibition panels holding paintings from the gallery art collection and can be used not only as the visitors virtual information system but also for gallery workers to model optimal show arrangement for exhibitions to be prepared. Although recent technology advances already enables automatic or at least semi-automatic construction of distributed virtual models, further research is still needed especially in the area of general surface object modelling. Similarly the VRML2 language has many functional restrictions and some better distributed virtual reality modelling language is clearly required.

Links:
VIRTUOUS project:
http://www.ee.surrey.ac.uk/EE/VSSP/3DVision/virtuous/virtuous.html
National Gallery demo:
http://www.utia.cas.cz/user_data/haindl/PR/demHP.html

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Computation of Medial Surfaces

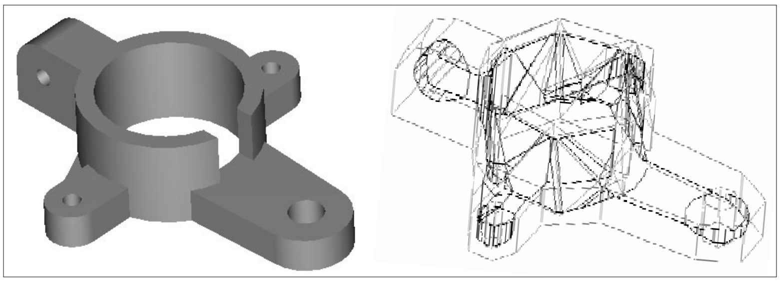
by Gábor Renner

Medial surfaces as skeletons of three-dimensional objects are geometric abstractions of solids, that facilitate volumetric and shape reasoning in many areas of engineering computations. In the Geometric Modelling Laboratory of SZTAKI fast and robust methods have been developed to calculate the medial surfaces of solids starting from their boundary representation.

The medial surface or medial axis transform is a skeleton of a three dimensional object, which is defined as the locus of the centres of the interior spheres with maximal radius. Together with the radius of the maximal spheres as a scalar function it reflects the topological and geometrical features of an object in a very compact form. Moreover this representation is unique for each 'valid' (ie manifold) solid object. It can be invertible, and the object can be reconstructed from the skeleton.

The boundary representation of a solid - which is used in commercial CAD/CAM systems - builds up a complete topological structure of the object, defining the connectivity relationships between the faces, edges and vertices. These are associated with corresponding geometric entities describing their shape. While many practical engineering tasks can be solved using this mechanism, there are important questions which can only be answered using very cumbersome and time-consuming procedures. Such topics are, eg to recover proximity relations of some parts of the object or to obtain an overall view of the object. Based on the skeleton these questions can be answered easily, and a number of geometric operations (eg proximity calculations, shape decomposition) can be performed very efficiently. This is the reason why skeletons can be used in many engineering applications with a great benefit. Such areas are for example NC process planning, design of robot trajectories, recognition and creation of geometric features, subdivision of a solid into simpler parts for example for automatic finite element mesh generation.

In spite of the above advantages of medial surfaces, there is no commercial CAD/CAM or geometric modelling system, which is based on the skeletons or at least supports the calculation of them. This is mainly due to the computational complexity inherent in medial surface computations based on the usual boundary representation of real three-dimensional objects. As a consequence, to develop a robust, efficient and at the same time user friendly algorithm is very important. A realistic simplification of the starting geometric model or the skeleton to be computed – or both – is generally needed in order to overcome the tremendous amount of computation and to obtain results with acceptable computational costs.



Part and medial surface.

In our research we concentrate on the medial surface computation of faceted objects. This means that curved faces of the object are approximated by planar facets and curved edges by several straight lines. This kind of approximation can easily be generated automatically in many solid modelers. We have developed an algorithm, which is based on the dual structure of the skeleton, and determines the spatial location of the vertices of the skeleton, together with their topological connections. One of our main improvements is the increase of speed and robustness of geometric calculations.

To compute the vertex positions of the skeleton, a highly nonlinear system of equations must generally be solved. For the numerical solution of the system a general nonlinear solver may be used, which proves to be a slow and unstable process. We have carefully analysed the system of equations from analytic and geometric points of view. It can be concluded that in a great majority of geometric situations a solution can be computed with analytic tools. In the remaining cases, specific geometric situations (that occur frequently with technical objects) can be detected, where again analytic solution is possible. Thus the use of a nonlinear system solver can considerably be reduced which results in fast and stable computations.

To illustrate the efficiency of the above case analysis a part with the corresponding medial surface is shown on the figure. The object was approximated by 94 facets, and the total number of skeleton vertex calculations was 121925, out of which only 305 (0.25%) required nonlinear system solving.

The speed and stability of medial surface calculations can be greatly increased by special topological considerations. Our research concentrated on the elimination of redundant calculations by analysing the structure of the object in a preprocessing step (by applying multiple start-points), and the development of a new algorithm to reduce the size of the problem by subdivision (divide-and-conquer algorithm).

Development of programs and methods is continuing in collaboration with the Ecole Polytechnique Fédérale in Lausanne, Switzerland.

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A Low-cost Optical 3D Scanner

by Claudio Rocchini and Roberto Scopigno

Automatic 3D acquisition devices (often called 3D scanners) can be employed to build highly accurate models of real 3D objects in a cost- and time-effective manner. The Visual Computing Group of CNUCE/IEI-CNR has experimented this technology in a particular application context: the acquisition of Cultural Heritage artefacts. Specific needs of this domain include: high accuracy, affordable costs of the scanning device and an improved usability of the data produced. We present the characteristics of a new low-cost 3D scanner, based on structured light, and discuss the first results of its use in a project for the 3D acquisition of a bronze statue.

Cultural Heritage is one of the few fields where classical 3D modelling tools result inadequate to model the shape of the objects or artefacts of interest. This is both due to the shape complexity of most artefacts (eg sculptures) and also to the high accuracy requested. The 3D model in many cases should not only look visually similar to the real object, but should also be very accurate, from a geometrical point of view. This is necessary for many applications such as the construction of 3D catalogues, the automatic reproduction of copies, the use of 3D models in the context of restoration plans, etc.

3D scanners can give a very precise reconstruction of the shape of a real object. This technology has been adopted in a number of recent cultural heritage projects. We can cite the Digital Michelangelo Project of Stanford University, the acquisition of Michelangelo's Pietà in Florence by the IBM T.J. Watson Laboratory, or the acquisition of a section of the Coliseum in Rome by an Italian research team.

3D scanning technology has evolved in the last few years, but unfortunately not as fast as other electronic devices. One critical problem is the high cost of the scanning devices. A good scanner, able to produce data at the accuracy required by this class of applications, often costs more than 100K US$. This discourages the use of this technology in many Cultural Heritage institutions, especially in our national context.

We have thus studied the design of low cost and medium quality optical scanners. The result is the design and prototypal construction of a new scanner based on consumer electronic technology. The architecture and features are described briefly here.

An Inexpensive 3D Scanner

Our scanner has been designed to fulfil the following goals:

- use only consumer technology, to ensure affordable hardware costs and enable easy technological improvements
- support sufficient accuracy and resolution, ie midway between commercial low cost laser scanners and high quality ones
- ensure easy operability and flexibility.

The scanner has been designed around two very common electronic devices:

- a video projector (preferably DLP technology), to project structured light patterns on the object to be scanned
- a digital still camera, to acquire images of the object under structured lighting.

Both devices are driven by a software module running on a standard PC. This acquisition module produces a series of patterns (stripes with decreasing width, projected by the video projector) and drives the camera. Photos are taken to acquire: images of the distorted patterns (from which the geometry is reconstructed, producing a range map), and images of the object under different

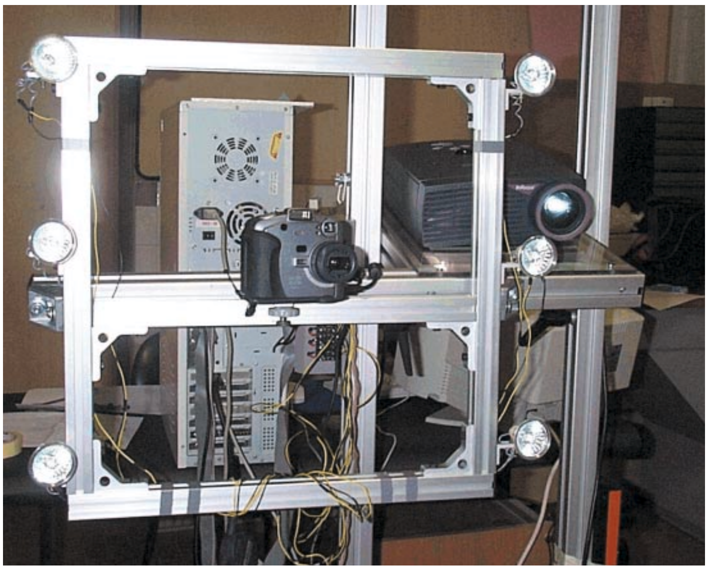

Figure 1: The low cost scanner developed at CNR, which uses structured light and consumer electronic technology.

Figure 2: A preliminary reconstruction of the head of the Minerva.

illumination conditions (from which the illumination-invariant color, or 'albedo', of the object surface is reconstructed). The color images by definition are self-recorded with range maps.

The scanning system depicted in Figure 1 produces:

- a range map of each selected surface portion, with sample density of 0.7mm (using a 1024x768 video projector, located at approximately 1.3 m from the artefact)
- an illumination-invariant colour texture (aligned with the corresponding range map) which represents the pictorial detail present on the acquired surface section.

As usual in 3D scanning, complex objects are modelled via the acquisition of a set of partially overlapping range scans. Our proprietary software is used to register and merge all the range maps in a single triangulated mesh.

The scanner is currently in use at the Soprintendenza Archeologica Toscana, in the restoration of the Minerva, a bronze statue of the Museo Archeologico of Florence. The entire statue was scanned in October 2000, producing 146 range maps and around 3000 images. We are currently processing this data, and a complete model will be ready at the end of 2000. Preliminary results are shown in Figure 2.

This project has been developed in cooperation with the Centro di Restauro (Restoration Laboratory) of the Soprintendenza Archeologica Toscana in Florence, and with the financial support of the Progetto Finalizzato 'Beni Culturali' of the Italian National Research Council and the Project 'RIS+' of the Tuscany Regional Government.

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Shape Modelling and Processing: Methods and Applications

by Bianca Falcidieno and Michela Spagnuolo

Shape modelling is both a cognitive and creative process and reasoning about shape is a common way of describing and representing objects in engineering, architecture, medicine, biology, as well as in daily life. Computers have revolutionised the field of shape modelling and opened up new applications, such as Computer Aided Design, Computer Graphics and Computer Vision. The Computer Graphics Group at the Istituto per la Matematica Applicata (IMA-CNR), Genoa, has been working on different aspects of shape-based modelling since 1980. The focus of the research has been on the definition of abstraction tools for deriving high-level descriptions of complex shape models.

A key objective in research on shape-based modelling is to enhance traditional approaches to surface modelling through the definition of representations that are closer to our semantic coding of shape perception. Surface reconstruction techniques can be used to faithfully reproduce complex shape models of existing or virtual objects, which may be thought of as 'digital mock-ups' to be visualized or analyzed using appropriate software. If, on the one hand, geometric representations are necessary for their approximation function, on the other, it is desirable to communicate with the model using higher-level abstractions, directly connected with specific properties of the shape. For example, when describing a landscape in words we would use terms such as 'mountainous', or expressions such as 'many ridges and ravines'. It is thus clearly not important to communicate the number and the shape of the polygons that compose the digital model and its features, when we use abstraction and/or classification tools to group low-level geometric entities into classes with an associated meaning (conceptual model).

IMA-CNR is working in a number of projects using shape-based reasoning for shape representation and processing. Reverse engineering is a good example of an interesting application field for our approach. Digitizing machines usually

Figure 1: A digitized object with the structural features recognized.

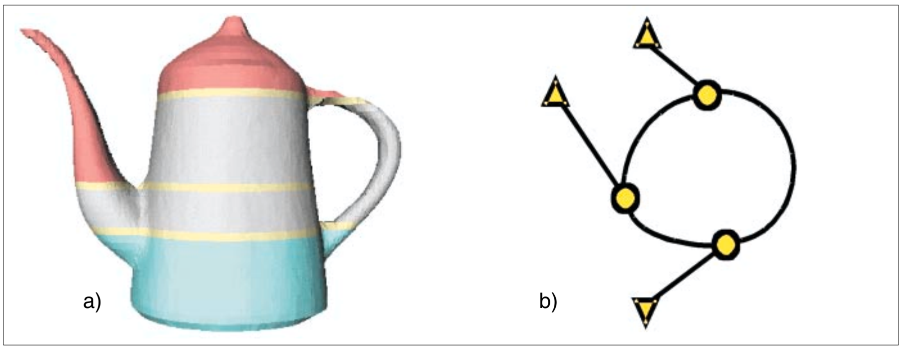

Figure 2: An object with the colour-coded characterization of its critical levels (a) and the corresponding shape graph (b).

perform sampling along predefined directions, sections or profiles, which induce at least a partial ordering in the data set. Shape-based techniques are especially efficient in this context since structural features of the underlying surface can be easily detected by analysing the configuration of points along the sampling directions. Reconstruction can thus be performed a posteriori with respect to the recognition of a rough shape skeleton. This is shown in Figure 1, where the approximating triangulation is fitted to the recognized structural features. IMA has also signed an important research contract with Monolith Ltd, Tokyo, within the framework of a programme funded by private and public Japanese research organizations, for the development of a terrain modelling system based on the topological and semantic structure of natural surfaces.

Our main current research efforts are in the field of computational topology, incorporating abstraction mechanisms in shape modelling. To properly represent shape information, automatic mechanisms must be developed to associate properties (eg meaning) with geometric data within the object description. To do this, properties, or shape features, are identified in order to describe objects effectively,

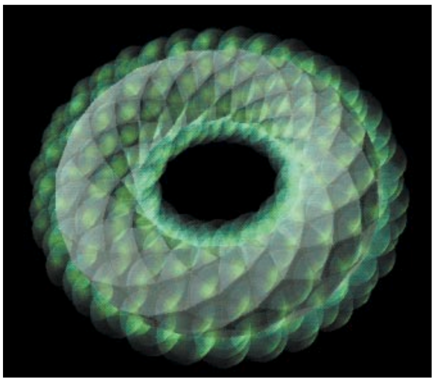

Figure 3: An object defined by uncertain sample points.

and these properties must be defined formally so that they can be easily associated with a geometric representation.

Understood mathematically, topology is the study of shape properties that do not change under deformation; it provides a sound theoretical basis for the formalisation of a number of problems related to shape and its understanding. For example, we are currently investigating the use of a critical point configuration graph, automatically extracted from a triangulated object model, to define a sketch of the shape suitable for classification and compression purposes (see Figure 2). Another technique studied and developed at IMA concerns the extraction of morphologic features from surfaces represented by cross sections. Cross sections implicitly contain information about features like ridges, ravines, peaks, etc., which can be automatically recognized in order to improve the accuracy of the reconstructed model.

Finally, we are also studying the use of digital object models for the visualization and coding of uncertain information. Different forms of uncertainty and errors can be introduced during the modelling pipeline as data are acquired, modelled and visualized. Different approaches for coding uncertainty have been considered, eg intervals, probability distribution functions and fuzzy numbers. Graphical primitives, such as cubes and spheres, can be used to visualize sets of spatial measures affected by uncertainty, while animation and other visualization techniques such as transparency, can effectively represent the surface at various levels of presumption (see Figure 3).

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Reverse Engineering Shapes

by Tamás Várady

In many areas of engineering, medical sciences or art there is a strong demand to create an appropriate computer representation of existing objects from huge sets of measured data points. This process is called reverse engineering of shapes. While this topic has been an important topic in computer vision, due to the advances in laser scanning, now it has become a realistic expectation in the geometric modelling community to generate accurate and topologically consistent models, ready to be used in CAD/CAM. Recent research results of the Geometric Modelling Laboratory at SZTAKI are reviewed within the framework of the whole reverse engineering process.

In conventional computer aided design the computer representation of objects are created by means of commands typically using an interactive design program with 3D graphics. This representation is used for further design, analysis and optionally for numerically controlled manufacturing. While conventional engineering transforms engineering concepts and models into real parts, in reverse engineering real parts are transformed into such computer models which are suitable to exploit all advantages of modern CAD/CAM technologies and transfer real objects into virtual reality environments.

Typical applications include reproducing and redesigning parts, when no original drawings or documentation are available. In areas where aesthetic design is particularly important - such as in the automobile industry - real-scale wood or clay models are often needed, because stylists prefer to evaluate real 3D objects rather than 2D screen images at reduced scale. Another important area of application is to generate custom fits to human surfaces, for mating parts such as helmets, or prostheses.

The Geometric Modelling Laboratory at SZTAKI, Budapest has been conducting reverse engineering research since 1995. This activity has been supported by various grants including an EU COPERNICUS grant (RECCAD) and several smaller ones by the Hungarian Scientific Research Fund (OTKA). Research has been focused to develop fundamental techniques to process and create accurate geometric models and also to exploit the theoretical results in various applications. (See the web pages of GML and its spin-off company Cadmus Ltd. at http://www.cadmus.hu.) The process of reverse engineering is decomposed into the following steps: data capture, preprocessing measured data, merging multiple point clouds, creating the topology of the object by forming a triangular mesh, simplifying meshes, segmenting point clouds, fitting surfaces, building boundary representation models, adding blending surfaces and finally 'beautifying' models. Maybe the most crucial part is the segmentation of the point cloud: subsets of points need to be separated from each other according to their fundamental geometric or functional properties. Once we have this information, we can fit surfaces to the individual point sets, but without this or with incorrect segmentation the final result is likely to be wrong. For example, if we have a subset of points with rotational symmetry, but we fail to separate all corresponding data points and include wrong points, the 'best fit' rotational surface may be distorted. If we detect only a shrunk subset of the rotational portion, our estimate will not be too accurate.

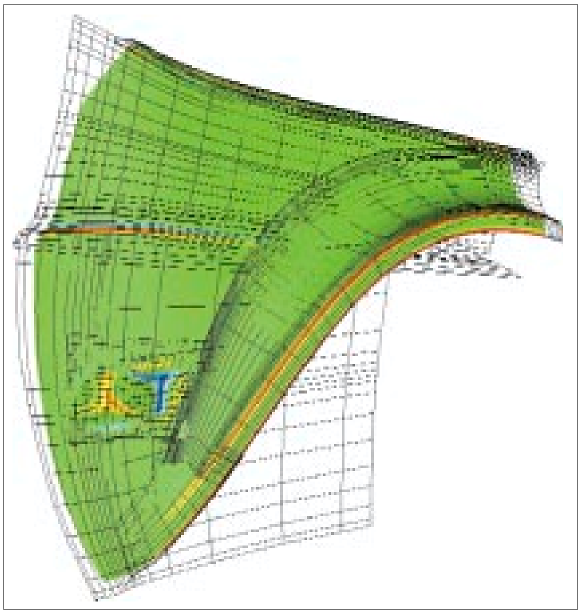

Figure 1: Car body panel - surfaces reconstructed.

This problem is even more difficult for free-form surfaces, where there are unknown smooth edges between the individual surface elements, which need to be separated. A new paradigm called 'functional decomposition' helps in these situations. A free-form object is assumed to be bounded by relatively large primary surfaces plus connecting surface elements called feature surfaces, such as blends or steps. In the reconstruction procedure first we create primary surfaces over topologically irregular regions with several holes, and enforce smoothness to assure fair shapes and natural extensions outside the given point regions. Then we fit feature surfaces, which are constrained to be smoothly connected to the primary surfaces. In this way, based on partial point information, we can get complete CAD models having the likely original surface components by means of which the object might have been originally constructed (see Figure 1).

For conventional mechanical engineering objects a different approach - 'direct segmentation' has been developed. In this context, conventional means bounded by simple analytic surfaces, swept surfaces and blends. These objects have many faces, which typically intersect each other, but the surface elements are much simpler from geometric point of view. Linear extrusions and surfaces of revolutions are particularly important here, and need to be detected and accurately reconstructed based on their 'regularity '. Having this limited, but very important class of surface elements, it is possible to perform segmentation without user interaction. This is illustrated in Figure 2, where different colors has been assigned to segmented point sets. In Figure 3, the corresponding reconstructed CAD model is shown. Note, that smoothness between neighboring surface elements is assured, once their likely smoothness has been detected. For example, rotational symmetry was detected for the left part of the object, consequently the reconstructed torus and cylinder pieces will be joined smoothly in strict mathematical sense. Engineering constraints, such as parallelism, perpendicularity, concentricity and others can also be recognized thus the final model will satisfy these as well.

The diversity of reverse engineering problems has provided and still provides many interesting research topics for the Geometric Modelling Laboratory. By now this technology has reached an advanced level, and it is being directly exploited in various CAD environments. Our current partners are from the automotive and medical industries.

Figure 2: Benchmark part - point cloud segmented.

Figure 3: Benchmark part - reconstructed CAD model.

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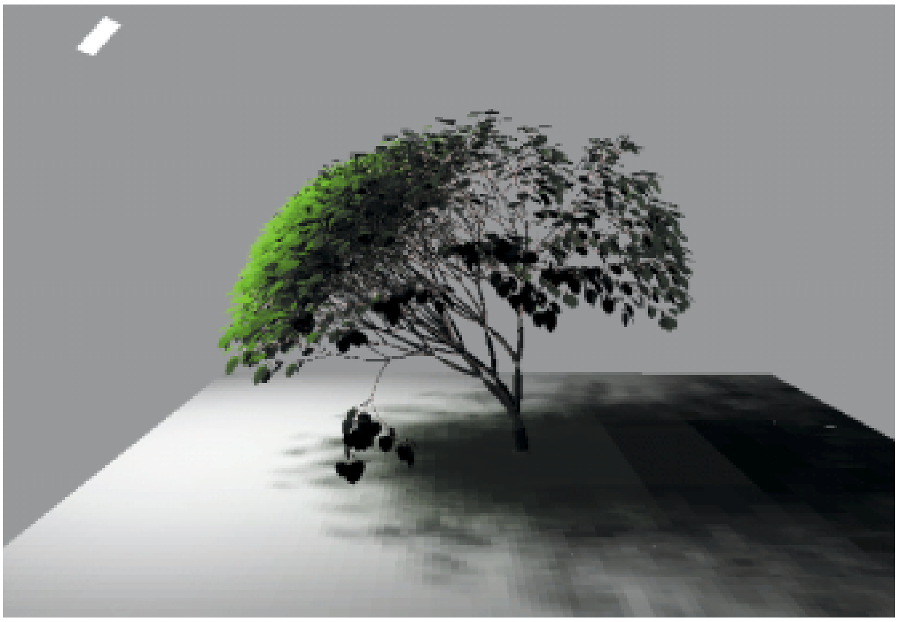
SOLEIL – Application of the Radiosity Method to the Physiological Simulation of Plant Growth

by François Sillion and Cyril Soler

The goal of the SOLEIL project is to simulate the ecophysiological processes in plants and to interactively compute their growth and productivity depending on external conditions, especially the presence of light. The lighting simulation in the plant models is performed by a new technique based on a combination of hierarchical radiosity and instanciation. This combination allows to perform accurate simulations in very large models, which was not possible before.

SOLEIL is a cooperative research project between INRIA, LIAMA - the French-Chinese Laboratory of Computer Graphics and Applied Mathematics, and CIRAD - the International Research Center for Agronomy and Development. The work carried out in the project can have major impact on at least two different fields: as it is simulates the physiological behaviour of plants, based on calibrated models of growth, it will permit to study the influence of environmental conditions on plant growth for various agronomic applications. it is also of interest for virtual reality systems, because the very realistic plant models it creates can be incorporated into any virtual reality systems such as architecture design programs or video games.



This virtual plant illustrates the action of lighting conditions onto the shape and size of the simulated models. The non uniform allocation of vegetal matter into the plant model is an indirect consequence of the non uniform repartition of light energy in the plant during its growth. As a result the simulated plant reacts as would a real plant: it tends to grow in the direction of the light source and has denser foliage in regions that receive more light.

The physiological simulation of plant growth consists in growing virtual models of plants from the biological laws that rule plant internal functionality. A physiological simulator thus accounts for hydraulics inside the plant structure, mechanics that is responsible for the shape of the plant, and the amount of light received by the leaves. While the photosynthesis activity of each leaf indeed strongly depends on the local illumination, all previous plant growth models did not compute an accurate estimation of this quantity because of the extensive computation cost traditionally associated with lighting simulations that accounts for diffusion and shadowing inside the foliage. We have derived a new algorithm capable of performing efficient yet accurate lighting simulations in plants consisting of millions of polygons.

The method is based on the concept of instanciation, adapted to the traditional hierarchical radiosity methods for computing global illumination. Instanciation consists in replacing parts of the plant geometry that share common geometric or radiometric properties by references to shared objects during the simulation. Thanks to the high degree of self similarity in common vegetation models, this results in important savings in memory consumption. Using this tool, we can simulate the effects of light on plant growth like self-shadowing or heliotropism and thus create models of plants that can react to their environment. One other important impact of our work is the possibility to study ecological factors on entire plantations, for example in order to optimize the distribution of plants in a field so that they do not shadow each other. The applications of the research project are important and numerous in at least two domains: image synthesis and agronomy.

Building realistic models of plants is a difficult task since traditional digitization methods (3D-scanners, 3D sampling) and modelling tools (CAGD or CAO) can not be used to produce valuable plant models even having a small number of leaves. The only reliable methods are to grow plants using either morphogenetic approaches (L-system, Fractals, ...) or physiologically based approaches. Our plant growing approach belongs to the second category and thus produces realistic models of plants, that naturally react to their environment as real plants do. Such realistic plant models are very important in the judgment of realism in synthetic images. They can be used in virtual reality systems as well as in architectural modelers or landscape design software, and even video games.

Since we not only simulate the shape of plants but their complete biological behaviour, direct applications of our simulation model also concern agronomy. Small scale or local simulation can help understanding the reactivity of plants to various external conditions such as lighting, water supply or even pruning. Large scale simulations allow to virtually explore the different possibilities for optimizing plantations in regions where resources are scarce, for instance cultures in the tropical forests. Finally, virtual plant models can also be used to replace costly or unpracticable experiments on real plant canopies, which is the case for deriving global models of canopy reflectance and in many remote sensing applications.

Among direct commercial applications, we are planning to integrate the environment sensitivity of plants into the commercial version of the CIRAD plant growth simulator, called AMAP. This software is already used by designers of various application fields for integrating realistic plant models into their own scenes. It also provides plug-ins for modelization/animation software such as SoftImage™ and Maya™. Thanks to the results we obtained on simulating these different kind of interactions, and especially concerning lighting simulation, we will soon be able to bridge the gap between these plants and a complete virtual garden.

Links:
SOLEIL projcet:
http://www-imagis.imag.fr/SOLEIL/
AMAP Plant growth simulator:
http://www.cirad.fr/produits/amap/amapen.html

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Image-Based Rendering for Industrial Applications

by Samuel Boivin and André Gagalowicz

Several techniques have been recently developed for the geometric and photometric reconstruction of indoor scenes. The MIRAGES team at INRIA-Rocquencourt designed a new analysis/synthesis method that can recover the reflectances of all surfaces in a scene, including anisotropic ones, using only one single image taken with a standard camera and a geometric model of the scene.

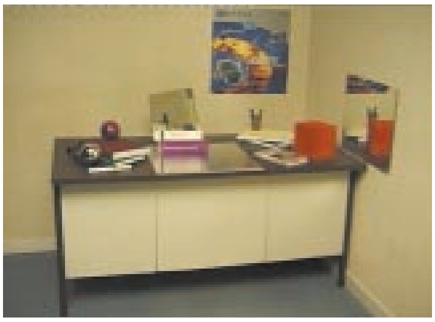

Figure 1: Real image captured with a camera.

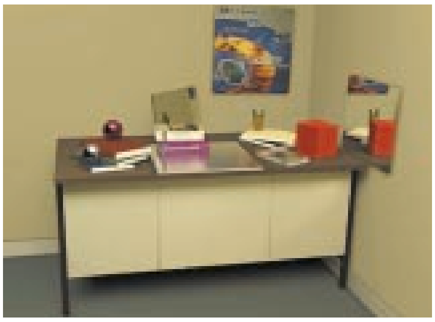

Figure 2: Synthetic image generated using our technique.

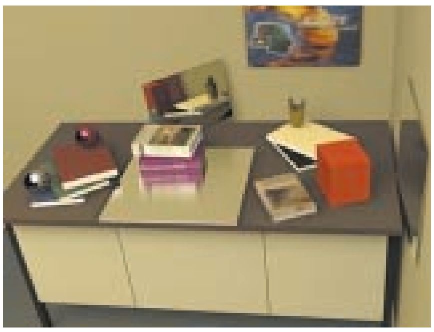

Figure 3: An application example of our technique in augmented reality: the observer's position has been modified.

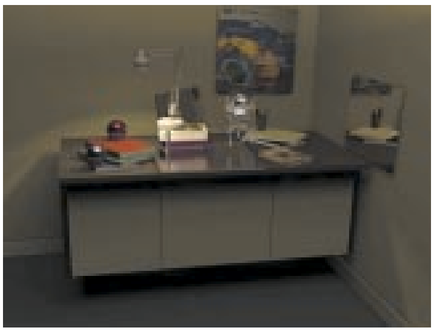

Figure 4: An application example of our technique in augmented reality: some synthetic objects have been added and the light sources positions have been modified. A new light source has been added on the desk to generate different illumination conditions. The legs of the desk have been cut.

The first step of the technique developed by MIRAGES is to capture a single photograph of the scene that we want to reconstruct. The second step is to position the 3D model (including the light sources), that can be built manually using the real image, thanks to a classical modeler such as Maya (Alias|Wavefront). Once the parameters of the camera (position, orientation, ...) have been automatically recovered, our image-based rendering software may recover a full BRDF (Bi-directional Reflectance Distribution Function) of all the objects in the scene. Starting with a first assumption about the reflectances of these surfaces, we generate a computer graphics image using an advanced photorealistic rendering software, called Phoenix, developed by our team. Phoenix is a global illumination renderer that can produce photorealistic images in a very short time (faster than current radiosity software). Phoenix takes advantage from the internal architecture of the computer, to greatly accelerate the process of image generation.

The first image created by Phoenix using the initial hypothesis about the reflectances of the objects, is directly compared to the real one applying a difference or a more complex operation. This error image is then used to correct the estimated reflectances until the result synthetic image becomes as close as possible from the real one. Our image-based rendering technique is iterative because it iteratively corrects the BRDF of the 3D surfaces, and it is hierarchical because it proceeds with more and more complex assumptions about the photometry of the objects inside the scene. If a particular reflectance property has been tried for a surface, and if it produces an image that still has important errors on all the surface area, this reflectance is automatically forced to be a more complex one (perfect specular or isotropic for example). Using these new assumptions, it is now possible to create a new synthetic image that will be again compared to the real image, to assess if the error between these two images decreased. If the error for an object is smaller than a user-defined threshold, then it is confirmed that its photometry has been correctly simulated and it does not need to have a more complex BRDF. Moreover, when there are high optical and thermal interactions between two objects (suppose for example that a book is lying on an aluminium sheet and that this book is reflecting on this sheet), our technique uses several complex algorithms to estimate the reflectances of these two objects, because they simultaneously interact on one another. This is a very complex procedure that can require several minutes of computation time, depending on the complexity of the BRDF of the surface: the most complicated case that we treat is anisotropic surfaces on which highly textured objects are reflected.

We show some results in this presentation, including a real image (figure 1) and the full (photometrically and geometrically) reconstructed synthetic image (figure 2). The mirrors and the aluminium sheet are simulated respectively as real mirrors and real complex BRDF surfaces: they are not simulated as textured objects which is the case of most of the techniques developed today. In other words, with one single image we know how to reconstruct mirrors, isotropic and anisotropic surfaces. This procedure possesses the ability, on one hand, to analyse through the mirror some objects that were not directly seen in the real image, and on the other hand, allows several industrial applications. The first application is called Augmented Reality and it is very used for special in movies in cinema and postproduction applications. Figure 3 presents an example of this application, with a modification of the viewpoint position, while figure 4 shows the same scene containing added synthetic objects under novel illumination conditions. A lot of other direct applications are possible, especially in high rate compression of video sequences (with no visible loss). Our technique can also be applied to automatic positioning of mirrors and light sources, advanced reflectance analysis of surfaces, etc.

As a conclusion, we have presented a new image-based rendering technique that is very fast and that recovers the BRDF (for diffuse, specular, isotropic, anisotropic and textured objects) of all surfaces inside a scene, including very complex ones. Our method is very efficient and needs very few data: one single image taken with a camera and a 3D geometric model (including light sources) of the scene are sufficient for the full reflectances recovery. Some future directions are currently investigated in order to develop new applications and to take into account scenes containing more complex BRDF and objects that combine both anisotropic reflections and texture properties.

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Colour Texture Modelling

by Michal Haindl and Vojtěch Havlí ek

The Textures Modelling Project carried out at CRCIM - UTIA and supported by the Czech Grant Agency, aims at developing mathematical models capable to simulate natural colour textures.

Virtual models require object surfaces covered with realistic nature-like colour textures to enhance realism in virtual scenes. Although such models can work also with digitised natural textures, synthetic textures are far more convenient, not only because of their huge data compression ratio (dozens model parameters irrespective of the required texture size) but can be designed to have certain desirable properties (eg, they can be made smoothly periodic).

Among several possible modelling approaches which are capable to learn a given natural texture sample (eg, fractals, random mosaic models, syntactic models, SARMA, etc.) the Markov random fields (MRF) are the most powerful and flexible ones, because choosing different neighbour sets and different types of probability distribution for the random variables a variety of distinct image types (sharp edges, patchy images, etc.) can be generated. Unfortunately MRF models require in general time-consuming Markov chain Monte Carlo synthesis methods and MRF analysis is complicated task even for simple MRFs.

Modelling multi-spectral images requires three-dimensional models. However if we are willing to sacrifice some spectral information a 3D model can be approximated with a set of simpler 2D models without compromising its visual realism. Random field based models quite successfully represent high frequencies present in natural textures though low frequencies are much more difficult for them. One possibility how to overcome this drawback is to use a multi-scale random field model. The resolution hierarchy provides then a transition between pixel-level features and global

Natural textures from the MIT VisTex database (odd rows) and their synthetic counterparts.

features and hence enables to model a large variety of possible textures.

Two fast multi-spectral multi-scale MRF texture models developed in the project synthesize single mono-spectral single-resolution factors of a given natural colour texture using either Gaussian MRF (GMRF) or causal wide-sense Markov (WMRF) sub-models. Hence a complex 3D MRF texture model is approximated with a set of simpler 2D MRF models. WSM model parameters as well as the optimal contextual support set of the model can be found analytically using Bayesian estimators (the WMRF statistics can be evaluated also recursively if required) and the model is easily synthesized from the model equation. Fast GMRF parameter estimation requires an approximate maximum likelihood estimator and similarly fast estimators exist only for a sub-optimal contextual support set. However, also the Fourier transformation based GMRF synthesis avoids the time consuming Markov chain Monte Carlo iterations. Finally the set of single synthetic mono-spectral single-resolution factors from either of the models is transformed into the resulting synthetic texture.

Some our synthetic textures reproduce given natural texture so well that both textures are visually indiscernible. The original colour tones are reproduced realistically in spite of the restricted spectral modelling power of the model. The multi-scale approach is more robust and allows far better results than the single-scale one if the synthesis model is inadequate (lower order model, non-stationary texture, etc.). The GMRF multi-scale model seems to be superior to the causal WMRF model for some textures, however the WMRF model synthesis is much faster than the GMRF model synthesis. Another advantage of the WMRF model is its consistent and efficient analytical estimators for all model parameters which is not the case for the GMRF model. Both proposed methods allow large compression ratio for transmission or storing texture information while they have still moderate computation complexity (see our Java applet demo) and avoid any time-consuming numerical optimization.

Links:
texture demos:
http://www.utia.cas.cz/user_data/haindl/virtuous/dema/demtexsyn.html

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Comparing Real & Synthetic Scenes using Human Judgements of Lightness

by Ann McNamara

Increased application of computer graphics in areas which demand high levels of realism has made it necessary to examine the manner in which images are evaluated and validated. Research carried out at Trinity College Dublin explores the need for including the human observer in any process that attempts to quantify the level of realism achieved by the image synthesis method, and involves running sets of experiments that compare a simple physical test scene to a number of graphical images which are intended to represent it.

The aim of realistic image synthesis is the creation of accurate, high quality imagery that faithfully represents a physical environment, the ultimate goal being to create images that are perceptually indistinguishable from an actual scene. Reliable image quality assessments are necessary to help determine how close image synthesis systems come to achieving that goal. Typically the quality of an image synthesis method is evaluated using numerical techniques that attempt to quantify fidelity using image-to-image comparisons (often comparisons are made with a photograph of the scene that the

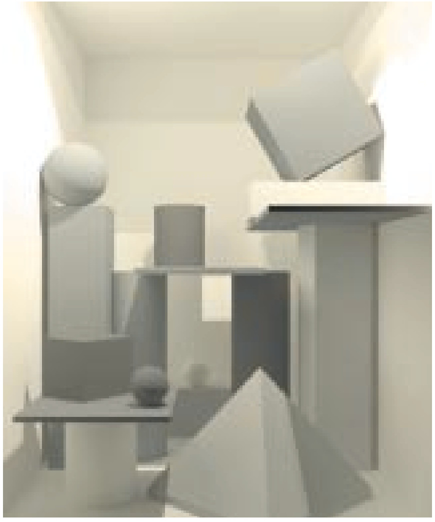

Figure 1: A graphical rendition of the scene used.

Figure 2: The experimental set-up.

image is intended to depict). However, this may not reveal specific errors in the portrayal of lighting and shadows; furthermore it could be argued that one needs a measure of fidelity which involves assessment of performance on a specific visual task, performance on that task in a real scene can be compared with performance on that task in a graphical scene to give a measure of fidelity. By conducting such a set of experiments, based on psychophysics, it can be estimated how close a rendered image is to its original counterpart.

The Experimental Set-Up

The test environment was a simple five-sided cube. Several small objects were placed within the box for examination. The test scene was then modelled and rendered on computer. In total ten graphical images were considered for comparison to the real scene, these included rendered images of varying degrees of quality and a digital photograph. A small, front-silvered, high quality mirror was incorporated into the set up to allow the viewing conditions to facilitate alternation between the two settings, viewing of the original scene or viewing of the modelled scene on the computer monitor. When the optical mirror was in position, subjects viewed the original scene. In the absence of the optical mirror the computer representation of the original scene was viewed, see Figure 2.

The Experiment

Each participant was presented with a series of images, in a random order, one of which was the real environment. The images presented were the real scene, the photograph and the 9 rendered images. The task - that of matching materials in the scene against a display of originals ˆ was chosen because the task has a number of attractive features. First, it has been shown that the perception of lightness (the perceptual correlate of reflectance) is strongly dependent on the human visual system's rendition of both illumination and 3-D geometry. These are key features of perception of any scene and are in themselves complex attributes. However, the simple matching procedure used here depends critically on the correct representation of the above parameters. Therefore, the task should be sensitive to any mismatch between the original and the rendered scene.

Results and Conclusions

The results show there are indeed differences between the judgements of lightness in the real scene and the synthetic images. The main conclusions from the analysis of the experimental results are that there is indeed hard evidence that the certain images are perceptually degraded compared to the real scene. However, there is no evidence that the others images in this study are perceptually inferior to the real scene. From this we can conclude that the certain images are of the same perceptual quality as the real scene.

The main focus and motivation behind this project was the development of a process that led to the evaluation of computer graphics images with respect to the real world scene they depict. This has resulted in a new experimental framework that facilitates human comparison of real and rendered scenes.

The ultimate goal of this work, which is continuing in the Image Synthesis Group at Trinity College Dublin, is to develop a computational algorithm to judge the quality of computer images that mimics the quality judgement of a human being. In effect this would mean designing a form of „visible differences predictor‰ which matches human judgement of an image to its real world scene. This would eliminate the need for further, time consuming psychophysical studies, by incorporating the actual response of the HVS into a difference metric. This new metric would then give the same results as image comparison by human observers, facilitating subjective comparison of computer graphics imagery.

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Facial Repertoires for Animation on the Web

by Zsófia Ruttkay

The CharToon system is a tool dedicated to design and animate 21/2D non-photorealistic, cartoon faces for web and other applications. Novel features are based on the concept of a facial repertoire, containing ready-to use, but adaptable facial features as well as facial expressions. With constraint-based animation editing facilities, the user can define expressions on a high level and design the dynamism and behaviour of a face. CharToon was developed at CWI in a 3-year project and will be sold in 2001 by EPICTOID, a CWI spinoff company.

Humanoids with expressive faces have become popular in social user interfaces as well as virtual reality, telecommunication, Web and entertainment applications. There is demand for tools with which a non-professional user can make a variety of expressive and appealing faces with little effort and resources. CharToon is a vector-graphics based facial animation tool written in Java, with which one can construct faces which can be animated and compose animations for faces. A player module can generate the animation on the fly, real-time, based on scripted description of the face and the animation. The basic CharToon system was already introduced earlier in ERCIM News No. 35.

In the last year, CharToon has been extended with facilities enabling the re-use of higher-level building blocks, both when making faces and when animating them. CharToon is equipped with two ready-to-use, extensible and adaptable sets of repertoires:

- The facial feature repertoire consists of a choice for each facial feature such as mouth, eye, hair and facial outline. The variants may differ in look, in potential motion characteristics or viewpoint. The user starts creating a face by selecting building blocks. He has the freedom to adapt the look and shape of the included features, in order to create an original, new face.
- The facial expression repertoire contains still and dynamical expressions, stored as animations.

Due to consistent labeling of the so-called control points which define deformations, the facial and the expression repertoire are orthogonal: an expression can be 'applied' for any face made of (adapted) facial feature repertoire elements (see Figure 1).

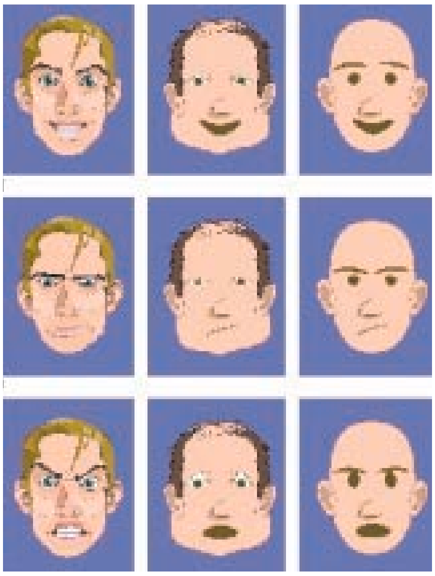

Figure 1: Three faces made from facial repertoire elements, showing identical expres- sions in each row.

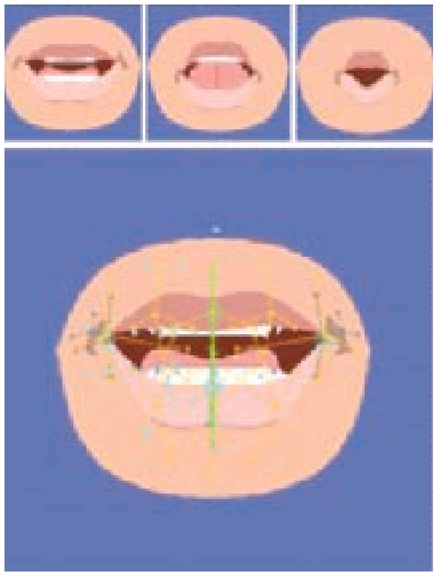

Figure 2: Visemes for a mouth, and the control points.

A specific set of facial expressions are the visemes, containing mouth shapes for talking heads (see Figure 2). By using different viseme repertoires, the lipsync for different languages or for different user groups (eg hearing impaired) can be automated.

Another extension to CharToon is the Emotion Disc: a device which allows to generate and explore a continuum of facial expressions, assuming that initially the snapshots of the 6 basic expressions - joy, surprise, fear, sadness, anger and disgust - were designed. The further elements of the emotion space are

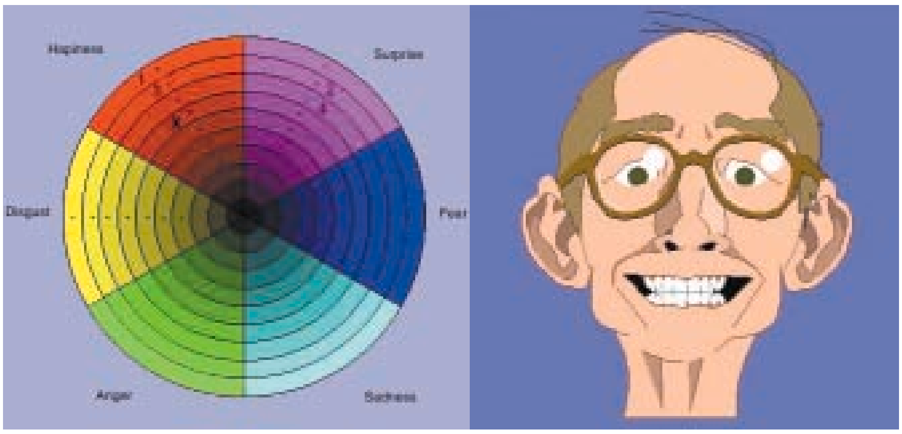

Figure 3: Emotion Disc with the 6 basic expressions. Expressions at * marks are weaker versions of the expression on the perimeter. The expression at location X is computed as bi-linear interpolation of the expressions given at points 1, 2, 3 and 4. The corresponding expression is shown on a well-known ERCIM face.

generated by blending (animation parameters of) two of the given emotions in a certain way. The design of Emotion Disc is based on an almost 50-year old (though debated) observation by Schlosberg, stating that the six basic emotional expressions are perceptually related in such a way that they can be arranged in a two-dimensional space along a circle. The continuous space of Emotion Disc is, accordingly, a round disc showing a neutral face in the centre and maximal expressions on the perimeter (see Figure 3). The Emotion Disc can be used in all stages of the animators' work. It has also been used as a direct controller of the expression of an avatar's face.

Currently we are implementing a new version of CharToon, extended with constraint-handling mechanisms. The constraints are to be used in two roles:
- to define characteristics of generic or specific expressions (declarative role);
- to aid the user during editing to produce an animation which fulfils initially set requirements (imperative role).

By using constraints as conceptual means to declare expressions, we will be able to address the still open issues of superimposing and concatenating pieces of animations and experiment with different strategies.

Though CharToon was initially developed as a research tool, it raised much interest in a broad circle of potential users. To turn it into a commercial product, the spinoff company EPICTOID was created recently, starting to sell CharToon in 2001.

Links:
http://www.cwi.nl/CharToon

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3D Medical Visualization: Breaking the Limits of Diagnostics and Treatment

by Andreas H. König and Eduard Gröller

Three years ago a research team at the Vienna University of Technology joined forces with a development division at Tiani Medgraph (one of Europe's leading companies in Picture Archiving and Communication Systems) in order to develop a medical 3D workstation. Today this comprehensive software tool changes the way radiologists and other medical specialists diagnose and treat health problems of patients. Two examples out of the variety of new techniques (Virtual Endoscopy and the specification of transfer functions for Volume Rendering) are discussed in this article.

For purposes of medical diagnosis it is most desirable to have available as much detailed information on the anatomical and pathological features of the patient as possible. In clinical practice examinations by the various scanning modalities (like Computed Tomography (CT) or Magnetic Resonance Imaging (MRI)) try to find the optimal trade-off between a high scanning resolution and the radiation harm or inconvenience for the patient. With the recent rise of modalities featuring high spatial scanning resolutions (like Multi-Detector CT), special strategies for the investigation of huge data sets are more necessary than ever.

Traditionally, a radiologist supposed to diagnose such data sets would look at the scanned images slice by slice. By mentally reconstructing the sampled information into a three-dimensional representation, he would judge on the health of the patient. This procedure requires the radiologist to have well-founded experience as well as a highly sophisticated understanding of human anatomy. To create a 'complete' mental image of the patients structures, the radiologist has to take all available slices into account. It is obvious, that looking at hundreds of slices (and soon thousands!) is way to time consuming for a single patient. Although these new modalities provide for the very first time ever reasonably enough information to find even small (and still curable!) pathological structures, it has become impossible to do the diagnosis the traditional way. 3D Medical visualization can help to overcome this problem by providing the user with a 3D representation of the patients anatomy reconstructed from the set of image slices. Two examples for the application of medical visualization are discussed in the following sections.

Virtual Endoscopy
Virtual endoscopy is an application which deals with the exploration of hollow organs and anatomical cavities using volume data. Using a real endoscope is always painful or at least inconvenient for the patient. Virtual endoscopy is used as a non-invasive diagnostic technique. It may also be applied in surgical planning, training and exploration of structures not reachable with a real endoscope. All these fields have similar requirements concerning the visualization system : accuracy, intuitive interaction, fast visualization, and a short preprocessing time.

The common approach for the visualization of a virtual endoscopy is surface rendering, yielding images close to a real endoscopy. If external structures are of interest, volume rendering techniques have to be used. These methods do not display the exact shape of the inner lumen very well. For certain applications, eg operation planning of a transbronchial biopsy, both, the shape of the inner lumen as well as outer structures like blood vessels and the tumor have to

Figure 1: Real endoscopy compared with surface shading and volume rendering (left to right).

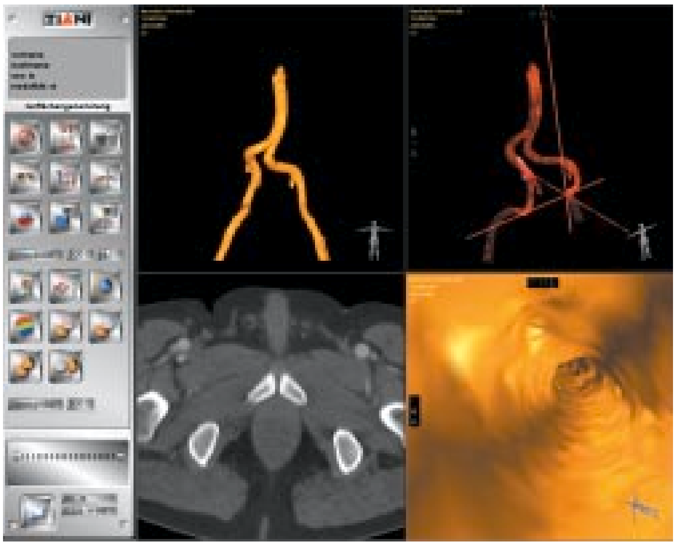

Figure 2: Virtual Endoscopy of the aorta and the main bifurcation. Surface Rendering (top left), Volume Rendering (top right), reference slice (bottom left), and endo-luminal view (bottom right).

Figure 3: Rendering of a human hand. A complex transfer function was used to separate bones, blood vessels, ligaments and skin.

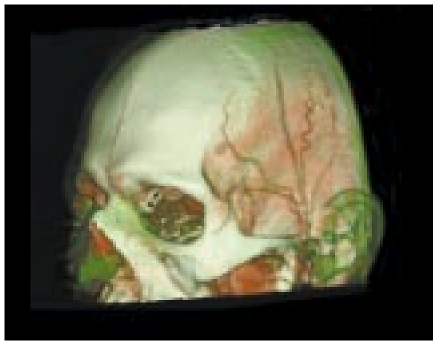

Figure 4: Another transfer function was used to display bone, blood vessels, and skin independently.

be delineated. A new method has been developed, that allows a quick and easy hybrid visualization using overlays of different visualization methods like different surfaces or volume renderings with different transfer functions in real time on a low-end PC. To achieve real time frame rates, image based rendering techniques have been used. Virtual Endoscopy images are shown in figures 1 and 2.

Advanced Transfer Function Specification

When employing direct-volume-rendering for the visualization of volumetric data sets, typically a transfer function is used to classify the data. Data values are mapped into optical properties like color or transparency information. Especially medical doctors with little experience in computers or the mathematical background of volume rendering are usually not able to handle complex paradigms for specifying the high-dimensional functions needed for the visualization. Therefore a new user-interface paradigm for the specification of transfer functions has been developed. The specification is usually a difficult task as mapping information for a number of different domains (data range, color, opacity, etc.) has to be defined. In the new approach, the definition of the mapping information can be realized independently for each property domain. A set of specification tools is provided for each domain, enabling users with different levels of experience or demanding time restrictions to choose an appropriate approach for their needs. Real-time feedback during the manipulation of parameters has been proven to be crucial to the specification.

An interactive direct-volume-rendering display is realized by utilizing dedicated hardware acceleration. Figures 3 and 4 show examples of direct volume rendering displays utilizing transfer functions specified with this technique.

Conclusion

Just two examples from a variety of approaches included in the developed software system were presented here. Other applications include cardiovascular imaging, transplantation-surgery planning, orthopedic diagnosis and surgery planning, neuro-radiological applications, vascular diagnosis and treatment planning, and a lot of other specialized techniques. One of the future goals of computer aided diagnosis using 3D visualization is the establishment of screening examinations. If technology is evolved enough, every person in our society will spend a couple of minutes per year in a scanning modality. The acquired data will be analyzed automatically by an computer system. Potential hazards to the patients health will be reported to medical experts, who will be able to detect and cure most diseases in time.

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Real-time Visualization through the Internet

by Xavier Cavin and François Cuny

VSP Technology (Visualization Service Provider™)is a new start-up company born from a technology transfer from INRIA and providing services for a realistic and interactive visualization of complex 3D models. The core technology relies on an advanced rendering software developed at INRIA Lorraine within the ISA research team. The innovative objective of VSP is to offer a new approach of real-time visualization through the Internet as an Application Service Provider (ASP).

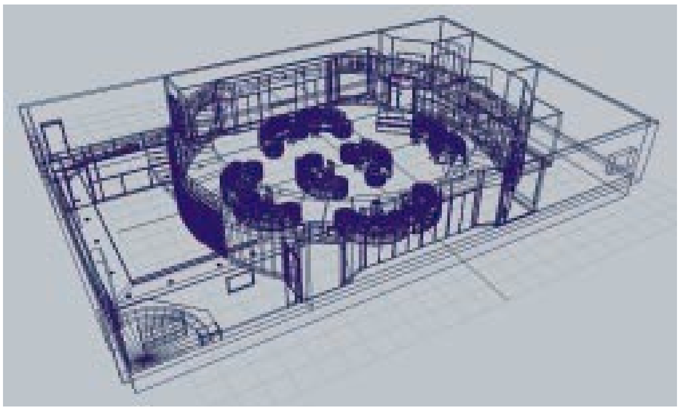
Virtual prototyping is expected by the industrial world to offer an important competitive advantage in comparison with traditional prototyping techniques. On one hand, it allows to greatly reduce the design times and costs of new products; on the other hand it may advantageously assist the marketing and the high-end management in their making decisions. However, existing visualization solutions continue to suffer from too many limitations that have restricted their spread and use: physical inaccuracy, very rough visual perception, poor interactivity and over all an incapacity of coping with the scale required by industrial applications.

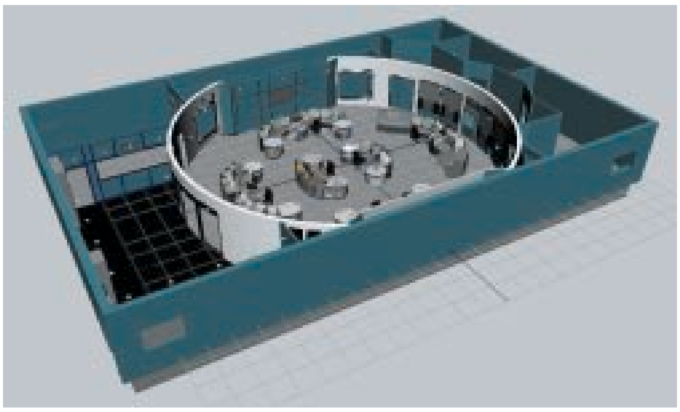
VSP Technology provides solutions for high quality virtual prototyping of very large sized numerical models for industries such as automobile, aeronautics, energy, architecture, etc through an advanced system of geometric optimization, numerical physically based simulation and real-time images generation, directly following from the most recent research in the field of computer graphics.

The process of Visualization Service Providing can be decomposed into three phases: geometric and physical modelling, light transfer simulation and interactive visualization.

For immediate integration purpose, the geometric 3D model can directly come from the traditional CAD/CAM/CAE modelling tools used in the industry, such as CATIA™ or Maya™. Unlike standard CAD polygon-based interchange vocabulary, our loading module generates a compact mathematical representation of the initial geometry that preserves the topological properties of the objects. In addition, physical and spectral properties of surfaces and light sources are taken into account into the model using standard industrial data formats, in order to ensure the physical accuracy of its numerical representation.

Then, the propagation of light in the model is computed from a global physical simulation based on a high performing radiosity algorithm. This algorithm efficiently performs the calculations using high order wavelet functions on parametric surfaces, and can take advantage of existing multi-processor: it can thus be applied with extreme precision and speed to models of very





Interactive design and real-time visualization of an oil and gas control room for ALSTOM: Original model in Maya (top left), Maya visualization (bottom left), VSP visualization (right).

large size. By contrast to classical Monte Carlo ray tracing approaches giving static images, the radiosity method results in a view-independent solution, meaning that views can be displayed without requiring any supplementary lighting computation.

The final step consists in interactively visualizing the illuminated model. Thanks to advanced techniques - including lighting textures, level of details and optimal mesh simplifications - intensively using graphics hardware acceleration, realistic images can be displayed with a high resolution at a high frequency. Supplementary complex optical effects (that were indirectly taken into account in the original simulation) can be added in real-time, and some modifications can be applied to the model, updating the solution accordingly.

Furthermore, a strong concept of VSP Technology is to put forward the complete visualization solution in an Application Service Provider type of process. This concept must allow users to make the most of all the technological power of VSP Technology via the Internet, and to focus all their efforts on their know-how by leaving apart all hardware and software aspects. No matter where they are located in the world and regardless of which resources (high-end or low-end) they are in dispose of, they will be able to interactively visualize and modify their numerical models, even the most complex and largest ones, with a never achieved realism.

The objective of VSP Technology is to bring the academic results of the research made at INRIA to a competitive technology. This work will be done in collaboration with the ISA (Nancy) and iMAGIS (Grenoble) INRIA research teams on one hand, and our strategic partner SGI on the other hand. In particular, INRIA is involved with France Telecom in the RNRT/VTHD project, whose objective is to settle a very high bandwidth network (2.5 Gbits/s) between the five INRIA institutes (Paris, Grenoble, Nancy, Nice and Rennes): this network will help us to conduct experimentations of the ASP aspects and to validate this approach.

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The Pond: Trawling the Information Sea

by Lennart E. Fahlén, Jan Humble, Olov Ståhl, Jonas Söderberg and Anders Wallberg

The Pond is a desk-projection based system for search, visualization and transactions of data elements stored in local databases or on the Internet. Based on a 3D ecosystem metaphor, the Pond approach for querying, presenting and manipulating data elements differs considerably from more conventional information systems.

Conventional data search engines (eg Internet search tools such as AltaVista , Yahoo and products such as Oracle DBMS) mostly provide textual representations of results, and are thereby somewhat limited to 2-dimensional layout. 3D data visualization systems such as VR-VIBE from Nottingham University and Q-PIT developed at Lancaster University show some promise in building a general overview, but require prior knowledge of the system in order to interact and especially navigate.

The ICE laboratory at SICS experiments with new approaches to information presentation and manipulation. As part of this effort the Pond has been developed. The Pond is an information system based on an ecosystem metaphor allowing users to search for data elements stored in local databases or the Internet, and present the results as flocks of aquatic entities inside a 3D virtual pond. The key element in the interface is the information carrying entities' ability to make their presence known and adapt their behaviour based on how they are handled, such as acquiring or relinquishing interest towards user presence.

The design is that of a desk-based projection system, a table around which users gather to perform queries and interact with the resulting pond flocks. The back-projected tabletop surface is touch-sensitive, allowing for direct interaction with the pond environment (see Figure).

Queries

Users perform queries by using credit card sized tags associated with specific keywords that are matched against data stored in a database or on an Internet site. A number of tag readers have been incorporated into the Pond tabletop, and users need only place keyword tags (eg The Beatles or 'techno') on one of these to initiate a search. Once the search results have been retrieved, a flock of pond creatures representing the query result is created and inserted into the virtual pond environment, where the flock starts to move around and respond to user manipulations.

Entity Flocks

Each member of the flock has an autonomous behaviour, controlled by a number of simple navigational rules which, when combined, gives the flock a lifelike behaviour. For instance, entities within a specific flock try to stay together and avoid members of other flocks. This allows for easily identifiable result

The Pond table with back-projected display in the center. Also visible are a number of tags placed on the table-top.

groupings, even long after the flock was created and with the environment vastly populated. The flocks also have a 'garbage collection' behavior that helps to ensure that the pond will not be cluttered with old or uninteresting information. As more and more flocks are added, older flocks that haven't been manipulated for some time will automatically sink towards the bottom of the Pond, and eventually be removed. However, users are able to 'revive' a sinking flock by interacting with it, in which case the flock will return to the surface.

Accessing Information

Each flock member represents some information element that is the result of a database query. Users are able to access this information by manipulating the entities in different ways. In the current version of the Pond, entities represent consumer audio items (eg CDs, MiniDiscs, cassettes etc.), which means that there are two types of information available for each entities, the record data (eg, artist and album title), and the audio data itself. Entities in the Pond are easily identifiable because they are texture mapped with the cover image from the album they represent.

By tapping on an entity (ie touching the display surface), a user selects an entity and is then able to see information identifying the artist and album title for the corresponding record. This information is attached to the 3D entity object, moving alongside it and is only visible for a short while.

Tapping on a creature that is already selected activates playback of audio samples from the corresponding album. When this happens the entity will float to the surface making it easy to identify the record being played. A text will also appear inside the pond, stating the record name, artist and title of the track being played. By repeated tapping on a entity currently being played, users are able to step through the audio clips available for the album. Once a track has been played the entity will swim away from the surface and return to its flock.

Building a Selection

Users can gather entities in creels, specific areas of the pond environment placed close to the tag readers. Once inside the creel, an entity is constrained to move only within the creel boundaries and a new flock is automatically generated, contextually related to the gathered selection(s). Placing a recordable-type tag on the reader reintroduces the entities previously stored on that tag (if any), merging them with the existing selection in the creel. The link between a recordable-tag and selected entities within a creel is created when the tag is removed from the reader, at which point the creel flock will also be removed from the pond environment.

Sound

The audio environment of the Pond consists of both ambient and feedback style sounds. Since the metaphor is that of a pond or pool of information, the soundscape consists of a family of aquatic, bubbling, splashing and whirling sounds, giving the impression of the data elements ascending from an abyss of ooze or mud. The ambient sounds fade out when a chosen music sample is played, and fades smoothly back in when the music stops. The interface sounds indicate various actions taken by the users, for instance placing tags on a reader, dragging entities, etc.

Conclusion

The Pond is a tool for exploring database results in an appealing and inviting fashion, encouraging a collaborative space. Based on flocking algorithms to group data and direct user manipulation via a touch sensitive display, the Pond investigates alternative interfaces to databases, information and transactions systems. The Pond is an example of an Electronic Landscape Artifact developed within the eScape - Esprit long term research project 25377 and the Swedish Research Institute for Information Technology (SITI) Internet3 project ELP.

Links:
The Pond project: http://www.sics.se/ice/research/projects/pond/index.html

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Advances in Computer-assisted Visualization

by Julian Gallop

Rutherford Appleton Laboratory (RAL) uses visualization techniques on large amounts of data as a service to its scientists. Two research topics currently under investigation to maintain the quality of this service are the use of VR to support 3D visualization, and distributed co-operative visualization.

The main function of the CLRC is to provide large science facilities that cannot be placed in each UK university. RAL hosts a large particle accelerator which produces muons and neutrons, a synchrotron radiation source to provide X-rays and photons, a laser facility to provide pulsed light, and a large NMR facility to provide magnetic waves, all to probe the structure of matter. Once experiments using these facilities are designed they produce large amounts of data on the structure of samples of materials from various specialised detectors. We also host a large space science facility that serves earth observation data from satellites, and act as a data centre for particle physics data from experiments at CERN. These facilities produce vast amounts of disparate data that has to be integrated and investigated by teams of scientists throughout the UK and Europe. Part of that investigation involves hunting for novel or interesting phenomena in individual data sets, or more often in combining data sets from different detectors or facilities. To identify the novel or interesting in the mass of data available, visualization is a powerful technique, exploiting the human visual system's ability to search and manipulate objects.

The use of VR to support 3D Visualization

Many computer-assisted visualization applications involve the use of 3D and are now sufficiently complex that additional assistance is needed. VR is one technology which promises to help in this since it uses all of the human visual system as it has evolved to detect moving objects in a three dimensional world, rather than just using interpreting static 2D images which is an artificial task at the best of times.

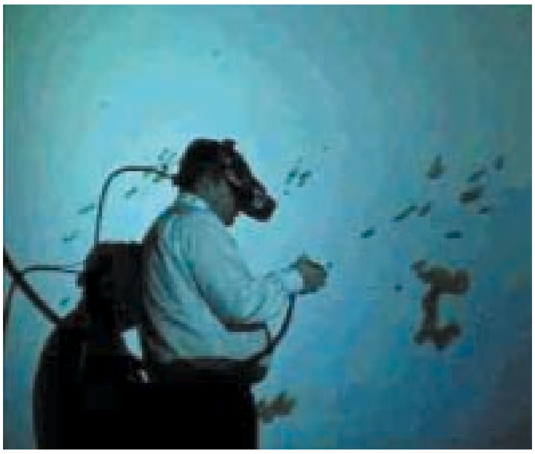


Figure 1: Visualization of isosurfaces showing the distribution of micro-organisms in the mouth using virtual reality.

Studying micro-organisms in the mouth can involve investigating the presence and distribution of small regions where concentrations are high. If one represents this by isosurfaces, one has the visual task of inspecting and interacting with a collection of sparsely distributed blobs in 3D. Particularly when the number of separate objects is large, VR offers the ability to quickly perceive the 3D spatial relationships that are lost in a 2D presentation - see Figure 1.

The behaviour of solid materials that creep when subjected to loading and high temperatures is a problem which requires the investigation of the inside of the material. When welds are involved, the problems are more complex. Computational techniques are becoming more reliable at making predictions, and improvements are being made, but the results need careful examination. Several parameters are examined including stress, strain and the extent of the creepage at any point. It is necessary to quickly identify critical regions within the materials and examine all relevant parameters that may contribute to the problem. A static 2D solution to this presents the information, but a moving 2D image allows the creepage to be captured over time. Further, a moving 3D image that the scientist can navigate through promotes the experience of change and allows scientists to identify

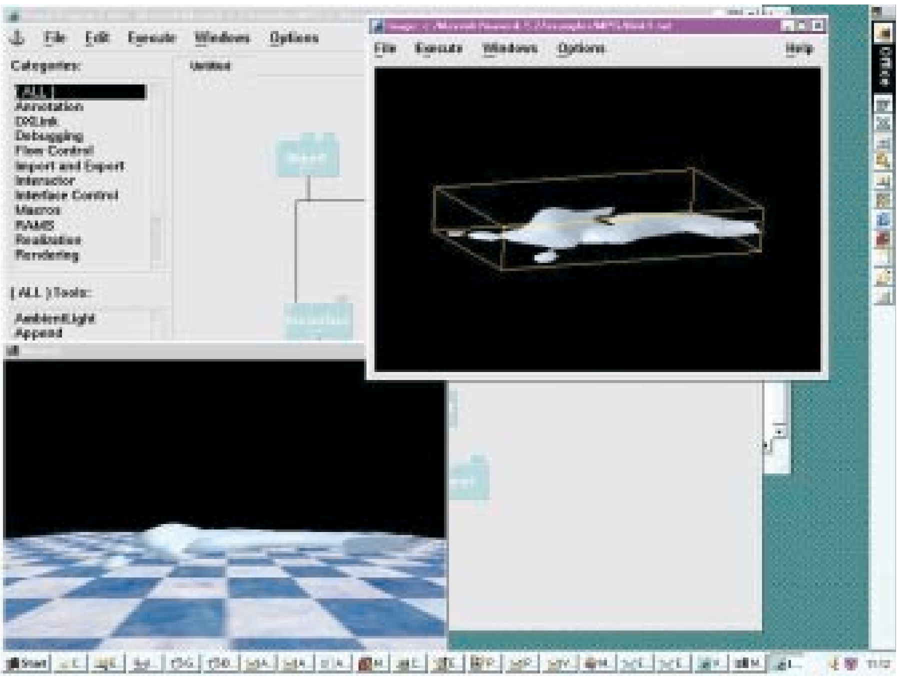
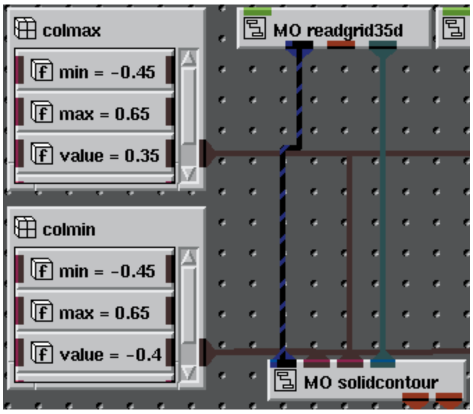


Figure 2: 3D VR visualization of creep in a weld using a dataflow visualization package.



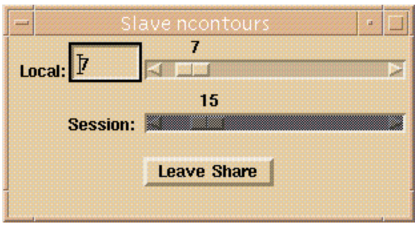


Figure 3: Part of a visualization execution network with a mixture of conventional visualization modules and collaboration modules on the left.

critical regions, or more accurately, dismiss non- critical regions more quickly - see Figure 2.

Different system architectures have been used for data visualization. In these and other examples, a dataflow visualization system and a VR system have been combined. A visualization execution network is set up for the application in the usual way but with the addition of special modules that communicate 2-way with the VR system. The user then interacts with the 3D world through the VR system. The user has the advantages of VR, such as stereoscopic projection, time-critical rendering and 6 DOF input devices, and also the advantages of a dataflow visualization system, where alternative visualization solutions may be rapidly prototyped. In different projects using this approach, 3 different visualization systems (AVS, IRIS Explorer, IBM Open DX) have been used with two different VR systems (PTC Mockup & Manchester University's Maverik).

Distributed Co-operative Visualization
When data from different detectors must be combined, groups of scientists need to combine their complementary specialist knowledge to identify interesting phenomena. A previous project (MANICORAL) developed a prototype system that enabled dispersed scientists to collaborate on such an analysis through a common visualization. By basing the work on a dataflow visualization system, it was possible to develop modules that handled the necessary dissemination and arbitration. It was therefore possible to design visualization execution networks that handled the application requirements and the collaboration tactics - see Figure 3.

A current project (Visual Beans) takes this further by making use of Java and also component technology. It will build on work at Lancaster University (ADAPT project) which has adopted CORBA to solve certain problems of delivering continuous media, where adaptation to varying network and processor conditions is necessary. This development allows distributed scientists to combine components from different visualization systems and different display and navigation mechanisms to facilitate the integration of their knowledge without introducing the barrier of having to learn a specific novel visualization system favoured by another group or discipline.

Links
MANICORAL: http://www.acu.rl.ac.uk/projects/manicoral.html
Visual Beans:
http://www.acu.rl.ac.uk/VisualBeans/
ADAPT project: http://www.comp.lancs.ac.uk/computing/research/mpg/most/adapt.html

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Graph Visualization of Complex Information

by Ivan Herman

Graph visualization is an emerging branch of information visualization, applicable when data possess inherent relations, so that they can be represented by the nodes of a graph, the edges representing the relations. A research group at CWI focuses on cases where graphs form the fundamental structural data representation. The group has developed the Java-based graph visualization system Royère, in co-operation with partners at the universities of Bordeaux, Montpellier, and Bath. The system is freely available for research purposes.

Graph visualization has many areas of application. Systems which can be represented as graphs include hierarchies of files, taxonomies of species, Web site maps, evolutionary trees, and genetic maps. Other applications include class browsers, compiler data structures, state-transition diagrams, semantic networks, PERT diagrams (project management), VR scene graphs, and document management systems. As the information is not always purely hierarchical, more general graphs than trees need to be studied.

A key issue when visualising graphs in information visualization is the size of the data. Many applications require analysis of graphs with several thousand nodes and edges. Large graphs pose several difficult problems. Even if all elements can be displayed, one may obtain an overall indication but the graph is difficult to comprehend (nodes and edges cannot be distinguished).

CWI has developed innovative techniques to navigate, to filter, and to create abstractions from such graphs, in order to make them usable in practice. A key

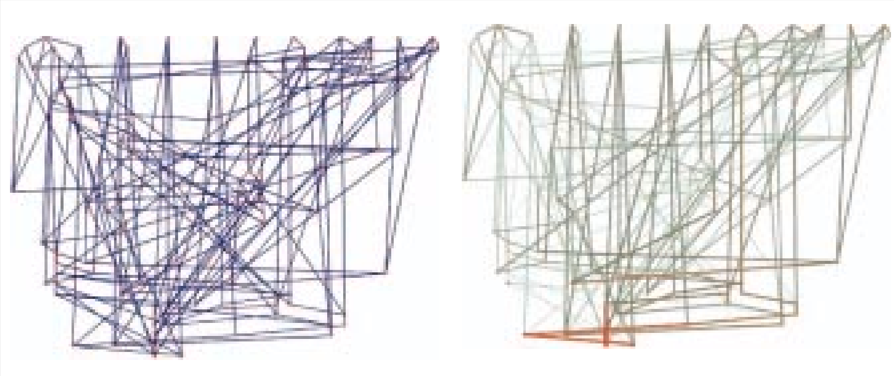

Figure 1: Two views of the same graph: without (left) and with (right) emphasis mapping.

feature is the use of metrics, as a measure associated with a node or an edge. The idea is to define the relative importance of a node or an edge with respect to some semantics. The measure can be application specific or based on graph structure, for example the degree of a node (= the number of adjacent edges), the size of a subtree, or the flow of information in a directed graph.

Such metric values can be translated into visual attributes like colour and saturation. A technique that we find useful renders an edge with continuously shaded colour reflecting the metric values of the nodes at its endpoints. In this approach, higher metric values are considered more interesting and are assigned higher saturation values. The result is an emphasis on the most 'interesting' nodes and edges (see Figure 1). Metrics can also be used to hide elements with low values, thus emphasizing the more important elements in a tree ('semantic fisheye').

Another use of metrics lies in the partitioning of a large data set by subdividing the corresponding graph into subgraphs of manageable size. This technique is vital to navigation in large graphs and to identification of important relations among elements. It is particularly important when no 'natural' division into subtrees exists. Based on the idea of subdivision, innovative interaction techniques could be developed to enhance the user's possibilities in analysing the underlying data structures (see Figure 2).

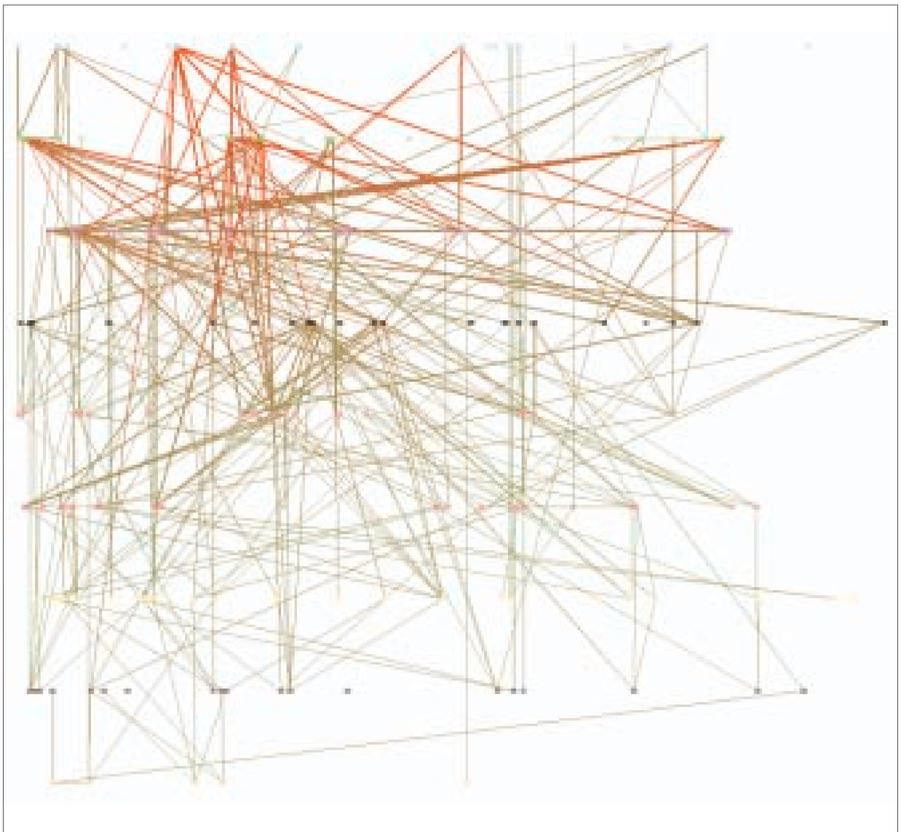

Figure 2: The result of simple clustering (skeletoning) combined with metric based colouring, applied to a data set graph with around 600 nodes and 900 edges, which on the screen would look like a uniform blue 'cloud'.

Visual attributes or clusters are generated automatically. If the metric values are uniformly distributed, a simple linear mapping to, for example, colour saturation will do. If the distribution is not uniform, the statistical behaviour of the metric values should be taken into account. We have developed techniques to describe the necessary distributions for the various metrics, and apply them as part of the navigational tools. Knowledge of the exact statistical behaviour would save us the process of finding an approximation function or building a look-up table. Unfortunately, some of these behavioural descriptions are very involved , and require a strong foundation in mathematics. Here lies a potential field of fruitful cooperation between the visualization and the mathematics communities.

All our ideas are incorporated in the graph visualization system Royère, which can be used as the basis for further developments.

Links:
CWI's Information Visualization Project:
http://www.cwi.nl/InfoVisu/

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Interactive Visualization of Protein Dynamics

by Henk Huitema and Robert van Liere

Understanding the function of a protein is fundamental for gaining insight into many biological processes. Proteins are stable mechanical constructs that allow certain internal motions to enable their biological function. Structural properties of a protein can be obtained with X-ray crystallography or NMR acquisition techniques. Molecular dynamics (MD) simulations at pico/nano-second time scales output one or more trajectory files which describe the coordinates of each individual atom over time. The main problem with animating these trajectories is one of temporal scale. Taking large time steps will destroy the impression of smooth motion, while small time steps will result in the camouflage of interesting motions.

Together with the Department of Microbiology of the University of Amsterdam, CWI has developed an interactive visualization environment to study protein dynamics. Instead of animating atom trajectory files, essential dynamics is used to filter out non-interesting motions and only visualizing correlated atom motions. The basic idea of essential dynamics is to separate the configurational space into two subspaces: an essential subspace containing only a few degrees of freedom, and a remaining space in which the motions can be considered as physically constrained. The essential degrees of freedom describe motions which are relevant for the function of the protein, while the physically constrained subspace describes irrelevant local fluctuations. A number of interactive techniques are added to explore the configurational space spanned by the essential eigenvectors. One may drag one or more atoms along the eigenvector. The resulting new displacement is used to position other atoms in the protein. An angular widget to monitor the hinge bending properties can be pegged onto any part of the backbone. A measuring stick widget to monitor the distance between atoms during exploration can be pegged between two atoms.

Figure 1:
Line drawing representation of a protein. Arrows indicate the degrees of freedom of individual bonds.

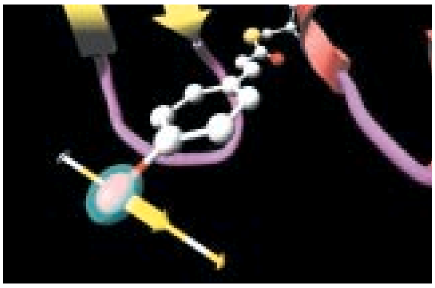

Figure 2: Exploration of the essential eigenspace.

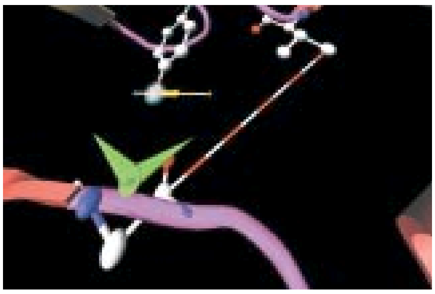

Figure 3: Measuring widgets during exploration.

These techniques have been used to study the dynamics of the Photoactive Yellow Protein (PYP). The 3D structure of PYP is known; it binds a chromophore via a thio-ester linkage to a unique cystine. When the chromophore receives blue light its conformation changes, which affects the overall structure and dynamics of the protein. How to animate internal protein motions?

One hypothesis is that a conformational change on the surface of PYP functions as a signalling device for another protein. Our visualization and interaction techniques help to find which domains in PYP are affected when the chromophore changes state, and which residues are involved in these conformational changes. Animation of the data provides a global overview of the internal protein motions and an indication of concerted fluctuations. Then exploration techniques are used to gain a deeper understanding of particular concerted motions. Finally, exploration combined with measuring widgets provide quantitative insight into the specific internal protein motions and fluctuations.

In Figure 1 a cartoon representation is used for the backbone (side groups are not shown). The chromophore is shown as a colored ball and stick representation. Animation of the MD trajectory reveals that the chromophore fluctuates considerably along the most relevant essential dynamics eigenvectors, and that these fluctuations are correlated with large motions on the backbone and side chains. In Figure 2, the eigenvector is drawn in yellow on a selected atom of the chromophore. The minimum and maximum bounds are displayed on a yellow-white cylinder. The atom is drawn as a semi-transparant sphere. Our exploration shows that the motion of the chromophore along the eigenvector induces a contraction of the 50-helix, causing the N-terminus region to pivot around the 25-turn (not shown in the Figure). Finally, Figure 3 shows an angular widget (drawn as a green compass) for measuring the dihedral angle that glycine-51 makes with the backbone. We could see that the large conformational freedom of this angle is responsible for the contraction of the 50-helix. The distance widget (shown as a red-white cylinder) is used to measure the distance between the 100-loop and the 50-helix.

Definite answers to the biochemical questions posed cannot be obtained by visualization alone. However, visualization helped to formulate a hypothesis which can be tested by further biochemical research. A candidate domain for the signaling function was found to be the N-terminal region. Critical residues for the conformational changes are glycine-51 and several residues in the 25-turn.

Our work revealed that filtering techniques enable the study of internal protein motions. Second, active exploration of the space spanned by the selected eigenvectors yields a more intuitive understanding than that of passive viewing of an animation. And finally, by exploration in combination with measuring widgets very specific properties of a motion may be examined.

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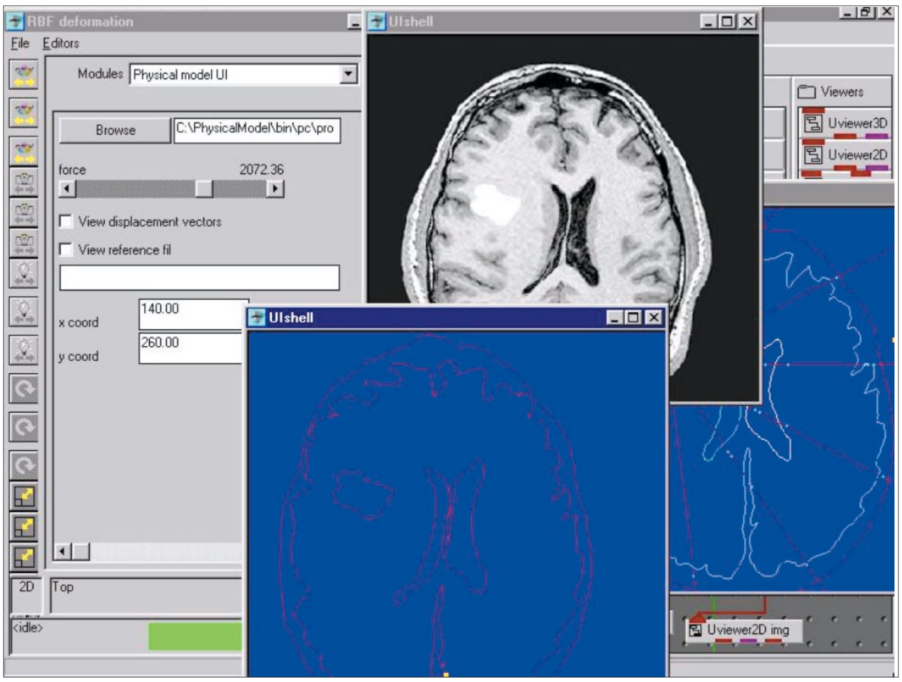
Physical Deforming Agents for Virtual Neurosurgery

by Michele Marini, Ovidio Salvetti, Sergio Di Bona and Ludovico Lutzemberger

A model of the brain has been developed at IEI-CNR on the basis of data acquired via Computer-assisted Tomography (CT), Magnetic Resonance (MR) scans and other types of information gathered from anatomical atlases.

A model of the brain has been created by means of geometrical and functional data-fusion so that a characterization of each of the internal structures is possible. A set of deforming agents has been placed over the geometry of the three-dimensional model in order to simulate the evolution of different pathological intra-cranial phenomena such as haemorrhages, neoplasm, haematoma etc. and to describe the consequences that are provoked by their removal as well as the influences they have on the anatomical and neuro-functional structures of the brain. This model can be used effectively in virtual neurosurgery. The deforming agent action is an isotropic pressure that can be studied using a number of 'lines of force' traced radially, within the geometry of the model. These lines start from a fixed region, chosen as the source of expansion, to the bone boundary limits, as the skull represents a physical limitation to the cerebral expansion phenomena.

The tissue elastic response can be simulated as a series of springs, each of which is associated with the underlying tissue section. The reaction of a tissue to the deforming action develops continuously in all directions and causes a resultant that is equal and opposite to the modifying charge. An approach of this type necessitates some corrections to adapt the discretization to the real-world situation. This can be done by assigning a 'pressure transmission coefficient' to each tissue, which simulates the force dispersion and is transmitted from one spring to another. Moreover, the effects induced by the presence of a liquid mass, which in our study can be considered as



Example of the system interface when simulating an intracranial expansion phenomenon, applied to a healthy brain CT scan.

static, must also be taken into account. The physiological mechanism adopted also favours the use of a spring model in the case of those overlapping 'lines of force' sections that contain liquid. Each straight line coming from the initial point of development represents a direction of the force field whose vectors are oriented from the centre of the source of the expansion to the external contour. The intersections where the straight lines cross regional contours define the knots that are used as control points for the application of the geometric deformation. Each section comprised between two adjacent control points lying on the same line is associated with a single spring that rules the elastic behaviour of the underlying region. The generic spring is then characterized by a set of parameters whose values depend on the regional characteristics. Under AVS/Express', an interactive system has been implemented which includes both single data-set slices and three-dimensional deformation tools to interactively control the virtual actions (see Figure 1).

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Visualization of Complex Dynamical Systems in Theoretical Physics

by Anatoly Fomenko, Stanislav Klimenko and Igor Nikitin

A research team at the GMD Institute for Visualization and Media Systems Design has developed methods of computer visualization to understand complex dynamical systems in theoretical research, like string theory or time-symmetric electrodynamics.

Investigation of dynamical systems in theoretical physics is often reduced to analysis of properties of certain geometrical objects, particularly, surfaces, characterizing the physical state of the system. Singularities of such surfaces correspond to critical phenomena in underlying dynamics. Methods of computer visualization can help to understand a structure of singularities on characteristic surfaces, shed light on deep mechanisms of complex physical processes and give inspiration necessary to find a solution of the problem.

Topological Atlas of Integrable Cases in Rigid Body Dynamics

In Hamiltonian mechanics of a rigid body there is a wide class of special (integrable) cases, for which the motion of a body has stable, regular properties. The most well-known of them are the so-called Euler, Lagrange and Kovalevskaya cases. In spite of the fact that during the last 100 years a large number of papers and even monographs have been devoted to the investigation of their properties, since only recently the analysis of their global topology is performed. It turns out that computer and visualization methods work very effectively in this field, and sometimes allow to solve new purely analytical problems. The project combines the two approaches: classical analytical methods and computer visualization to investigate such integrable cases. Particular result, obtained in the project, is visualization of bifurcation diagram for Kovalevskaya top, a surface, subdividing the phase space of the system to regions, where the top has topologically different types of motion.

String theory is a contemporary model of elementary particles, which presents them as a system of point quarks, connected by a string-like tube of chromodynamical field. The evolution of strings is governed by the following dynamical principle: surfaces, swept in motion of the string through the space-time, called worldsheets of strings, are extremals of area functional in Minkowski space-time. In other words, worldsheets are non-Euclidean analogs of soap films.

One of the interesting properties of such surfaces is existence of topologically stable singularities, correspondent to points of energy concentration inside elementary particles. Recent research,

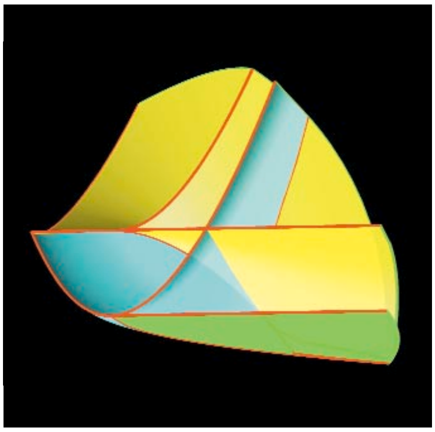

Figure 1: Bifurcation diagram.

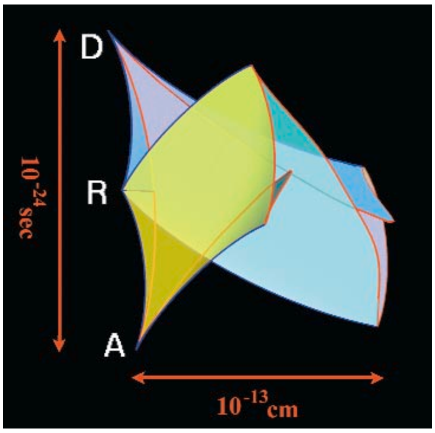

Figure 2: Fold on worldsheet.

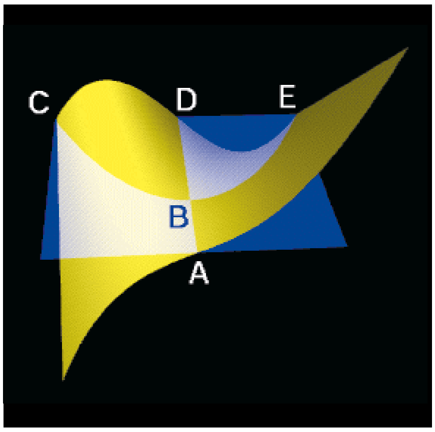

Figure 3: Cayley surface.

based on visualization of worldsheets, detects solutions of new type, whose density of energy changes sign in passage through the singularities. Correspondent worldsheets have folds, like shown in the figure. Slices of the fold by planes of constant time produce the following string evolution: appearance of string component with total zero energy from vacuum in point A, its recombination with main positive energy string component in point R and disappearance of resulting zero-energy string component in vacuum in point D. In this way the usage of visualization methods allows to demonstrate instability of vacuum state in string microworld.

Time-symmetric Electrodynamics

Theoretical physics knows several examples of dynamical systems, which incorporate direct influence of future to the present, ie the systems with equations of motion x''(t) =F(x(t+1)) or similar. One such system, called time-symmetric electrodynamics, was introduced in the beginning of 20th century, and strictly

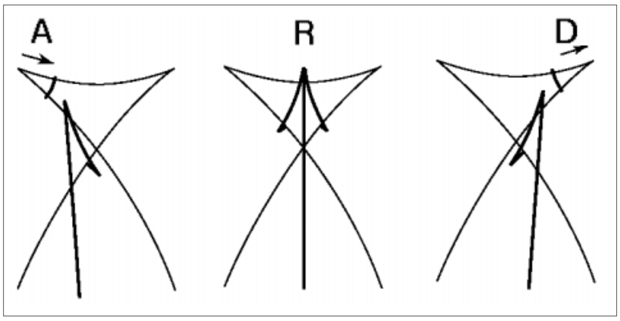

Figure 4: String dynamics.

formulated in works of Wheeler and Feynman in 1949, who had shown full mathematical consistency of such theory. Since this time the model of Wheeler and Feynman attracts the interest of theoretists. Particularly, structure of solutions in a problem of 1-dimensional relativistic scattering of 2 particles in time-symmetric electrodynamics is defined by properties of stationary manifold of Poincare map. Visualization of this manifold shows, that it has a shape of Cayley surface, one of elementary surfaces in the catastrophe theory. As a result, at a certain critical value of velocity of colliding particles, equal to 93.7% of light velocity, solution undergoes elementary catastrophe of bifurcation (splitting): in point B one solution (A) splits into three (C,D,E). Pictures of scattering for solutions A,D have a symmetry under spatial and temporal reflections, while such pictures for solutions C,E are not symmetric, but transformed one to another by reflections. Thus, the bifurcation is followed by an effect of spontaneous breaking of mirror symmetries in studying dynamics.

Links:

Homepage of the project:
http://viswiz.gmd.de/~nikitin/viz.html

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Simulation and Visualization of Processes in Moving Granular Bed Gas Cleanup Filter

by Pavel Slavík, František Hrdli ka and Ondřej Kubelka

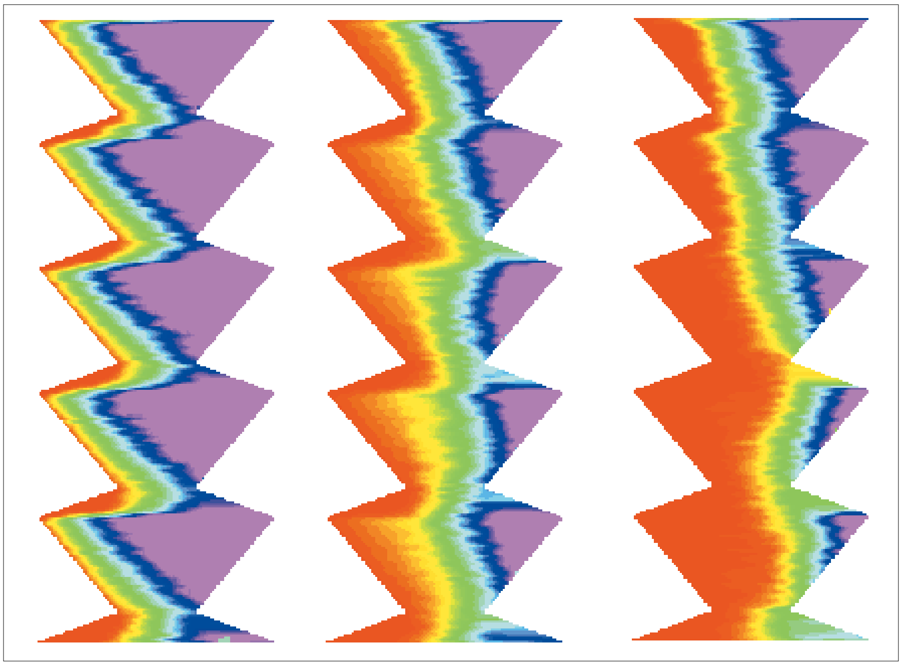
Computer graphics in last years has been used in many new application areas. Its use allows the user to investigate many phenomena in very detailed ways that was not possible before. Many applications are linked-up with simulation processes and computer graphics is used to visualize results of these simulations. In the project described further we deal with a specific application where the use of computer graphics (namely its visualization capabilities) is rather new.

The project GACR 101/99/0647 (Simulation model of filter with vertical moving layer) is solved in collaboration between the Czech Technical University (Department of Fluid Dynamics and Power Engineering and Department of Computer Science and Engineering) and the Institute of Chemical Technology in Prague.

The project was targeted to the simulation of moving granular bed that has cleanup filter. These filters are used mainly in new combustion technologies that increase the efficiency of the electricity production process. The coal is processed by means of special technology that converts it into gas. This gas before it is used in boilers must be purified. One of the most used purification technologies is based on the moving granular bed gas cleanup filters.

These filters consist in principle of a filter body (that might have a various shape that influences the efficiency of the cleaning process) and from the large number of spherical granules that fill the volume of the filter body. The gas that has to be cleaned goes under pressure through this volume of granules. Due to their absorption capabilities the granules remove the polluted part of the gas. In order to remove the granules that have reached their level of saturation and thus are not able to absorb more pollutants the whole volume of the filter (virtually all granules) are moving downwards to the lower outlet. The saturated granules are continuously removed from the filter and the new (clean) granules are added through the top filter inlet.

Design of these filters is rather complicated as there are many parameters that influence the efficiency of the



Visualization of gas purification.

cleaning process. The most important ones are the speed of the granules within the filter, shape of the filter and absorption capability of granules. Especially the shape of the filter is of a key importance as it determines the size and location of stagnant zones where granules do not move with appropriate speed or they do not move at all. The existence of the stagnant zones decreases efficiency of the cleaning process as the saturated granules are not removed from the filter (either at all or very slowly). To achieve some kind of optimal solution it is necessary to establish proper filter shape and appropriate velocity values that lead to optimal performance of the filter.

Traditional approach to the filter design is to construct a physical model of such a filter and perform set of measurements on this model. It is obvious that this solution is expensive and also time consuming. Solution to this problem is to develop a computer model that contains both simulation and visualization part. In our project there was developed a model based on the use of discrete element method. The algorithms developed were designed for 3D environment what allows the user to extend the system capability to investigate the gas flow in 3D (and thus to investigate absorption conditions in any place of the filter). Also areas where stagnation zones can occur are easily detectable. In order to prove validity of the model it was necessary to compare results obtained by means of the model with real results measured on the physical model. The real data were obtained from National Taiwan University where the physical experiments have been performed for quite a long time. The results obtained by means of simulation (and subsequent visualization) were very encouraging. The match was very good see the figure. It is possible to see how group of granules is moving through the filter (and how the initial volume of granules is distributed in the filter volume within certain period of time). Having this sort of simulation and visualization tool it is possible to design in very quick and effective way the described type of filters. It is possible to experiment with various shapes of filters and various speeds of granules in the filter.

The system has been implemented in C++ programming language for MS Windows9X/NT platform.

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Watching Chromosomes during Cell Division

by Robert van Liere

Visualization is an important tool to provide insight in the structure and functioning of time dependent 3D processes in live cells. In cooperation with the Swammerdam Institute for Life Sciences in Amsterdam, CWI has applied a number of visualization techniques to analyze the condensation and decondensation of chromosomes during cell division. To this end, an interactive VR enabled visualization system specially equipped for time dependent 3D data sets was developed.

In order to understand the biological processes underlying control of gene expression, the organization of the cell nucleus must be studied. Time dependent volume data describing specific processes of the living cell are available by now, but their structural analysis in space and time is next to impossible with traditional techniques. Whereas 3D volume data may be analyzed with traditional volume rendering and isosurfaces, the visualization of complex 3D time dependent multi channel data demands a combination of techniques not found in standard systems. Therefore a special visualization system, called Proteus, was developed. Next to basic support tools it comprises an open ended architecture in which application specific demands can be easily incorporated, and can be used in fully immersive, semi-immersive, and desktop environments.

Using 3D confocal microscopy, biologists have been able to produce time dependent 3D data sets of DNA/chromatin in the nuclei of living cells. Time series of 3D images are made of the process of decondensation of the chromatin after cell division (mitosis). During mitosis chromatin is densely packed in chromosomes. After mitosis, part of the chromatin decondensates to form a new nucleus. The data set consisted of a series of fifty stacks containing thirty optical sections of 256x256 voxels each. The voxel size is 90x90x700 nanometer. The time step between scans ranges from 30 seconds in the beginning of the process to 180 seconds at the end. The required storage size was 98 MB.

In order to get an overview of the data, volume rendering was used because this presents the data in a natural and intuitive way (see Figure 1). This gave insight into the global structure of the data. Visible tracking of the structures in the nucleus is complicated by the overall movement and rotation of the cell nucleus and by noise of the data. Hence, the movement of the cell was filtered out using a center of mass estimation, and the noise was suppressed using a low pass filter. Isosurfaces were useful for analysis of the motions of dense parts in the chromatin data. Transparant isosurfaces were introduced to show the boundary of the nucleus using a low iso-value (see Figure 2). These dense parts moved apparently mainly outward, without much reorganization inside the nucleus.

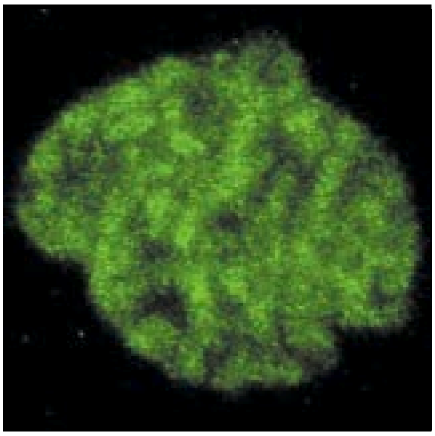

Figure 1: Volume visualization of the data during the decondensation process.

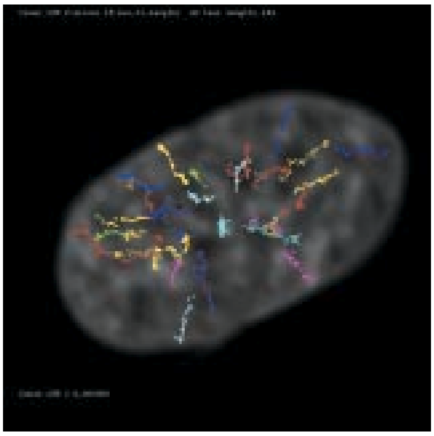

Figure 3: Tracks of dense parts in the data for 22 time steps.

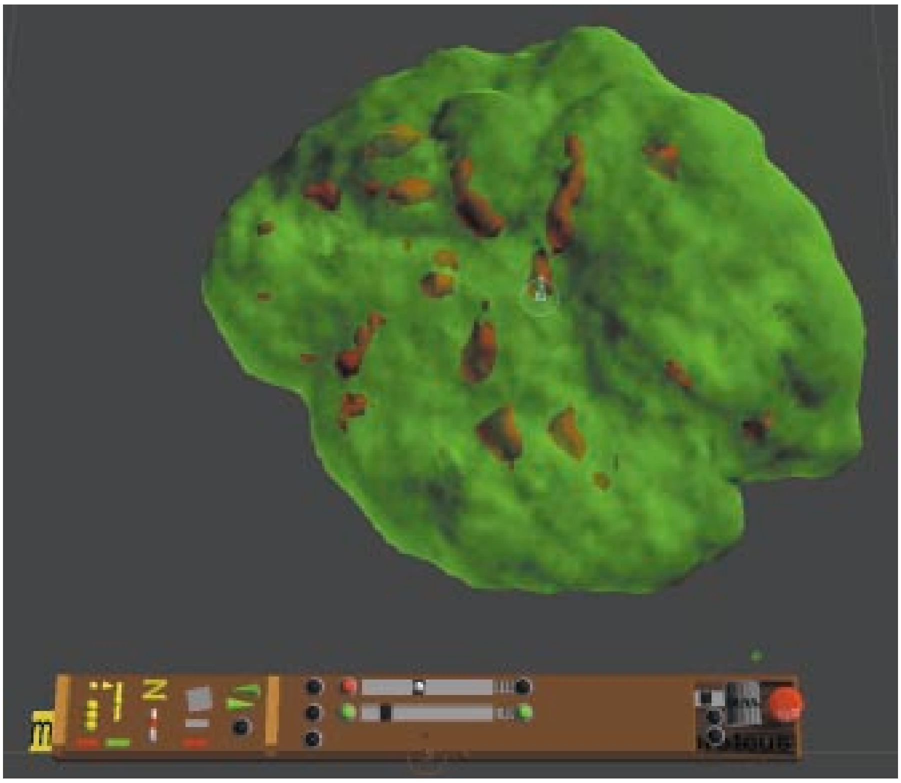

Figure 2: Isosurfaces in the filtered data. A low threshold value was used to show the boundary of the nucleus (green transparent isosurface). The dense parts of the chromatin are shown in red.

Automatic object detection was combined with manual editing. The extensibility of the Proteus system allowed for integration of the feature detection and tracking algorithms into the visualization of the raw data. The tracks found can be manually edited using direct manipulation in places where the algorithm was not capable of calculating the tracks. In many cases the found tracks could be improved by visual inspection. By using the tracking algorithm in combination with the track editing tool the main tracks of dense chromatin spots were found (see Figure 3).

The following lessons were learned from this case study. First, the visualization system used must be flexible enough to cooperate with the other parts of the process. Hence, Proteus was designed as an open system in which the output or other analysis tools can be incorporated. Second, since each visualization technique has its strengths and weaknesses, a whole repertoire of techniques should be offered for use. Finally, for visualization to be an effective tool for collaboration and communication as well, results found in a highly sophisticated environment should be recordable, such that the results can be reproduced for discussion and publication.

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The blue-c Project

by Markus Gross and Oliver Staadt

The blue-c is a joint research project between several institutes at ETH Zurich. Our goal is to build a collaborative, immersive virtual environment which will eventually integrate real humans captured by a set of video cameras. The project has started in April 2000 and its first phase is expected to be completed by spring 2003.

Mastering the rapidly changing computing and communication resources is an essential key to personal and professional success in a global information society. The main challenge consists not only in accessing data, but rather in extracting relevant information and combining it into new structures. The efficient and collaborative deployment of applications becomes increasingly important the more complex and interactive tools we have at our disposal. Today's technology enables information exchange and simple communication. However, it often fails in the promising field of computer enhanced collaboration in virtual reality environments. Some improvements were made by coming-of-age virtual reality systems that offer a variety of instrumental tools for stand-alone visual analysis. Nevertheless, the crucial interaction between humans and virtual objects is mostly neglected. Therefore successful models of truly computer supported collaborative work are still rare.

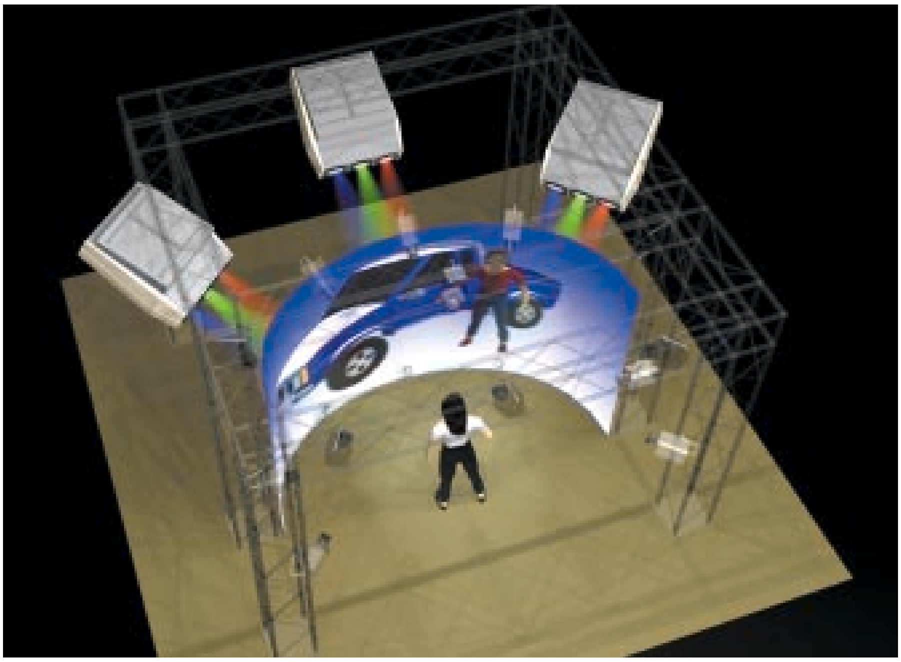

Figure 1: The blue-c: Design study of the envisioned system depicting projection and life video stream acquisition.

Real Humans in Virtual Worlds

The blue-c project aims at investigating a new generation of virtual design, modelling and collaboration environments. Three-dimensional human representations will be integrated in real-time into networked virtual environments. The use of large screens and cutting edge projection technology creates the impression of total immersion. Thus, unprecedented interaction and collaboration techniques among humans and virtual models will become feasible.

Computing – Communication – Collaboration

The blue-c features are:
- full immersion of the participants in a virtual world
- three-dimensionally rendered human inlays, supporting motion and speech in real-time
- new interaction metaphors between humans and simulated artifacts of functional and/or behavioral nature.

The Technology

The blue-c system foresees simultaneous acquisition of life video streams and projection of virtual reality scenes. Color representations with depth information of the users will be generated using real-time image analysis. The computer generated graphics will be projected onto wall-sized screens surrounding the user, allowing him to completely enter the virtual world. Multiple blue-c portals, connected by highspeed networks, will allow remotely located users to meet, communicate and collaborate in the same virtual space.

The blue-c system will include:
- a fully immersive three-dimensional stereo projection theatre
- real-time acquisition of multiple video streams
- three-dimensional human inlays reconstructed from video images
- voice and spatial sound rendering
- distributed computing architectures for real-time image processing and rendering
- a flexible communication layer adapting to network performance
- a scalable hard- and software architecture for both fixed and mobile installations
- an advanced application programming interface.

Architectural Design

Today's architects work with both low-scale physical models and computer generated images of buildings. But the advantages of full immersion, involving visual, acoustic, and haptic senses remain widely unexplored. The blue-c system will provide the technology for a variety of new collaborative design, management and refinement procedures between the architect, his customer and third-party experts.

Next Generation Product Development

A new generation of development environments will emerge in the near future. The underlying metaphor is a virtual space which is adaptable to various scenarios and to different stages of the product development process. A network of globally distributed development spaces enables engineers and product managers, field technicians and sales consultants to meet and collaborate in one common virtual environment. We envision the blue-c technology as the product design space of the future.

Computer-aided Medicine

Collaborative diagnosis and telepresence open new possibilities in the field of computer-aided medicine. Remotely located experts can participate in the diagnostic process. Highly immersive virtual environments allow researchers and medical students to take interactive journeys into the human body. The unprecedented quality of natural human interaction in a distributed environment makes of the blue-c system an essential tool for future remote collaborative diagnosis.

Blue-c is designed by an interdisciplinary team of researchers, including people from the several ETH institutes.

Links:
Project home page:
http://blue-c.ethz.ch/

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Augmenting the Common Working Environment by Virtual Objects

by Wolfgang Broll

While people are used to interact in their natural three-dimensional environment, they often face difficulties to work efficiently using 3D applications. This especially applies for unskilled or inexperienced users. The Virtual Round Table is a new innovative collaboration environment enhancing the user's workspace by virtual 3D objects. It provides a basis for natural 3D interaction by using real world items as tangible interfaces for virtual world objects. Thus intuitive collaboration between multiple participants is supported without sustaining existing communication skills.

In order to give a large number of people access to 3D technology to improve their daily working environment, interacting in a 3D environment should be as intuitive as interacting within the real world. The Virtual Round Table tries to realise an environment, which provides the basis for intuitive collaboration. It extends the users, physical environment by artificial 3D objects. This approach allows us to represent even complex dependencies within the common working environments providing the basis for a collaborative planning and presentation environment. The Virtual Round Table realises this environment using a location independent and inexpensive approach.

Simple Virtual Round Table scenario in the area of urban planning.

The Virtual Round Table allows all participants of a work group to stay and to act in their natural environment. Additionally familiar verbal communication and interaction are not restricted by the system. Intuitive interaction is a central aspect for the user,s acceptance of the system. Combining real and virtual objects into a conceptional unit enables users to intuitively grasp and re-arrange virtual objects. Thus the Virtual Round Table emphasizes common collaboration and cooperation mechanisms within regular meeting situations and extends them by arbitrary virtual scenarios (see Figure).

Visualization

The visualization of a synthetic scene within a real world working area is realised by using see-through projection glasses. Thus each user receives an individual visual impression of the work space that includes both, physical as well as virtual objects. The visualization of an individually adapted stereoscopic view for each user is realized by the multi-user virtual reality toolkit SmallTool. In order to provide a seamless integration of the real and virtual world, the virtual view of each user has to be visualised according to his or her current real world location and viewing direction in real-time. This requires a continuous tracking of the user,s head position and orientation. Due to the high sensitivity of the human vision system, the device,s position and orientation detection mechanisms have to be highly accurate. Moreover, the device should be insusceptible against external ascendancies.

Our current prototype is realised on PCs with high-end stereo-capable graphics accelerators. User head tracking is provided by an InterSense Mark 2 tracking system. However, this tracking device does not fulfil the requirements of light-weight and non intrusive system. Thus a sourceless and wireless six degree of freedom inertial tracking device based on the existing MOVY prototype is developed.

Tangible Interfaces
In our approach we use real world items as natural tangible interfaces for 3D interactions. By associating manipulable virtual objects with arbitrary physical items, we create an intuitive interaction mechanism. This interaction mechanisms allows users to interact with virtual 3D objects similar to real world items. It is realised by directly mapping the items, position and orientation to the appropriate properties of the associated virtual object. The superimposition and synchronization of the real items with virtual objects leads to a fusion of the artificial object and its physical reference into a symbiotic unit. These interaction units allow users to interact on virtual objects directly and naturally.

This requires an additional mechanism in order to recognise and track the position and orientation of these real world items. Since we do not want to use designated representatives based on markers or attached sensors, we use a computer vision based approach. Real world items are tracked by analysing video images of head-mounted or fixed cameras. Our first approach is based on simple pattern and luminance detection. Future developments however, will use feature vectors for object recognition and localisation.

Application Areas
We currently evaluate the Virtual Round Table environment in the area of collaborative planning applications. This includes the planning of events such as concerts, fairs, theatre plays and product presentations. Other application areas are architectural design, urban planning, disaster management (eg coordinating action forces for forest fires) as well as cooperative simulation and learning environments.

Conclusions and Future Work
Natural interaction mechanisms are facilitated by using real items as tangible interfaces to virtual objects, without restricting the users, common interaction and communication mechanisms. In our future work we will elaborate these interaction units and evaluate multi-modal interaction mechanisms. We will extend the inertial tracking device to support six-degrees-of-freedom and enhance the computer-vision based system.

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Levels of Detail in Physically-based Real-time Animation

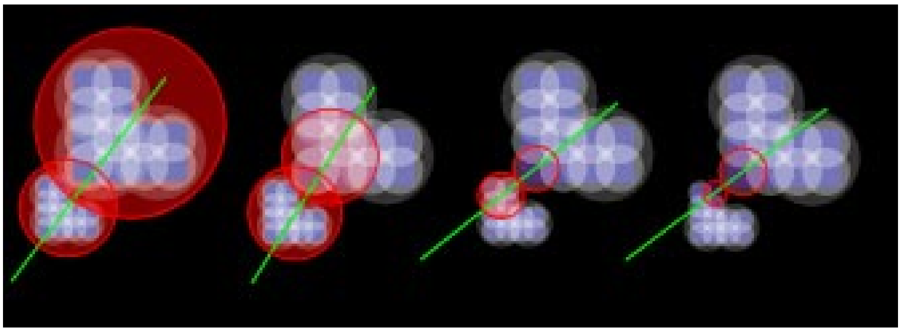
by John Dingliana and Carol O'Sullivan

The demand for realism in interactive virtual environments is increasing rapidly. However, despite the recent advances in computing power, it is necessary to make certain simplifications, sacrificing accuracy in order to meet the demands of real-time animation. An ongoing project at the Image Synthesis Group (ISG) in Trinity College Dublin (TCD) addresses the problem of optimizing this speed-accuracy trade-off by using adaptive processes for computationally intensive tasks such as Collision Detection.

Physically-based modelling concerns itself with emulating the properties and behaviours of objects in the real-world. Objects in a physically based virtual environment interact with each other based on rules that are modelled on the laws of physics. Unfortunately, given the finite nature of machines in comparison to the infinite complexity of the physical world, we must always accept that no matter how detailed our model, it will be at best an approximation. This is particularly true in the case of real-time animation where the requirement is to produce frames on the fly at a rate of at least 20 per second. Current work at TCD addresses this problem by using adaptive, time-critical algorithms to deal with some of the more computationally-intensive processes in the production of an animation.

A naive approach to ensure real-time frame rates would be to simplify the scene to such a degree that it would always be possible to perform the necessary calculations involved in producing each frame of an animation. However, it is frequently the case, particularly in interactive animations, that the complexity of a scene will change significantly over time. Such pre-emptive simplification, based no doubt on worst case scenarios, is usually excessive as we would end up simplifying the entire animation for the sake of what is likely to be relatively fewer snapshots of high complexity. It would be more desirable to be able to dynamically adapt levels of simplification based on the workload at every stage of the animation. Even better would be if we could strategically simplify, in every frame, certain parts of the scene that were less important.

One consistently time-consuming part of physically-based animation is detecting and handling the case where two or more



Collision Resolution at different levels of Detail. Image shows the results of interrupting the collision handling process at different stages. Red spheres indicate the nodes which will be treated as colliding. Green lines indicate the direction in which impulses are finally applied.

objects in the simulated world come into contact. It is often through such events that the user is able to interact, directly or indirectly, with the environment. Thus, it is important that the effect of such events is modelled accurately as it will significantly impact upon the believability of the animation from the user's perspective. On the other hand, such events are not only quite frequent but also require a large amount of processing time to deal with appropriately. It seems apparent that collision handling is one of those processes where significant gains can be made by carefully balancing the speed-accuracy trade-off.

We employ an approach which uses hierarchical multi-resolution volume models to represent objects in the scene. This is an approximation of an object's volume at different levels of detail and is separate from the model used in rendering the object. The volume model is used instead in calculations involving the objects state and behaviour in the virtual world. Typically, it consists of unions of simpler volumes (eg spheres) which are stored in hierarchical tree structures so that it is possible to localize which part of colliding objects are touching. The process of collision detection involves intersection tests using the volume models at different levels of detail, traversing the volume tree to get a better approximation of the actual contact points. Interrupting this tree traversal at different stages allows us to obtain approximations of the contact at different levels of accuracy. Thus, we can not only process individual frames but also individual objects in a single frame at different levels of detail.

Collisions in a scene are prioritised based on their potential effect on the believability of the animation. A scheduler deals with collisions based on their perceptual importance, allocating more time to the processing of higher priority collisions. Criteria for judging the importance of particular objects are based on paychophysical tests to determine the effects of states and conditions which might affect user-perception of collisions.

Ongoing Work

A library for adaptive collision detection and response entitled ReACT (Real-time Adaptive Collision Toolkit) is currently under construction and will allow the low level procedures for collision handling to be used in more specific applications. Extensive user-tests have been performed to determine user perception of collisions, and an eye-tracking device is being used to track which collisions a user is looking at. Further user tests will be undertaken with the specific goal of determining the perception of collision response. More efficient volume representation schemes using heterogeneous unions of subvolumes are also being investigated. All of this goes towards the goal of optimising the speed accuracy trade-off whilst guaranteeing real-time animation.

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Static Solution for Real Time Deformable Objects With Fluid Inside

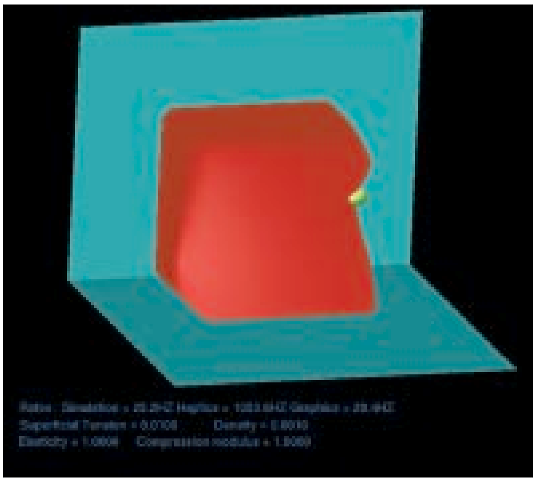
by Ivan F. Costa and Remis Balaniuk

Long Elements Method (LEM) is a new method for physically based simulation of deformable objects, suitable for real time animation and virtual environment interaction. The approach implements a static solution for elastic global deformations of objects filled with fluid based on the Pascal's principle and volume conservation.

Physically based simulation of deformable objects is a key challenge in Virtual Reality (VR). LEM was conceived for soft tissue real time simulation, particularly for surgical simulation. The priorities in this kind of application are: unrestricted multi-modal interactiveness, including interactive topological changes (cutting, suturing, removing material, etc), physically based behavior, volumetric modelling (homogeneous and non-homogeneous materials) and scalability (high accuracy when needed). The choices made to define the method were driven by these priorities.

The approach is based on a static solution for non-linear elastic deformations of objects filled with uncompressible fluid, what is a good approximation for biological tissues. The volumes are discretised in a set of Long Elements (LE), and an equilibrium equation is defined for each element using bulk variables. The set of static equations plus the Pascal principle and the volume conservation are used to define a system that is solved to find the object deformations and forces.

The discretisation adopted by the method, based on the long elements, has two main advantages: the number of elements used to fill an object is one order of magnitude less than in a discretisation based on tetrahedric or cubic elements; the graphic and the haptic feedback can be directly derived from the elements, and no intermediate geometric representation is needed. The use of static instead of PDE equations avoids all the problems concerning numerical integration, ensuring stability for the simulation.



Soft tissue (cube) touched by a rigid probe (sphere).

No pre-calculations or condensations are used, in order to enable real time topology changes. The idea is to fill the volume with long elements, to define equilibrium equations for each element based on the stated principles and to add global constraints in order to obtain a global physical behavior.

Different meshing strategies can be conceived to fill the objects. We use Cartesian meshes. The long elements are parallel to the Cartesian axis and cross the object. One mesh defines one deformable face for the object. Multiple meshes can be combined to obtain a full 3D deformable object.

A long element can be compared to a non-linear spring fixed in one extremity and having the other extremity attached to a point in the movable object surface. These springs are relaxed when the solid is not touched (not deformed). The spring constant depends on its length. A long element does not occupy real space and has no mass. The real space inside the solid is occupied by some incompressible fluid with mass (density).

To re-establish the only one entry solid, two border conditions are applied:

- Pascal's principle says that an external pressure applied to a fluid confined within a closed container is transmitted undiminished throughout the entire fluid
- The fluid is considered incompressible. It means that the volume conservation must be guaranteed when there is some external contact to the object. The volume dislocated by the contact will cause the dislocation of the entire surface, or in other words, the variation of volume due to the elements touched by the contact have to be equal to the sum of the volume created by the dislocation of all untouched elements to ensure the volume conservation.

LEM was used to implement a generic soft tissue VR simulator. The simulator was implemented in C++ in a Windows NT platform. The system main modules are:

- Model definition: the geometry and the physics of the objects to be simulated are defined using available information. This information can be derived from segmented real data or from intermediate models. The volumes are meshed to define the long elements.
- Simulation loop: solves the system equations to obtain the deformed shape of the objects.
- Rendering loops: graphic and haptic loops enable the interaction with the objects.

In a standard dual 700MHz PC one iteration of the simulation loop takes about 0.05 seconds for a 600 elements mesh. Note that a given discretisation in our method gives far more precise deformations than the same number of tetrahedra or cubes in a standard mesh. The global deformations are physically consistent and important phenomena such as the movement of all parts of the solid due to the preservation of volume are automatically produced. The method presented in this paper is intended for being part of a more general VR simulator. The method solves the deformation problem in an elegant and simple way, independently of other simulation aspects as movements (translation, rotation, dynamics integration, etc), topology changes and collision handling. To obtain a generic simulator the LEM must be integrated to methods suitable to handle these aspects. To add movements to the simulated objects we intend to implement a skeleton-like structure inside the object and to base the dynamics estimation on it. Larges deformations, as twisting and bending will be then possible.

To facilitate modelling and collision detection we intend to couple the LEM to implicit or parametric surface methods. The deformations of the model will be simulated in a set of LE meshes defining deformable 2D sheets and rendered as a 3D volume through an implicit of parametric formulation of the object shape.

The transformation from 2D sheets to 3D surfaces can be done using texture mapping techniques. Topology changes are typically task-oriented and use task-specific interfaces. We intend to implement a surgical interface based on medical procedures (cutting, suturing, removing material, etc).

The method can also be useful to validate and to adjust estimated biomechanical parameters in biologic tissues. Experimental data can be compared to simulation results.

The project is carried out among the SHARP research groups at INRIA, CATSS-Stanford University-USA and Catholic University of Brasilia-Brazil.

Links:
Sharp Research Group at INRIA:
http://www.inrialpes.fr/sharp
CATSS-Stanford University, USA:
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Exploring Virtual Prototypes using Time-Critical Rendering Techniques

by Enrico Gobbetti and Riccardo Scateni

Scientists at CRS4, the Center for Advanced Studies, Research and Development in Cagliari, Sardinia, Italy, have developed a time-critical rendering algorithm that relies upon a scene description in which objects are represented as multiresolution meshes. In collaboration with other European partners, this technique has been applied to the visual and collaborative exploration of large digital mock-ups.

When undertaking a large and lengthy engineering or architectural project, it is vital to verify frequently the possible consequences of decisions taken during the design phase. The aim of virtual prototyping research is to allow architects, engineers and designers to work on digital mock-ups which simulate the visual appearance and behaviour of objects on a computer. The expected benefits of virtual prototyping technology include: a substantial reduction in development time and manufacturing costs, thanks to a reduced need for expensive physical mock-ups; the ability to maintain digital mock-ups in sync with the design, and therefore the possibility to use them for documentation and to help the dialogue between engineers from different fields talking about the same thing, even though they may use different terms; the possibility of using mock-ups during collaborative design sessions among geographically distant partners, a very difficult option when using physical prototypes.

Time-critical Rendering

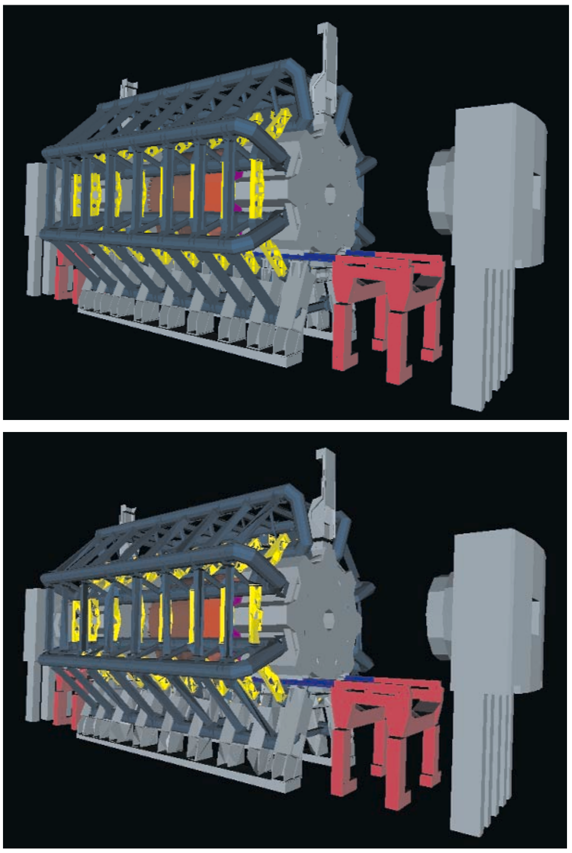
As for all virtual reality applications, virtual prototyping systems have very stringent performance requirements: low visual feedback bandwidth can destroy the illusion of animation, while high latency can induce simulation sickness and loss of feeling of control. Since virtual prototyping tools have to deal with very large dynamic graphic scenes with a complex geometric description, rendering speed is often a major bottleneck. When converted to an adequate accuracy, virtual prototypes often exceed the millions of polygons and hundreds of objects, and this poses important challenges to application developers both in terms of memory and speed.

Since the complexity of a scene from a given view-point is potentially unbound, meeting the performance requirements of the human perceptual system requires the ability to trade rendering quality with speed. Ideally, this time/quality conflict should be handled with adaptive techniques to cope with a wide range of viewing conditions while avoiding worst-case assumptions. The presence of moving parts and the need for interaction between virtual prototyping tools limits the amount of pre-computation possible, implying a run-time solution.

Time-critical rendering of scenes composed of many objects is an open research area. The traditional approach towards rendering these scenes in a time-critical setting is to pre-compute a small number of independent level-of-detail (LOD) representations of each object composing the scene, and to switch at run-time between the LODs. This technique has multiple drawbacks, both in terms of memory requirements, because of the need to store multiple level-of-details (LOD), and quality of results, because of the NP-completeness of the problem. We recently demonstrated that these drawbacks can be overcome when using appropriate multiresolution data structures (TOM, Totally Ordered Mesh) which make it possible to express predictive LOD selection in the framework of continuous convex constrained optimization.

Visual Exploration

Our time-critical multiresolution scene rendering algorithm has been implemented and tested on both UNIX and Windows platforms. The TOM data structure is integrated in a collaborative virtual prototyping system developed in the framework of the ESPRIT project CAVALCADE (#26285, 1/1998-2/2000).



A view of the whole ATLAS Experiment Pit. Comparison between full (top, 1,072,858 triangles) and adaptive resolution (bottom, 41,487 triangles).

All software modules are integrated in an in-house walkthrough application. We experimented with the system using multiple massive datasets, including the digital model of a very large machine (ATLAS) that is under construction at CERN in Geneva. When completed, this will be the largest machine for High Energy Physics in the world.

The results obtained suggest that our approach can be usefully employed for visual analysis at an early stage in the design phase of complex engineering or architectural models. It can handle scenes totaling millions of polygons and hundreds of independent objects on a standard graphics PC. In a controlled environment, it guarantees a uniform, bounded frame rate even for widely changing viewing conditions. The technique does not rely on visibility preprocessing and can be readily employed on animated scenes and interactive VR applications.

We believe that ultimately a time-critical rendering system should combine algorithms such as ours with occlusion culling, image-based rendering and other acceleration methods. The system should automatically partition the scene, choosing the most appropriate methods for different sets of objects based on cost/quality considerations and algorithm constraints. All these technologies have to be integrated in the same rendering context. This aspect is often neglected in current research. Integration is made more complex by the fact that dynamic LOD and visibility culling often have different time constraints.

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Haptic Rendering of Molecular Properties

by Aleš Křenek and Luděk Matyska

In 1998, a complex research project on human-computer interaction was started at the Masaryk university. One of its major streams focused on the development of new methods for efficient examination and extraction of principal features from large data sets produced by chemical computations. These methods are based on the interaction via haptic interface.

Many interesting chemical properties are function of force, which is usually understood to be a space gradient of potential energy. Visualization techniques represent force via 2D or 3D diagrams enhanced by use of colour, ie, user must translate visual phenomena to her internal force representation. The use of haptic interface opens a completely new dimension, when force (as potential gradient) can be represented and felt directly, without any unnatural transformation. Moreover, our physical experience makes it easy to mentally integrate the force, keeping a notion of the overall energy of the system as a consequence.

The idea is currently explored on computational results of a heuristic systematic search through conformational space of flexible biomolecules. Used method of the heuristic search was also developed at Masaryk University, where computational chemistry belongs among its well established research areas. The method was implemented as a production software package, currently consuming about 30% computational resources of the University's supercomputing center. Numerous papers were published on the method itself and results achieved.

Let's demonstrate the principle on a simple example of the dichloroethan (see Figure 1). The molecule is flexible, ie, its top part can rotate relatively to the bottom one along the vertical axis. The binding enthalpy (ie, a measurable and computable quantity corresponding, more or less, to internal energy) depends on the angle of rotation, as shown in Figure 2. The difficulty to overcome the rotational barrier can be directly related to the force necessary to move a point along the curve in the figure.

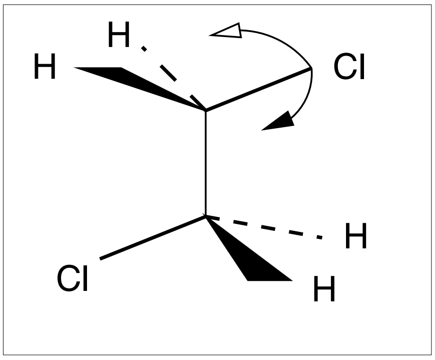

Figure 1: Dichloroethan - flexible bond.

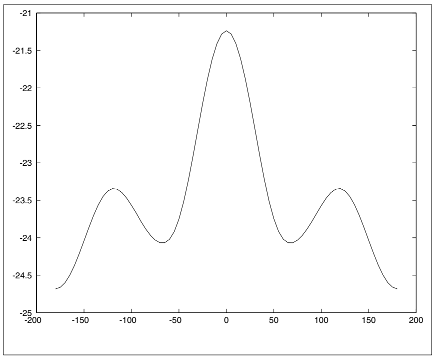

Figure 2: Dichloroethan - binding enthalpy.

The principal goal of this research is design of a haptic interface that allows the user to modify shape of a molecular model (eg, to rotate a particular bond) while 'feeling' the required energy via force resistance. In the example above the user can twist the model feeling resistance when the atoms get aligned vertically, maximal force corresponds to perfect alignment of the chlorine atoms.

A prototype application we presented recently builds a van der Waals surface of the modeled molecule and lets the user manipulate a spherical probe of about hydrogen size. The probe can touch the surface and deform the model by rotating the flexible angles if appropriate force is delivered. This haptic interface is accompanied with 3D visualization of the process.

The implementation uses PHANToM force feedback device manufactured by Sensable, Inc. The application is distributed, runs in UNIX environment, using PHANToM Linux driver also developed at our site.

Driving a haptic device requires fast computation of the model - in order to create illusion of smooth surfaces etc., the force has to be recomputed at the rate 1— 3 kHz. However, a convincing dynamic molecular model requires energy minimalisation in each step. In general, such calculation cannot be done in the available time (300 us - 1 ms).

The current implementation therefore performs the energy minimalisation at much slower rate (typically once per several seconds) and interpolates among the results. The energy model is also restricted to narrow neighbourhood of local energy minima in order to further reduce otherwise impossibly high requirements on computational resources.

In future we plan to extend our research activity in the following ways:

- to build a more general framework for performing the exhaustive energy calculation completely off-line and provide more robust, fast and physically reliable interpolation methods of the results, - to extend the energy model to entire conformational paths. As a consequence let the user flip the molecule from one conformation to another
- to deploy multiple haptic devices, ie to achieve more than three degrees of freedom of the haptic interface. Also, we plan to develop new haptic interface based on circular motion.

To conclude, we introduced a general concept of delivering information on energy of a molecular model (as function of force) via haptic interface. We built a prototype application that supports the concept. However, as the science behind haptic interfaces is very premature, a lot of effort is still needed to fulfill the primary expectation, ie, to provide an effective interface to huge data sets emerging from scientific calculation.

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The Virtual Museum of Daily Life in 20th Century Bologna

by Maria Chiara Liguori, Donatella Vasetti, Maria Elena Bonfigli, Antonella Guidazzoli and Alessio Mauri

Museums of Daily Life are dedicated to the reconstruction of domestic interiors and the displaying of consumer goods and other items related to everyday life in a certain period in time. The MUVI project, partially sponsored by 'Bologna 2000', realizes a VIrtual MUseum of Daily Life in 20th century Bologna and has been conceived as an interactive Virtual Environment (VE) accessible through the Web and the Virtual Theatre of CINECA, Supercomputing Centre in Bologna.

Daily Life Museums, common in Anglo-Saxon countries, are non-existent in Italy. The high costs involved in attempting to preserve Italy's enormously rich cultural heritage mean that there are cost priorities which make the creation of new museums very difficult, in particular where this particular type is concerned.

However, the use of Virtual Reality and Interactive Computer Graphics can offer a satisfactory alternative solution by:

- overcoming all problems related to space needed for and availability of a collection of furniture and/or objects
- allowing a high level of multi-medial involvement through a simplified management of music, sounds and voices
- avoiding the staticity, in terms of space and time, of a permanent structure.

The MUVI project consists of the development of an innovative interface system (implemented using an XML-based markup language) for accessing a corpus of information related to reconstructed virtual environments. 3D models of domestic interiors and historical information are coded in order to allow the user to personalize the type of information he/she is given during a virtual tour in the Daily Life Museum.

Each user type accesses a tailored version of the VE built dynamically and interactively on the basis of his/her language, profile, particular interests, and level of competence and knowledge. There is no doubt that different users (tourists, students, researchers, etc.) have different interests and needs: for example a researcher needs a more detailed description than a simple visitor, who may have a stronger interest in anecdotes than in historical analysis.

The interface enables the user to choose which elements are to be visualized during the virtual visit. In this way, the user will be able to visualize only those virtual components in which he/she is interested eg architectural elements, objects and their contextualization, photos, magazine and TV adverts, TV films, recorded speeches, etc. Moreover, in order to provide the visitor with "interesting" background information, every 3D object is linked to a historical description of the resources on which the virtual reconstruction is based. In this case too, the user can personalize the type of information to be received, obtaining for example just the visualization of the virtual environment, or simple descriptions of the 3D objects or more

Figure: MUVI, virtual reconstruction of an Italian '50s kitchen.

details about the related resources or the historical hypothesis.

After studying two sample cases, a kitchen and living-room of the 1950s, the overall project plan was structured as follows:

- The first phase consists of the selection of the sources and the definition of the descriptive language, following a hierarchical structure that allows for different customer profiles and access platforms.
- The second phase consists of the definition of a methodology for the development of models – considering the descriptions of the sources given by the historians – and of the technical characteristics, necessary for a multi-platform employment.
- The last phase consists of the planning and the development of prototypes for the interactive visualization of the virtual environments developed. This will allow the applicability of the proposed language to be verified.

The instruments used in this multidisciplinary project, involving computer scientists, historians and 3D modelers, include:

- XML and Dublin Core - to encode the information compatibly with standards already in use in many international museums
- VRML and Javascript – to develop Internet acessible 3D models
- Multigen, Performer graphical libraries and Vega development environment – to create an immersive virtual environment accessible at the CINECA Virtual Theatre.

MUVI implements a new way to access a 'certified' corpus of 3D models and related historical information - that can be expanded over time – creating a Virtual Museum which can be personalised according to user profiles. The project for the first two rooms, the Italian kitchen and living-room of the Fifties, will end around June 2001.

Links:
The MUVI project: http://www.cineca.it/muvi/
CINECA's Virtual Theatre:
http://www.cineca.it/visit/virtualtheatre.html

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Augmented Reality – Seeing More

by Hellmuth Nordwig

Augmented Reality is the term given by research scientists to a completely new, fascinating technique which inserts additional information directly into our view of the real world. The Fraunhofer Institute for Computer Graphics Research IGD in Darmstadt is one of the participants in the ARVIKA pilot project sponsored by the German Federal Ministry of Education and Research BMBF, working on new technology that helps people to see more than what is visible in real life. ARVIKA creates future-oriented solutions for industry, in volving interaction between human beings and technologies.

In a decade's time it could be possible to take a trip in Augmented Reality. "Initial research work has been under way for three years in this field", reports one of the pioneers: Dr. Stefan Müller, head of the Visualization and Virtual Reality department at the Fraunhofer Institute for Computer Graphics Research in Darmstadt. Virtual, or computer-simulated reality, is already shaping the everyday work of architects, designers and planners of products and assembly processes. Before the prototype of a new car is built, for example, the engineers put the model and its assembly through the most diverse variants on the computer using CAD and CAM programs. Rather than on-screen, such imaging acquires much more realistic form if presented in a 'CAVE', the facility installed at the IGD for three-dimensional projections.

"The key aspect of Augmented Reality is to superimpose virtual worlds on top of the real view of an object", explains Stefan Müller. This is interesting wherever 3D digital data is already available as a result of the object being designed or dimensioned using a computer. Some exemplary scenarios indicate potential applications: In the assembly hangar at an aircraft factory: The assembly engineer is standing on the wing and routing the cables for the control surface electronics. The virtual assembly instructions show him step by step which

'Augmented Reality' can be used for training purposes as well as for assembly and maintenance work. Assembly instructions are displayed on 'data goggles', which allow the construction engineer to look at the real component and relevant information at the same time.

strand of cable has to be routed where. He has both hands free and does not have to keep getting down from the wing to study the layout plan.

In the operating theatre: The surgeon has the patient's medical parameters in view at all times and does not need to move his eyes away to look for data on monitors. In virtually planned heart or brain operations the surgeon can also reach the diseased tissue by precisely the route he has envisaged. This minimizes the risk for the patient.

In the office of a town planner or architect: What will be the least obtrusive site for a pedestrian bridge over the Thames near St. Paul's Cathedral? Does this lamp match the planned interior design, will it illuminate the required area? Such questions frequently crop up in practice but the answers to them are, unfortunately, normally not very reliable. Augmented Reality can prevent many a false move from the outset.

Augmented Reality technology requires many innovative technological solutions, of which some have been developed at the IGD. The key unit is a portable computer – not a cumbersome laptop, but an extremely powerful mini-computer, which can be attached to the user's belt – because car mechanics and surgeons need both hands when they are working. Then there are the data-glasses which in their simplest configuration consist of a transparent LCD. In another variant a tiny screen is attached to the frame of the glasses, from which information is directed to the lens. This lens is actually a transparent mirror which guides the information into the sight of the wearer.

Another alternative for the future could be 'Virtual Retinal Displays', in which the image is projected by laser straight into the eye.

Stefan Müller describes one of the main challenges for the IGD's research scientists: "We had to teach the computer in particular how to recognize where the user is looking". The best solution turned out to be a tiny camera fastened to the data-glasses and sending 25 images per second to the computer. This compares the image information with previously stored orientation points on the object and calculates the user's current position and line of vision.

Many details still remain to be solved. The range of applications is, however, simply limitless. More and more products and facilities are designed on computer nowadays, and it would be beneficial if planners could see how their ideas fit into the real environment. Augmented Reality is set to provide the missing link for Man-Machine-Interaction in the Knowledge-Based Society.

Links
http://www.inigraphics.net/publications/brochures/vr_ar.html.en

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Interactive Computer Graphics at Rutherford Appleton Laboratory

by Lakshmi Sastry, Gavin Doherty and Michael Wilson

The two major directions for interactive computer graphics research at Rutherford Appleton Laboratory are interaction with the graphical representation (how can users manipulate graphical representation in real time to gain insight, learn, to reach decisions, or to enjoy a game) and to establish a development methodology for computer graphics – as one would at any other piece of software engineering; considering efficiency and quality measures.

Earlier research tried to computerise what was very difficult for humans, and leave the rest to people since they were more plentiful and cheaper. Today, application designers take the reverse view: once the data is in the machine, leave the whole process to the application except when a human is absolutely required (for legal authorisation etc..), since machines are cheap and humans are expensive. This has a dramatic effect on interaction between the user and the system. Where the interaction used to be there to allow the user as much control and awareness of the process as possible, now the interaction is only required when there is something that that the machine can't do. Then the machine must present the state that it is in to the user for them to take on their role - which they must clearly understand.

In applications such as simulations for training we need to provide an environment that mimics reality sufficiently to allow learning in the simulation and promote transfer of that

Figure 1: The control room and radar of the EISCAT facility in Tromso, Norway.

Figure 2: The second target station to the ISIS particle accelerator at RAL.

learning to the real environment. In an example such as the EISCAT radar control room (see figure 1) we need to simulate the appearance of the radar, the building and control machines to provide visual cues, as well as the behaviour of the devices for interaction with the radar, and also appropriate feedback. When users push switches, or pull leavers they not only need to learn the sequence of abstract operations and their consequences for the radar and control system, but they need to move their hands and body in such a way that the physical control sequences they learn can be transferred to the real control room. They also need feedback to their actions through sight, sound and eventually touch to reinforce this experience.

Another application class that we develop to support scientists is that of building and experiment prototyping and design review. In this case a new experiment such as a particle accelerator target station may be being designed, where the building, main accelerator, target, and each of 20 experiments may each be designed by different design teams in universities around Europe. We can collect and integrate their designs into a single model, but then we need to get the designers to see where conflicts arise. For example, where the particle beam passes through a support pillar in the building - clearly impossible in the real world. To do this we need to use the graphics to facilitate group exploration of the overall design, and decision making among the designers. We currently do this in a 20 seat auditorium providing 3D stereo presentation for all, while one user controls the navigation and interaction with the model.

In both these examples we require a clear set of requirements of the geometry, appearance, behaviour and interaction required of the graphics in order to achieve the task objectives, and a methodology to implement and evaluate that the requirements have been met. In one current project with York and Bath universities that has been previously reported in ERCIM News (April 2000, page 49) we have started to develop such a methodology. A second project is developing a reference model for characterising continuous interaction techniques (see ERCIM News, January 2000, page 21) with Grenoble, Parma, Sheffield and Bath, universities, and DFKI in Germany, Forth in Greece and CNR in Italy. Despite this current activity, a great deal of further work is required to incorporate mappings from requirements on learning or group decision making down to implementable and evaluatable geometry, appearance, behaviours, interactions and feedback for sight, sound and touch that use the skills that humans have and machine's don't, and even won't given Moore's law.

Links:
W3C Scaleable Vector Graphics (SVG):
http://www.w3.org/Graphics/SVG/Overview.htm8
ISIS second target station:
http://www.isis.rl.ac.uk/targetstation2/
EISCAT radar facility:
http://www.eiscat.no/eiscat.html
INQUISITIVE project:
http://www.cs.york.ac.uk/hci/inquisitive/
TACIT Project: http://kazan.cnuce.cnr.it/TACIT/TACIThome.html

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Conceptual Free-Form Styling on the Responsive Workbench

by Gerold Wesche and Marc Droske

A two-handed styling system for free-form surfaces, which runs directly in a table-like Virtual Environment, called the Responsive Workbench, has been developed at GMD. The user sees the model in 3D through stereo glasses, which are electromagnetically tracked. Curves can be drawn directly in 3D using a tracked, pen-like input device, called stylus. The curves are connected automatically, such that a curve network develops. Inside the loops, surfaces can be computed. Intuitive curve and surface deformation tools hide the mathematical representation from the designer.

Many designers would like to sketch free-form shapes quickly in the conceptual design phase without using a complex CAD system. Projection-based Virtual Environments like the Responsive Workbench offer the following advantages for sketching applications over traditinal desktop interfaces:

- The three-dimensionality of perception in combination with 3D interaction allows an immediate understanding of the shape
- parts can be localized and selected directly in space
- the large, high-resolution projection plane allows the representation of objects on a scale which corresponds to the working region of both hands.

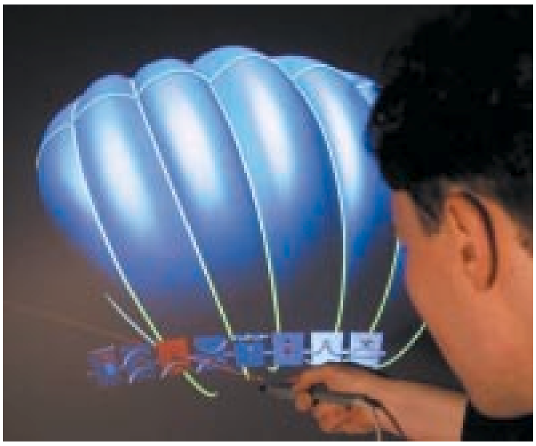

Figure 1: 3D free-form styling on the Responsive Workbench.

Our ambition is to support free-form styling capabilities on the Responsive Workbench. We provide the designer with intuitive deformation tools for curves and surfaces relying on familiar metaphors. Our basic approach is constructing curve nets by drawing cubic B-spline curves directly in space and creating surfaces inside the loops of the curve net, see Figure 1.

Features of the Modeler

In our system, cubic B-spline curves can be drawn freely in space. New curves are woven into the existing curve network automatically. If a closed loop of curve pieces has been formed, a surface patch can be created. We are using Catmull-Clark subdivision surfaces. A direct approach to modify the curves or surfaces of the network is to select individual control points and move them, changing the model locally. It is a very tedious task to bring the curve or surface into the desired shape with this technique. Higher level manipulation methods are needed, especially in a virtual environment.

Variational modelling techniques provide an elegant way of manipulating curves and surfaces. Attractors of intuitive behaviour can been defined, which minimize an energy functional and lead to fair and pleasant surfaces. Based on this technique, we developed the following intuitive operators, which can be applied locally or globally to curves and surfaces:

- smoother: curves can be smoothed out locally by pointing to the corresponding location directly in space. The curve is gradually smoothed out by moving the pointer along the curve until the desired shape has been achieved. In fact, this technique seems to be similar to applying a flat-iron. Currently, the pointing position cannot be changed for surfaces
- sharpener: this operation amplifies the details at the locations pointed to by the designer. It works in the same way as the smoother
- attractor: segments can be pulled towards a given direction, while local variations of the shape are maintained.

The non-dominant hand assists the modelling hand in drawing curves by controlling the position and orientation of a modelling coordinate system dynamically or by fixing it. Additionally, the non-dominant hand can control a virtual transparent drawing plane onto which curves are projected, or it applies symmetry planes globally or locally.

Future Work

The drawback of ‘interacting in the air’, which occurs particularly with regard to elastic deformations, will be attacked by integrating a large version of the PHANToM device into the workbench environment. In contrast to this, controlling the smoothing and sharpening tools described here works very well even without force feedback since the corresponding arm movements are rather indirect.

Conclusion

This article has presented a conceptual design system which supports the intuitive transfer of the design intent into virtual models. The tools are designed especially for free-form modelling applications in projection-based Virtual Environments. The modeler supports the quick input of surfaces by allowing the user to draw the primal curves of a model directly in 3D.

User studies have to evaluate the usefulness of the proposed techniques to suggest further improvements.

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Combining Operations Research and Constraint Programming to Solve Real-Life Scheduling Problems

by Philippe Baptiste

For a long time, Operations Research and Artificial Intelligence could be seen as alternative approaches to solve real life optimisation problems such as scheduling or resource allocation. It now seems clear that we can have the best of both worlds by some hybrid techniques embeded in a constraint programming framework.

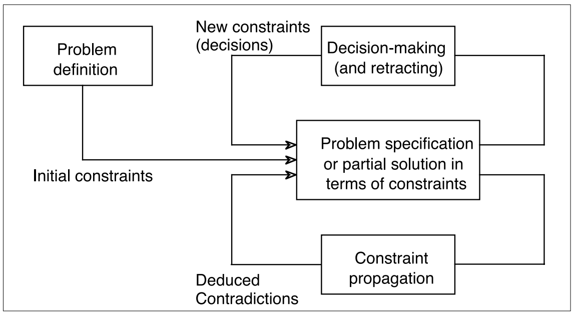
Scheduling, that can be defined as the process of allocating scarce resources to activities over a period of time, is the key point of many industrial problems. 'Good' schedules enable to make better decisions about how to commit resources, including equipment, capital, people, vehicles, facilities, etc. The problem of scheduling activities is a discrete optimization problem and therefore very hard to solve in practice (most of the scheduling problems are NP-Hard). To find good solutions or even solutions that meet all constraints, one has to explore a gigantic search space, most often exponential with the size of the problem. Because a brutal exploration of the search space is not possible, several techniques have been proposed in the past forty years, including Mixed Integer Linear Programming, Branch-and-Bound or more recently Constraint Programming.

Constraint programming is concerned with solving instances of the Constraint Satisfaction Problem (CSP). Informally speaking, an instance of the CSP is described by a set of variables, a set of possible values (domain) for each variable, and a set of constraints between the variables. The question is whether there exists an assignment of values to variables, so that all the constraints are satisfied. The interest of this technique lies in using constraints to reduce the computational effort needed to solve combinatorial problems. Constraints are used not only to test the validity of a solution, as in conventional programming languages, but also in a constructive mode to deduce new constraints and rapidly detect inconsistencies.

For example, from $x < y$ and $x > 8$, we deduce, if x and y denote integers, that the value of y is at least 10. If later we add the constraint $y \leq 9$, a contradiction can be immediately detected. Without propagation, the '$y \leq 9$' test could not be performed before the instantiation of y and thus no contradiction would be detected at this stage of the problem-solving process.

For complexity reasons, constraint propagation is usually incomplete. This means that some but not all the consequences of constraints are deduced. In particular, constraint propagation cannot detect all inconsistencies. Consequently, tree search algorithms must be implemented to determine if the CSP instance is consistent or not. The overall behavior of a constraint-based system is depicted on the Figure. The figure underlines the fact that problem definition, constraint propagation and decision making are clearly separated:

- first, the problem is defined in terms of variables and of constraints
- then, constraint propagation algorithms are specified. In practice the user of a constraint programming tool can use some pre-defined constraints (eg, constraints on integers, constraints on sets, scheduling constraints) for which the corresponding propagation algorithms have been pre-implemented
- finally, the decision-making process, ie, the way the search tree is built, is specified. It states how new constraints are added to the system (eg, instantiating a variable to a value, ordering a pair of activities).



The behavior of a constraint programming system.

The separation between constraint propagation and the other parts of the system is a key feature of constraint programming. It impacts a lot on the reusability of the constraint propagation algorithms in the several applications where similar constraints apply. This explains the success of commercial and public domain constraint programming packages such as ILOG SOLVER, CHIP, ECLIPSE, CLAIRE and ECLAIR.

The efficiency of constraint based scheduling applications could be drastically improved by using dedicated operations research techniques: On the one hand operations research offers efficient algorithms to solve problems that however might not be well suited to be used in practice, and on the other hand constraint programming offers algorithms that are more generally applicable, but that might suffer from somewhat poor performance. It now seems clear that the best of both worlds, ie, efficient algorithms that can be applied apply to a wide range of problems, can be reached by hybrid techniques. Following this idea, very good results have been obtained on several industrial applications such as Staff Planning, Vehicle Production Optimization or Job-Shop Scheduling.

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On-line Graph Coloring

by Jenő Lehel

Many variants of time tabling, sequencing, scheduling, and allocation problems boil down to the fundamental problem of partitioning a collection of objects into families according to certain requirements. Members of the Discrete Structures Group at SZTAKI initiated a natural model for a certain type of these practical questions in terms of chromatic graph theory.

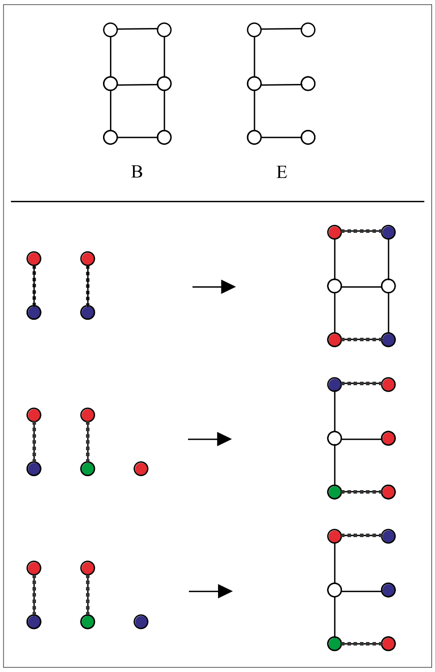
The scheduling of a set of tasks on parallel machines is a basic problem in combinatorial optimization. In certain applications, tasks are to be scheduled promptly and irrevocably without the complete knowledge of the input stream. The case in which a task must be processed in an uninterrupted fashion (the non-preemptive model), the scheduling on k machines becomes a question of coloring intervals or interval graphs on-line with k colors. An equivalent scenario of dynamic storage allocation due to Marek Chrobak and Maciej Slusarek, motivated us to introduce the notion of on-line coloring and on-line chromatic number of graphs or, more generally, families of graphs different from interval graphs. The research of the author with András Gyárfás (SZTAKI) and Zoltán Király (Loránd Eötvös University, Budapest) in this area over the last decade contributed to the development of classical graph theory with several noteworthy results and challenging open problems. Furthermore, it seems to have a certain impact on the theory of on-line algorithms, a recently outgrowing branch of combinatorial optimization.

The on-line chromatic number of a graph G is usually defined through a two-person game. The Drawer presents the vertices of G in some order together with adjacencies to vertices already given. The Painter assigns a legal color (positive integer) to the current vertex given. The aim of the Drawer is to force the Painter to use as many colors as possible and the aim of the Painter is to use as few colors as possible. The common optimal value is the on-line chromatic number of G. The most familiar on-line coloring algorithm is the First Fit (alias Greedy) algorithm which assigns the smallest proper color to the current vertex.

An on-line coloring algorithm is called on-line competitive against a graph family if there exists an upper bound on its performance in terms of the on-line chromatic number of the graphs in the family. Intuitively, it is a universal on-line algorithm with reasonable performance on every member of the graph family.

Against some graph families, for example against the family of trees, the First Fit coloring algorithm is an on-line competitive algorithm. However, this property does not hold in general: against the family of on-line 3-colorable bipartite graphs the First Fit algorithm is not on-line competitive.

An example shows that an on-line competitive algorithm against the family of 3-colorable bipartite graphs must use at least four colors: just consider the pair of graphs B and E in the Figure. The reader can easily check that each graph is on-line 3-colorable but the hint in the Figure indicates that 4 colors are needed if the Painter does not know in advance which one is presented by the Drawer, B or E. It turned out that this elementary example is the best possible one, moreover, there exists an on-line competitive algorithm using at most four colors against the family of all on-line 3-colorable ghraphs.



Drawer's strategy is indicated when playing on the pair of graphs B and E. Possible outcomes of Painter's on-line coloring are shown on the left after the first 4 or 5 moves, followed by Drawer's corresponding moves on the right to conclude the game by forcing 4 colors.

Many results in the theory of on-line graph colorings can be formulated in terms of on-line competitive algorithms. Some of these results demonstrate that against certain families of graphs these algorithms are competitive in a stronger sense (compared with off-line ones). The main open problem concerning on-line competitive algorithms is to decide whether there exists an algorithm like this against the family of on-line k-colorable graphs, for any fixed k. The answer is not even known for special graph families like the families of bipartite graphs, chordal graphs or even chordal bipartite graphs.

In addition to contributing to the development of recursive combinatorics, our research inspired some results of experts eg Hal Kierstead and William Trotter. Their earlier deep results on partially ordered sets have got a new interpretation in terms of on-line partitioning or coloring algorithms of graphs. The concept of on-line algorithms combined with graph theory turned to be a steady source of challenging new problems and led to a number of interesting graph theory results obtained by several competitive research groups. Our group is open for any further discussions.

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Boosting Algorithms for Automated Text Categorization

by Fabrizio Sebastiani, Alessandro Sperduti and Nicola Valdambrini

As part of its Digital Library activities, and in collaboration with the Department of Computer Science of the University of Pisa, IEI-CNR is working on the construction of tools for the automatic or semi-automatic labeling of texts with thematic categories or subject codes.

Text categorization (TC) uses machine learning (ML) techniques to build automatic text classifiers, ie programs capable of labelling natural language texts with thematic categories from a predefined set. TC has many applications, including automated document indexing for Boolean information retrieval systems, adaptive document filtering and spam e-mail blocking, Web page classification under hierarchical directories, and even author identification for documents of controversial paternity. In TC a general inductive process (called the 'learner') automatically builds a classifier by learning the characteristics of the categories from a 'training set' of preclassified documents. Once a classifier has been built, its effectiveness (ie its capability to take the right categorization decisions) may be tested by applying it to a 'test set' of preclassified documents and checking the degree of correspondence between the decisions of the automatic classifier and those encoded in the test set.

A wealth of different ML methods have been applied to TC, including probabilistic classifiers, decision trees, regression methods, batch and incremental linear methods, neural networks, example-based methods, and support vector machines. Recently, the 'classifier committees' method has gained popularity. The underlying idea is that, given a task that requires expert knowledge, several independent experts are better than one if their individual judgments are appropriately combined. In TC, this means applying several different classifiers to the same task of deciding under which category (or categories) a document should be classified, and then combining their outcome appropriately.

Boosting is a method for generating classifier committees which is characterized by state-of-the-art effectiveness and a strong theoretical grounding in computational learning theory. In the boosting method, the S classifiers that make up the committee are not trained in a conceptually parallel and independent way, as in other committee-based methods, but sequentially. In this way, when generating the i-th classifier the learner can take into account how the previously generated classifiers perform on the training documents, and can force the i-th classifier to concentrate on those training documents where the previously generated classifiers performed worst.

Each classifier is a one-level decision tree, ie tests for the presence or absence of a term in a document, depending on whether a positive or negative classification decision is taken. The term on which this decision hinges is generally different for each of the S classifiers and is chosen each time, according to a complex error-minimization policy. The key step of this policy consists in scoring each term by a scoring function, and picking the term with the smallest score. The scoring function adopted by the boosting method is extremely complex, and computationally onerous. As this computation has to be performed for each of the terms and this has to be iterated S times, boosting is a computationally expensive method (in typical TC applications both the number of terms and the number S of iterations are in the tens of thousands).

We have devised a new method, called AdaBoost.MH(KR), based on the construction of a sub-committee of classifiers at each iteration of the boosting process. Instead of using just the best term, as the standard AdaBoost.MH(R) algorithm does, we select the best K terms, and generate K classifiers, grouping them in a sub-committee. This idea comes from the observation that, while in the first iterations (ie in the generation of the first classifiers) the scores of the best terms are markedly different from each other and from the worst ones, in the last iterations the differences among scores are very small. In AdaBoost.MH(KR) we choose, at each iteration, K top-ranked terms that would be good candidates for selection in the next K AdaBoost.MH(R) iterations. We can thus build a committee composed of S sub-committees at a computational cost comparable to that required by AdaBoost.MH(R) to build a committee of S classifiers. In fact, most of the computation required by the boosting process is devoted to calculating the term scores, and by using only the top-scoring term AdaBoost.MH(R) exploits these hard-won scores only to a very small extent.

In all our experiments (conducted on the standard Reuters-21578 benchmark), AdaBoost.MH(KR) achieved better effectiveness and much better efficiency than AdaBoost.MH(R). For instance, in one experiment the effectiveness achieved by AdaBoost.MH(KR) with 300 iterations was not obtained by AdaBoost.MH(R) in 16,000 iterations. AdaBoost.MH(KR) is more effective than AdaBoost.MH(R) because of the latter's 'greedy' approach when selecting the best classifier for the final committee. This approach does not guarantee optimality of selection, and AdaBoost.MH(R) is unable to search the classifier space. On the contrary, AdaBoost.MH(KR) allows the designer to explore, at least partly, the space of classifiers by setting its internal parameters (eg number of classifiers in each committee) to different values or according to different policies.

Links:
http://faure.iei.pi.cnr.it/~fabrizio/Publications/CIKM00/CIKM00.pdf

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Pattern Formation in Electric Discharges

by Ute Ebert

If a material that normally does not conduct electricity, is exposed to strong electric fields, it can develop complex patterns of conducting areas, through which it 'discharges' the field. A group at CWI studies both fundamental and applied aspects of such patterns, in particular in so-called streamer and barrier discharges. The results can be used for combustion gas cleaning, ultrafast power semiconductor switches or for flat computer screens.

Electric discharges (sparks) appear on a variety of length scales: in nature between a cloud and the ground (Figure 1 shows man-made lightning across about one meter), in the sparkplug of a car engine, or in computer chips. Sparks or their precursors, the so-called streamers, are also used for, eg, combustion gas cleaning (see Figure 2), or water purification. Streamer-like discharges in doped layered semiconductors can be used for ultrafast switching of high power electric circuits.

Stationary discharges are also possible, the best known example being the neon tube. Since a discharge is a nonlinear process that easily can form patterns, the homogeneous and stationary glow of the neon tube is by no means trivial, and stays a continued challenge in the development of new energy saving and special purpose light sources, eg, at Philips. Figure 3 shows generic instabilities that can occur in such glow discharges. Particular effort is presently devoted to the development of so-called plasma display panels: flat and bright computer or TV screens operating essentially like an array of rapid, microscopic neon tubes.

The enormous increase of electric conductivity in a discharge is due to the multiplication of free charge carriers by an approximately local ionization reaction. It persists as long as the local electric field is high enough. However, conducting matter can redistribute its space charges and hence modify the externally applied electric field. Depending on the spatial distribution of the ionized areas, the ionization reaction then is enhanced at some places and suppressed at others. This nonlinear dynamical coupling of ionization and electric field accounts for the spatio-temporal patterns observed in discharge experiments. In some applications like combustion gas processing or spark plugs, pattern formation is the operating mode, while in others like light sources or ultrafast semiconductor switches, the onset of pattern formation limits the range of applicability.

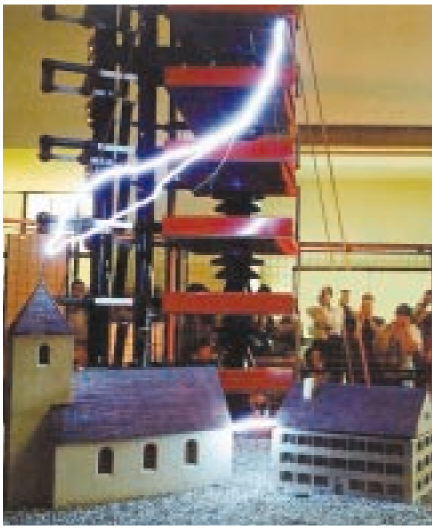

Figure 1: Spark demonstration at the 'Deutsches Museum München'.

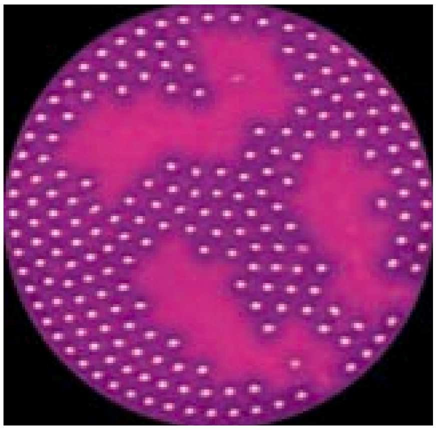

Figure 3: Generic instabilities in ac barrier glow discharges with wide coplanar electrodes seen from above (I. Brauer and H.-G. Purwins, Univ. Münster). Here areas with homogeneous glow and areas with spontaneous glow filamentation coexist.

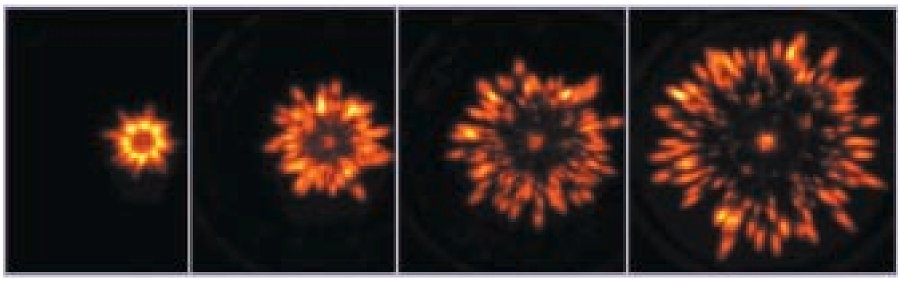

Figure 2: Temporal evolution of a streamer discharge within nanoseconds in a combustion gas processor at the TU Eindhoven [P.P.M. Blom and E.J.M. van Heesch]. The picture is taken on the axis of the electrode wire, and the maximal radius of the discharge is about 10 cm.

There is a surprising universality in the set of partial differential equations describing discharge phenomena in different materials. They are of comparable simplicity and generality as, eg, the Navier-Stokes-equation in hydrodynamics. Nevertheless, despite the enormous economical importance of discharge technologies, very little is known about basic solutions of the fundamental equations. However, recent developments in the theory of nonlinear partial differential equations and nonlinear dynamics promise that progress can be made in unravelling these features.

At CWI the basic laws of propagation of the ionized streamer channels — that can be seen in Figure 2, and that have preceeded and determined the spark in Figure 1 — are studied analytically and numerically. A basic insight is a strong mathematical analogy to patterns formed in viscous fingering or in the growth of crystals from undercooled melts. Another study concerns ultrafast high-power semiconductor switches that operate in a streamer-like manner. Applications are found in radar and laser technology, for example a possible new generation of GaAs pulsed lasers. This is a collaboration with the Ioffe-Institute in St. Petersburg that is internationally leading in the production of these switches, and is headed by Nobel laureate Z.A. Alferov who received the prize for the invention of the semiconductor GaAs laser last fall. A third project concerns the basic instabilities in barrier discharges as in Figure 3. Barrier discharges consist of a sandwich structure of electrode, resistive layer, glow discharge and electrode, driven by dc or ac voltage. The mechanism of pattern formation is only partially understood, and we work on quantitative predictions of its onset and structure. Here mathematical analogies, eg, with temperature driven convection in fluids or with chemical systems are exploited.

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Design of Efficient Input/Output Intensive Data Mining Applications

by Ranieri Baraglia, Domenico Laforenza, Salvatore Orlando, Paolo Palmerini and Raffaele Perego

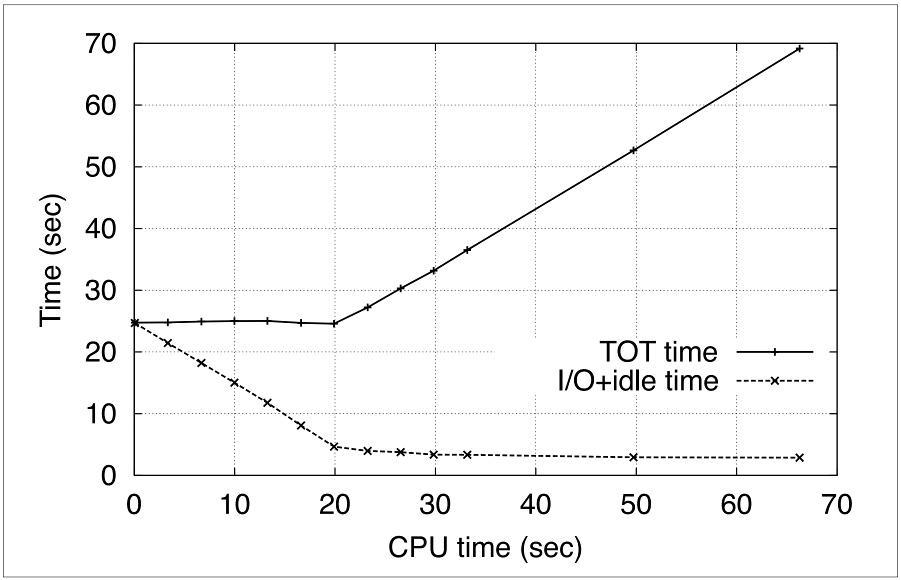
The goal of Data Mining is to discover knowledge hidden in data repositories. This activity has recently attracted a lot of attention. Because of the huge datasets to be accessed, most data mining algorithms must consider the I/O actions carefully, hiding or minimizing their effects. At CNUCE-CNR we are studying how the architectural features of modern high performance computers and operating systems can be exploited when designing efficient data mining algorithms that can cope with huge datasets.

High energy physics experiments produce hundreds of TBytes of data, credit card companies hold large databases of customer's transactions, web search engines collect web documents worldwide. Regardless of the application field, Data Mining (DM) allows to 'dig' into huge datasets to reveal patterns and correlations useful for high level interpretation. Finding clusters, association rules, classes and time series are the most common DM tasks. All require the use of algorithms whose complexity, both in time and in space, grows at least linearly with the database size.

In recent years much R&D has been focused on the design of hardware and software systems that can cope with the growth in the dimensions of the data. Nevertheless, the amount of physical memory of modern computers is still in orders of magnitude lower than the size of many databases. Various strategies can be applied to address this problem. One approach investigates the development of new algorithms that reduce the need for data, either by exploiting sampling techniques or by limiting direct access to the database. These methods usually introduce some inaccuracy or useless CPU overhead. Another possibility is the exploitation of High Performance Computing Systems, which can extend the range of applicability of DM algorithms, without changing the conceptual limitation.

Many DM algorithms require a computation to be iteratively applied to all records of a dataset. In order to guarantee scalability, even on a serial or a small scale parallel platform (eg a workstation cluster), the increase in the I/O activity must be carefully taken into account. We have recognized two main categories of algorithms, with respect to the patterns of their I/O activities: Read and Compute (R&C) algorithms, which use the same dataset at each iteration, and Read, Compute and Write (RC&W) ones, which, at each iteration, rewrite the dataset to be used at the next step. A typical reason for writing a new dataset is to 'prune' the original one.

The first class includes Clustering algorithms, such as 'k-means', or Frequent Set Counting (FSC) algorithms,



The result of an experiment implementing an R&C problem. Total execution time and I/O+idle time are plotted, varying the computational grain.

such as 'Apriori', while the second class covers some variants of 'Apriori', like the Direct Hash and Prune (DHP) algorithm, or the C4.5 algorithm for classification.

Modern operating systems (OS) provide effective mechanisms to access secondary storage units. While highly local problems can exploit OS caching and prefetching policies, the OS may fail to efficiently handle data movements through the levels of the memory hierarchy. The employment of 'Out-of-Core' (OOC) techniques which explicitly take care of data movements is thus often a must for performance reasons. Another important OS feature is time-sharing among processes. Multi-threading can be used to overlap I/O actions with useful computations.

We have demonstrated that it is possible to take advantage of such features in order to design efficient OOC DM algorithms that hold all the data on disk, and that these algorithms can be effectively scaled by exploiting High Performance Computing Systems, such as a cluster of Symmetric Multiprocessors (SMPs). The main results are summarized in the following points:

- In R&C DM algorithms we find that OOC techniques perform better than the in-core counterparts. This is mainly because data locality can be exploited and I/O actions can be overlapped with computation. The figure refers to a synthetic kernel code inspired by this class of DM algorithms. In this kernel, we scan a file of 256 MB sequentially, reading blocks of 4 KB. We artificially varied the granularity of the computation performed on each block of data. When the total CPU time is greater than 20 s, the I/O and idle waiting times become negligible due to the prefetching OS activities. We discovered that most of the interesting DM problems belonging to the R&C class can be solved by algorithms characterized by high granularities; this means that our OOC techniques are able to completely hide I/O overheads.
- Multi-threading used as a general technique to hide I/O waiting time may conflict with prefetching, another technique independently adopted by the OS to reduce the impact of I/O when files are accessed sequentially. We developed techniques to take advantage of both multi-threading and prefetching when implementing OOC DM algorithms.
- On clusters of SMPs, data parallel approaches have been used to parallelize these OOC DM algorithms by partitioning data among the machines of the cluster. This makes it possible to scale-up the system since storage and computation power are increased, and to exploit a larger I/O bandwidth since multiple disks interfaced with multiple buses are employed. We also developed dynamic techniques, such as load balancing and adaptive modification of the degree of parallelism, to take into account system heterogeneity and improve system utilization.

Our next goal will be to extend the DM set of algorithms tested against the general results found so far. We are now studying a classification algorithm for building decision trees and algorithms for data mining on the Web. We intend to build a set of methodologies for DM I/O intensive algorithms, characterized by application independence and run time adaptability. The methodologies should be implemented as a general tool in an Application Programming Interface.

Links:
http://miles.cnuce.cnr.it/~palmeri/datam

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Signware – A Learning Platform in Biology for Pupils with Hearing Difficulties

by Kathrin Bolits

The project Signware is developed in conjunction with a diploma thesis at GMD and the University of Cologne to implement concepts and realisation of a learning platform. Signware is aimed to form a part of the regular curriculum, at secondary high school level for pupils with hearing difficulties. The content subject of the learning tool is biology with the main theme focusing on 'blood' in general.

Signware in a nut shell is an interactive software tool which enables pupils with hearing difficulties to learn about 'blood' at large. The main element of Signware is the visualization of the German Sign Language (DGS), coupled with computer animations to motivate the user. It is well known that interactivity greatly enhances the level of reception. To cater for the special requirements of the users and their limited abilities through audio perceptions, the visualization as well as cognitive, motoric and social-emotional aspects are the constituting the essential parts of Signware.

To understand the communication problems of individual with hearing difficulties, it is essential to know that they have to keep their attention on three aspects during a discussion:

- language perception which is disturbed according to the degree of the hearing damage
- language processing (meaning the cognitive aspect about what to say)
- language production (meaning the motoric aspect of talking).

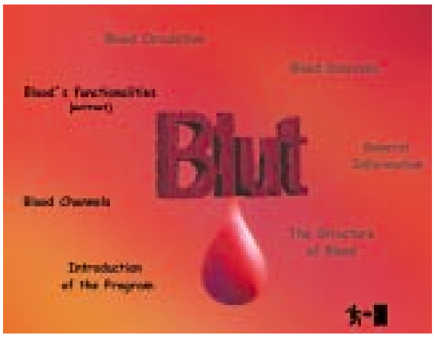

Figure1: schematic of blood - starting page.

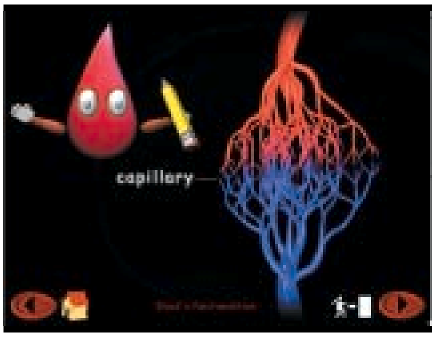

Figure 2: blood drop which guides the user through the programme.

Listeners with adequate hearing receptions only require to concentrate on language processes, whereas people with hearing difficulties need much more effort to follow and to participate in a communication. Hence for the latter group a higher degree of concentration is required when comprehending some discussions.

When teaching pupils with hearing difficulties, it is generally recommended to provide some additional information such as visual representations to enhance comprehension.

Structure

The programme is designed in such a way that the learning modules are based on some logical didactically structured units. The latter are divided through a number of single visual sites which are created through the integration of data formats such as graphics, videos and animations. Moreover the visual sequences are coupled with spelled words of the German Sign Language which may be activated through interaction.

The content is prepared using didactical principles of reduction and reproduction. Guiding through the programme is catered for using a cartoon character in the form of a blood drop, which leads the user through different sections of the tool. In this way, the concentration and hence the comprehension of the learner in question increases dramatically.

Practical Example

To test the efficiency of Signware, some practical examples are also available in the programme. One such example is simply say to describe the word 'blood' to the user. By clicking on a respective button identified by the word, one may not only receive information about 'blood' in general but also observe the German Sign Language spelling of the word.

When clicking on a drawn pencil it is possible to receive further information in the forms of graphic and text on the subject extending the pupil's knowledge and capabilities. In addition it is possible to define words' meanings in appropriate situations. For instance in the case of 'blood', an animated sequence defines how blood could drop from a finger tip, when it is cut.

Further Developments

The present version of Signware comprises of three completed learning modules, namely: 'Introduction to the Programme', 'Blood Channels' and some extracts on 'Blood Functionalities'. Further development in the part of multimedia representation of the tool is underway. This include visitation of more scientific signs like 'erythrocyte' and 'carbon dioxide' to facilitate using the German Sign Language.

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MFCS 2000 – Mathematical Foundations of Computer Science

by Branislav Rovan

The international symposium Mathematical Foundations of Computer Science (MFCS) is one of the top yearly events in theoretical computer science in Europe. The silver jubilee 25th MFCS took place on August 28 - September 1, 2000 in Bratislava, Slovakia. It was organized under the auspices of the Minister of Education of the Slovak Republic Milan Ftacnik by the Slovak Society for Computer Science and the Faculty of Mathematics, Physics, and Informatics of the Comenius University in Bratislava.

This series of symposia was initiated in 1972 in Poland and they are held alternatly in Poland, Slovakia, and the Czech Republic. The main goal of the series of symposia is to stimulate research in all branches of theoretical computer science. Its broad scope facilitates interaction among researchers who do not usually meet at specialized conferences.

The scientific program of MFCS 2000 consisted of invited talks by A. Gordon (Cambridge), J. Davenport (Bath), R. Grosu (Philadelphia), L. Hemaspaandra (Rochester), G. Italiano (Rome), J. van Leeuwen (Utrecht), M. Vardi (Houston), S. Zaks (Haifa) and of 57 contributed talks selected from the 147 submitted contributions by the 25 members of the Program Committee. Five ERCIM institutes were represented on the Program Committee together with many other leading research institutions in Europe and Northern America. The Proceedings of the symposium were published by the Springer-Verlag (http://www.springer.de) as Vol. 1893 of the Lecture Notes in Computer Science series. Three specialized workshops were organized on the days preceeding and following the MFCS: Algorithmic Foundations of Communication Networks coordinated by Marios Mavronicolas (Nicosia), New Trends in Formal Languages vs. Complexity coordinated by Klaus W. Wagner (Wuerzburg), and Prague Stringology Club Workshop coordinated by Borivoj Melichar (Prague). Please visit the symposium web page at http://www.mfcs.sk for more details on the program and attached workshops.

Over 120 participants from 20 countries (USA, Canada, Israel, South Africa, and most European countries) took part at MFCS 2000. The symposium was supported by the European Association for Theoretical Computer Science (EATCS http://www.eatcs.org), ERCIM, and the Slovak Research Consortium for Informatics and Mathematics (SRCIM http://www.srcim.sk). Telenor Slovakia supported the symposium by providing the Internet connection to the conference site and by hosting the symposium web page.

Links:
Symposium web page http://www.mfcs.sk

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EUROGRAPHICS 2000 Conference Report

by David Duce

The Eurographics 2000 conference, sponsored by ERCIM, was held in Interlaken, Switzerland, from 21 to 25 August 2000. The event was the 21st annual Eurographics conference, the first being held in Geneva in 1980. The 1990 conference was held in Montreux, so it was very appropriate to return to Switzerland after a further interval of 10 years.

The theme of the conference was 'Global Challenges of the Information Society: A Web of Opportunity' with sub-themes on modelling, visualization and collaboration. The conference proper was preceded by two days of tutorials on a wide variety of topics in the visualization and modelling areas, plus two workshops: Graphics Hardware 2000 organised in association with ACM SIGGRAPH and Computer Animation and Simulation (CAS 2000). Proceedings of the former will be available through Eurographics and ACM SIGGRAPH and the latter are published in book form by Springer-Wien.

The conference itself spread over three days. There were three invited papers. The first by Robert Cailliau was a thought-provoking account of his experiences as a user of computer graphics. Roger Hubbold gave the second on collaboration in virtual environments and Daniel Thalmann gave the third on virtual humans – ten problems not completely solved. A total of 52 papers were presented in the full paper sessions, and a further 24 in short presentation sessions. Six state of the art reports were included in the programme and provide very substantial reviews of areas such as recent advances in visualization of volumetric data, shadow computation: a unified perspective, etc.

The conference has a number of paper award categories. The best student paper award went to: 'Real Time, Accurate Multi-Featured Rendering of Bump Mapped Surfaces' by M. Tarini, P. Cignoni, C. Rocchini, and R.

Scopigno.3rd place overall went to 'Multiresolution Shape Deformations for Meshes with Dynamic Vertex Connectivity' by L.P. Kobbelt, T. Bareuther, H.-P. Seidel, in 2nd place was the paper by Tarini et al. and the Gunter Enderle Award for best paper went toExternal Memory View-Dependent Simplification', by J. El-Sana, Y.-J. Chiang. The full text of the award winning papers is publicly available at the Eurographics Association's web site: http://www.eg.org/.

A new prize was launced this year, the John Lansdown Prize, given in memory of Professor John Lansdown a key figure in computer graphics and computer art who died in January 1999. The judges were looking for an interactive web site or CD-ROM that works technically and artistically and that is innovative in its use of interaction. All judges being active in this field, they had in mind the quality of work that would be worthy of the John Lansdown award. John was known for the way he saw things from a different angle to most of us, often bringing new insights by an off-beat approach. It was this element of the interaction that the judges felt was generally not present in the submissions, but some works submitted by Fariba Farshad of the London Institute (UK) got very close to the judges' requirements, so a second prize was awarded to 'Celebrating Creativity'. The CD-ROM is a showpiece for arts awards for schoolchildren and their teachers, with prize-winning works in various categories being displayed. There is a playful, game-like interface that is engaging to users, encouraging them to seek out the different works displayed. Details of the competition being organised with Eurographics 2001 can be found at the web site together with a fuller account of the criteria by which competition entries will be judged.

The full conference papers are published in the journal Computer Graphics Forum, 19(3). Copies of all conference publications are included on the conference CD-ROM, for details please contact the Eurographics Association (contact details are at the web site).

Participants from 29 countries attended the event. There was very good participation from students, which gave a conference an all-important youthful atmosphere! ERCIM sponsorship of the event was very important to us, and is very gratefully acknowledged.

It is not too early to start preparing a paper for the Eurographics 2001 conference, which will be held in Manchester, UK.

Further information:
http://www.eg.org/

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FORTE/PSTV 2000

by Tommaso Bolognesi

The 20th anniversary of the IFIP WG6.1 Joint International Conference on Formal Methods for Distributed Systems and Communication Protocols was celebrated in Pisa, Italy, in October with FORTE XIII / PSTV XX. There were over 90 participants in this very successful ERCIM sponsored event.

The programme committee selected 22 papers for presentation at the Conference out of the more than 60 submitted. The central themes were the theory and practice of Distributed System Verification (with Model Checking playing a predominant role), and Testing. That the early pioneering phases in the development of Formal Methods (FMs), with their misconceptions and myths and their over-optimistic applications to toy examples and over-skeptical views about scalability to industrial cases, are essentially over was shown by a number of papers that reported on successful experiences in specifying and verifying real distributed systems and protocols. The Conference also indicated that testing theory and applications remain remarkably healthy, showing that the idea that the adoption of FMs would eventually eliminate the need for testing is still far from becoming a reality

Several presentations addressed the analysis of communication protocols, with some of them paying particular attention to multicast protocols. Other papers dealt with the specification, implementation and testing of hardware systems. The issue of formal semantics was also covered, but to a lesser extent than in past editions of the Conference; a further indication of the shift of emphasis from the definition to the application of FM's. Three invited speakers - Rocco De Nicola, Fausto Giunchiglia, and John Rushby - gave talks on Verification and Security protocols and there were also two tutorial/advanced seminar tracks.

On the first day, a multidisciplinary Satellite Workshop — 'Formal Methods Elsewhere' - was devoted to applications of FM's to areas other than communication protocols and distributed systems, such as physics, chemistry, biology, social sciences, arts and humanities, music. After two decades, FM's are perhaps ready to spread out of their native territory and invade new exciting areas of research, for a wider exploitation of the huge intellectual investment behind their definition.

A few copies of the Conference Proceedings (published by Kluwer Academic Publishers) and of the Tutorial Notes are still available; please e-mail Grazia Carrai at Consorzio Pisa Ricerche if interested (g.carrai@cpr.it).

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AD2000 – The Third International Conference on Automatic Differentiation: From Simulation to Optimization

by Uwe Naumann

111 people from all over the world, including Russia, Brasil, China, and Japan, attended AD2000, the third in a series of workshops devoted to Automatic Differentiation. The two previous conferences (Breckenridge 1991 and Santa Fe 1996, both USA) have created a momentum. Apart from having motivated further research and development they gathered researchers from different fields, from mathematics to scientific programming and to software engineering.

The domains covered by AD2000 reflected these different horizons. Mathematical aspects included the differentiation of iterative processes, and the analysis of non-smooth code. The use of adjoints in optimization and the propagation of rounding errors were looked at from the scientific programming point of view. Implementation problems, such as the complexity of the different differentiation modes, memory management problems, and static compile-time analysis to improve differentiated programs were also discussed.

Since the last meeting in 1996, research has progressed considerably. AD is being applied to larger and larger programs, for example for optimum shape design. In many such applications, modelling was restricted to simulations at various parameters settings. With the help of AD techniques, this trial and error approach could be replaced by a more efficient optimization with respect to modes, design, and control parameters. AD tools have also grown in variety, power and complexity. Their presentations and general discussions turned out to be highly profitable.

The objective of this third conference was to continue the work started in the previous meetings, and present recent developments to the audience. Special emphasis was put on the relationships and synergies between AD tools and other software tools such as compilers and parallelizers. Also, the maturation of AD tools motivated a special session on the use of AD in an industrial context. A panel discussion between several invited speakers from industry (NAG, Sun Microsystems, Frontline Systems) and academia (University of Western Ontario, Cananda, Argonne National Laboratory, USA) with strong participation of the audience underlined the importance of the development of a commercially supported AD tool.

The proceedings of AD2000 will be published by Springer next year. Topics covered will include: Sensitivities for ODEs and Optimal Control; Optimal Design via Adjoints in PDEs; AD Tools and Environments; Higher Order Derivatives; Diverse Applications.

Links:
Conference website:
http://www-sop.inria.fr/tropics/ad2000/

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Joint ERCIM Workshop on Databases and Environmental Modelling

by Brian Read and Thomas Lux

The ERCIM Environmental Modelling and the Database Research Groups combined to hold a joint Workshop on 27 to 29 September 2000. It was on Gran Canaria at the generous invitation of Professor Roberto Moreno-Díaz, Director of the Technology and Cybernetics Institute of the island's new University. With twenty-three researchers from twelve institutions participating, the seventeen speakers addressed the topic of the application of models and databases for environmental research.

The location of the Workshop was the historic Casa de Colón in the old part of the city of Las Palmas. The presentations and discussions focused on perspectives to advance the dialogue among researchers working on environmental modelling and database research, aiming to bring new ideas into these fields by intelligent systems approaches and GRID computing.

Crucial environmental research issues addressed included: modelling of air, water and soil pollution, use of remote sensing data for environmental management, and the improvement/parallelisation of numerical algorithms in environmental models. Information systems technologies covered were data mining, data warehousing, multidimensional data and knowledge discovery in environmental databases, web and semi-structured data management, geographic information systems, decision support systems, knowledge-based systems (neural nets, expert systems), image and visual processing, data uncertainty, validation, integration and visualization.

Besides the regular presentations of the working group members, two additional sessions have to be emphasised. The first, very interesting one presented the current research topics of the host Instituto Universitario de Ciencias y Tecnologías Cibernéticas of the Universidad de Las Palmas de Gran Canaria as a new member of the Working Group Environmental Modelling. A second, valuable session presented by Guy Weeks (EC, DG IST), focused on the IST Programme within the Fifth Framework Programme of the European Commission. Encouraged by the latter, new project ideas were discussed. These lead to a new project proposal of the Working Group Environmental Modelling that was submitted to the fourth Call for Proposals of the IST Programme by the end of October deadline. In addition, the opportunity was taken during the workshop for a working meeting on current tasks of the DECAIR project, an EC R&D collaboration also initiated by the Environmental Modelling Group.

Overall it was an enjoyable meeting, benefiting from the interaction of the two ERCIM Groups within a traditional social programme. During the Workshop, a formal meeting with the Island's President and the Minister for Science and Education provided the opportunity to thank them for their hospitality and to promote the value of ERCIM in integrating Las Palmas within Europe.

Links:
Joint Workshop: http://www.first.gmd.de/applications/ercim7.html
Working Group Environmental Modelling: http://www.first.gmd.de/applications/em.html
Database research group: http://www.ercim.org/activity/wg/EDRG/
DECAIR Project homepage: http://www-air.inria.fr/decair/

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First Results of the Cross-Language Evaluation Forum

by Carol Peters

More than twenty research groups participated actively in the first campaign of the Cross-Language Evaluation Forum (CLEF 2000). The results were presented at a Workshop in Lisbon, 21-22 September, immediately following the fourth European Conference on Digital Libraries - ECDL 2000.

The Cross-Language Evaluation Forum (CLEF) is an activity of the DELOS Network of Excellence for Digital Libraries. The goal of CLEF is to provide an evaluation infrastructure and benchmarking facilities for the testing and tuning of monolingual and cross-language information retrieval systems operating on European languages.

The first evaluation campaign offered four evaluation tasks designed to test multilingual, bilingual, domain-specific, and monolingual (non-English) IR systems. The main task consisted of querying a multilingual corpus of newspaper documents in four languages (English, French, German and Italian) and submitting the results in a ranked, merged list. Any one of eight European languages could be used to query this collection.

Eight North American and twelve European research groups, mainly from academia – a few from industry, managed to submit results within the 1 July deadline. A total of 90 runs were received; runs were submitted for all tasks and for all topic languages. This was a very good result for the first year of activity, especially in consideration of the severe time constraints on participation.

The results of the activity were presented during a two-day workshop on Cross-Language Information Retrieval and Evaluation, 21-22 September, Lisbon, Portugal. The first day, attended by nearly sixty participants, was open to all those interested in the area of Cross-Language Information Retrieval (CLIR). The morning was dedicated to the presentation of invited papers and discussion sessions on CLIR research related issues. The afternoon addressed the topic of CLIR system evaluation: the current situation and future developments. The objective was to promote a discussion on 'What is needed to improve CLIR system performance' and 'How can evaluation campaigns assist in this'. The goal was to identify the actual contribution of evaluation to system development and to determine what could or should be done in the future to stimulate progress.

The second day was restricted to participants in the CLEF 2000 evaluation campaign. The results of the evaluation activity were presented and discussed in detail. Both traditional and innovative strategies had been adopted to address the CLIR task; various approaches had been experimented for query expansion and results merging. Preliminary papers describing the approaches adopted by the different groups in their experiments were published in the Working Notes printed by ERCIM as part of the DELOS Workshop series and distributed at the Workshop.

Details of the two-day Workshop, including slides of the presentations and copies of the Working Notes, can be found on the CLEF Web site. The Proceedings will be published by Springer in their Lecture Notes for Computer Science series. The volume will include a record of the talks given on Day 1 and of the experiments and results of the CLEF evaluation campaign presented on Day 2. All papers will be revised and extended with respect to the preliminary draft version

The programme and schedule for CLEF 2001 is to be found on the CLEF Web site. The agenda will be similar to that for 2000 but with the addition of more languages to the multilingual text collection (Spanish, Dutch and perhaps Greek).

Links:
http://www.clef-campaign.org/

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CALL FOR PARTICIPATION

First DELOS International Summer School on Digital Library Technologies

Pisa, Italy, 9-13 July 2001

The DELOS summer school is one of the activities of the DELOS Network of Excellence on Digital Libraries. The DELOS NoE is an initiative funded by the 5th Framework Programme of the European Commission. The main objective of DELOS is to contribute to the advancement of European DL research and to the creation of a European DL research community. DELOS aggregates active European research teams in the DL field with the intention of enhancing their collaboration, improving the effectiveness of their research, and increasing the impact of their research achievements on the interested applications areas.

This is the first summer school organised in the context of the DELOS NoE, and it will focus on fundamental issues related to the multidisciplinary area of Digital Libraries. The lecturers of the school will be leading researchers in the Digital Library field. Each lecture will be devoted to a presentation of the state-of-the-art on one of the key DL topics.

The main purpose of the school is to foster research and understanding in the fundamental technologies underlying the Digital Libraries field. It is directed towards members of the research community in the wide sense, that is, graduate students and young researchers and professionals involved in R&D in DL-related areas, possibly representing the information technology scientist, the industrial communities (electronic publishing, broadcasting, software industry, etc.) and the user communities interested in Digital Libraries technologies (libraries, archives, museums).

The School will be held in Pisa in the beautiful and evocative setting of the Santa Croce in Fossabanda (http://www.fossabanda.it), an ancient monastery dating from the 14th century recently renovated. Students and lecturers will reside in the monastery for the duration of the School, giving students ample opportunities to know each other and to exchange ideas among themselves and with the lecturers, who are expected to stay for most of the duration of the School. The School is directed by Professor Maristella Agosti, University of Padua, Italy.

Further information:
http://www.ercim.org/delos/

CALL FOR PARTICIPATION

The Fifth Pacific-Asia Conference on Knowledge Discovery and Data Mining — PAKDD'01

Hong Kong, 16-18 April 2001

The PAKDD-01 conference will be an international forum for the sharing of research results and practical experiences from the many constituent areas of KDD, including artificial intelligence, databases, e-commerce, Internet computing, machine learning, high performance computing, statistics and visualization.

Further information:
http://www.csis.hku.hk/pakdd01

CALL FOR PARTICIPATION

Joint EUROGRAPHICS — IEEE TCVG Symposium on Visualization

Ascona, Switzerland, 28-30 May 2001

Following Vienna'99, and Amsterdam'00, the third joint Eurographics – IEEE TCVG Symposium on Visualization will be held in Ascona, Switzerland. The 3-day programme will include research papers, case studies and invited presentations. Students are particularly encouraged to participate.

Topics

Suggested topics for research papers include: flow visualization, Internet-based visualization, visualization systems, volume rendering, database visualization, large data sets, surface extraction, human factors in visualization, multi-variate visualization, information visualization, user interaction techniques, multiresolution techniques. Proposals of case studies from all areas of visualization are welcome.

Further information:
http://www.cscs.ch/vissym01/
E-mail: vissym01@cscs.ch

CALL FOR PAPERS

Continuity in Future Computing Systems – I3 Spring Days Workshop

Porto, Portugal, 23-24 April 2001

One of the next major developments in computing will be the embedding of computation, information storage, sensing, and communication capabilities within everyday objects and environments. These new systems may have a profound effect on the way we interact with computers and information, and ultimately the way we work and live. The design of these artefacts is potentially very different to traditional interactive system design. In many cases the user interface is moved from a computer screen into the 'real world', and interaction between user and system is of a more continuous nature. We must take into account the physical and temporal aspects of these interfaces, the use of a wide range of modalities, and adaptive technologies.

As part of the I3 (Intelligent Information Interfaces) Spring Days event, the partners of the TMR project TACIT (Theory and Applications of Continuous Interaction Techniques), which includes several ERCIM member organisations, will hold a workshop to focus on continuous interaction issues in future computing systems, and modelling to support the design of such systems.

Participation is by means of paper submission – see the link below for more details. Submission deadline: 15 February (full papers), 2 March (position papers).

Further information:
http://kazan.cnuce.cnr.it/TACIT/I3WS.html

CALL FOR PAPERS

International Symposium on Virtual and Augmented Architecture – VAA01

Dublin, 21-22 June 2001

This symposium aims to bring together researchers investigating the intersection of architecture, computer graphics and computer vision. Example applications of this fusion include: representations of real buildings in virtual environments, historical and cultural setting reconstruction and presentation, virtual graphics overlay of real buildings for navigational support, education, or architectural presentation.
The symposium will have a mixture of invited lectures by established researchers and research presentations describing current results. Topics of interest (but not limited to) include: 3D Reconstruction, Architectural Photogrammetry, plenoptic recovery, uncalibrated recovery of buildings from video, range sensors for environment scanning, multi-scan fusion, data representations for environments, use of architectural knowledge, media/tourism applications, architectural applications, construction industry applications, video registration, data representations for environments, use of architectural knowledge, media/tourism applications, architectural applications, construction industry applications, video registration, interaction in virtual and augmented environments, user navigation in virtual buildings,physics in virtual buildings, realistic rendering of architecture, hardware for augmented reality, interactive buildings, fusion of video with virtual components, autonomous avatars in augmented/virtual buildings.

Important Dates
- Reception of papers: 15 January 2001
- Notification of acceptance: 15 March 2001
- Reception of final papers: 9 April 2001

Further Information
http://www.dai.ed.ac.uk/VAA01/
E-mail: vaa01@cs.tcd.ie.

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MFCS 2001 – 26th International Symposium on Mathematical Foundations of Computer Science

Marianske Lazne, Czech Republic, 27-31 August 2001

The series of MFCS symposia, organized alternately in Poland, Slovakia, and the Czech Republic since 1972, has a long and well-established tradition. The MFCS symposia encourage high-quality research in all branches of theoretical computer science. Their broad scope provides an opportunity to bring together specialists who do not usually meet at specialized conferences. Papers presenting original research on theoretical aspects of computer science are sought. The submission deadline is 15 March 2001.

Further information:
http://math.cas.cz/~mfcs2001/

CALL FOR PAPERS

ICSM – International Conference on Software Maintenance

Florence, Italy, 6-12 November 2001

ICSM is the major international conference in the field of software and systems maintenance, evolution, and management. The focus of the conference will be to explore the new challenges that the Internet, as a driver for business changes, poses for software maintenance, and the new opportunities it opens as infrastructure and enabling technology. ICSM 2001 will bring together researchers, practitioners, developers and users of tools, technology transfer experts, and project managers. The Conference will be held in conjunction with SCAM – Source Code Analysis and Manipulation, WESS, the seventh Workshop on Empirical Studies of Software Maintenance and WSE – Workshop on WEBsite evolution

Important dates
- Research Paper submission: 15 January 2001, notification of acceptance: 1 June 2001
- Dissertation submission: 15 January 2001
- Industrial Application submission: 12 March 2001
- Tools request and submission: 12 March 2001
- Tutorial submission: 12 February 2001

Further information
http://www.dsi.unifi.it/icsm2001/

CALL FOR PAPERS

Journal of Intelligent Information Systems, Special Issue on Automated Text Categorization

Guest Editors: Thorsten Joachim, GMD and Fabrizio Sebastiani CNR; Published by Kluwer Academic Publishers

Seeked are submission of high quality, original work that has not been submitted, accepted for publication, or published elsewhere, covering any aspect of automated text categorization, including but not restricted to:
- Machine learning methods for text categorization
- Theoretical models of text categorization
- Hierarchical text categorization
- Text analysis and indexing methods for text categorization
- Dimensionality reduction for text categorization
- Evaluation issues in text categorization
- Applications of text categorization
- Automated categorization of Web pages and Web sites
- Text filtering and routing
- Topic detection and tracking
- Spoken text categorization
- OCR'ed text categorization

Important Dates
- Submission deadline: 28 February 2001
- Acceptance/rejection notification: 31 May 2001
- Submission of final copy: 31 July 2001
- Tentative Publication Date: December 2001

Further Information
http://mason.gmu.edu/~kersch/JIIS/Special_Issues/TextCategory.html

ERCIM NEWS

ERCIM News is the 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.

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ECOOP 2001 – 15th European Conference on Object-Oriented Programming

Budapest, 18-22 June 2001

The ECOOP 2001 conference invites high quality technical papers reporting research results and/or experience related to the object technology. Traditionally, ECOOP 2001 hosts a two day tutorial programme. Proposals for high-quality tutorials in all areas of object-orientation from academic research to industrial applications are solicited. As in previous years, ECOOP 2001 will host a number of workshops addressing different areas of objet-oriented technology. Workshops serve as a forum for exchanging late breaking ideas and theories in an evolutionary stage. They typically focus on either in depth analysis or broad-ranging approaches to areas related to object-oriented technology.

More information:
http://www.sztaki.hu/conferences/ieaaie2001/

CALL FOR PAPERS

FMICS 2001 – 6th ERCIM Workshop on Formal Methods for Industrial Critical Systems

Paris, 16-17 July 2001

The aim of the FMICS workshops is to provide a forum for researchers who are interested in the development and application of formal methods in industry. In particular, these workshops should bring together scientists that are active in the area of formal methods and interested in exchanging their experiences in the industrial usage of these methods. They also aim at the promotion of research and development for the improvement of formal methods and tools for industrial applications.

Topics include, but are not restricted to:
- Tools for the design and development of formal descriptions
- Verification and validation of complex, distributed, real-time systems and embedded systems
- Verification and validation methods that aim at circumventing shortcomings of existing methods in respect to their industrial applicability
- Formal methods based conformance, interoperability and performance testing
- Case studies and project reports on formal methods related projects with industrial participation (e.g. safety critical systems, mobile systems, object-based distributed systems)
- Application of formal mehtods in standardization and industrial forums.

Important Dates
- submission deadline: 29 March 2001
- notification: 22 April 2001
- final paper: 11 May 2001

More information:
http://www.dsse.ecs.soton.ac.uk/FMICS2001/

CALL FOR PARTICIPATION

SCCG 2001 – Spring Conference on Computer Graphics

Budmerice Castle, Slovak Republic, 25-28 April 2001

This event is the oldest regular annual meeting of the computer graphics community in Central Europe. The spring conference attempts to cover all interesting projects from computer graphics and image processing in CG and the applications. The philosophy of SCCG is to put together top experts with young researchers in CG and to support a good communication channel for East-West exchange of prospective ideas. The conference chairman is Prof. Tosiyasu L. Kunii, from Hosei University, Japan.

Important Dates

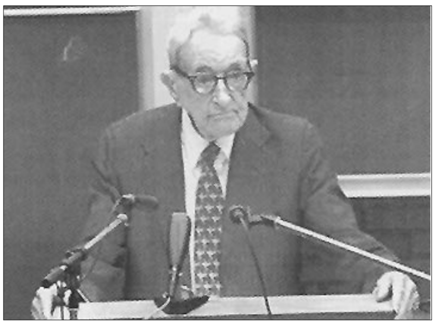
- 11 February 2001: contribution submission deadline
- 11 March 2001: review notification
- 1 April 2001: camera-ready submission deadline

Further information:
http://www.isternet.sk/sccg/

CWI – **Edsger W. Dijkstra** (70) visited his old institute CWI in October, 2000, where he delivered a lecture on combating complexity in problem solving. Dijkstra, now emeritus professor of the University of Texas at Austin, where he went to in 1984 after positions at Eindhoven University of Technology and Burroughs, graduated from Leiden University as a theoretical physicist. He worked at CWI in the period 1952-1962. In 1959 he defended his PhD in Computer Science. He is generally considered as the father of structured programming (one of his famous slogans in the late 1960s was 'GO TO considered harmful'). Several of his fundamental concepts had considerable impact on the development of programming languages. He received the ACM Turing Award in 1972. Dijkstra neither owned nor used a computer until recently.

Edsger W. Dijkstra during his visit to CWI.

CWI – When **Dirk Struik** passed away on 21 October 2000 at the age of 106 years, his life had covered three centuries. Struik was a mathematician born and trained in The Netherlands, which he left when Norbert Wiener asked him in the 1930s to come to Harvard. He became famous with his History of Mathematics (1948) which was translated into sixteen languages. During his whole life he remained a convinced marxist, which brought him into difficulties before WWII in The Netherlands, and afterwards in the USA, where he was temporarily dismissed from his post in the 1950s. He remained active until the end, still handling all his correspondence himself.



Mathematician Dirk Struik (1894-2000) addressing a crowded audience at CWI during celebrations of his 100th birthday in 1994.

SZTAKI actively participated in the Cactus testbed demo of the European Grid Forum in Dallas at the Supercomputing conference 4-10 November. The Cactus testbed demo demonstrated the usage of a European Grid connecting the following sites: Albert-Einstein-Institut (Potsdam), Brno Supercomputing Centre, the DAS supercomputer (The Netherlands), Konrad-Zuse-Zentrum (Berlin), SZTAKI (Budapest), Poznan Supercomputing and Networking Centre, Padernborn Centre for Parallel Computing. The program that was partially demonstrated by Ferenc Szalai (staff member of SZTAKI) was solving 3D wave equations related to the collision of black holes and was executed in parallel on the machines of the participating institutes. The program was also able to move from site to site demonstrating a new kind of potential application of the Grid. For more information on the European Grid Forum, see http://www.egrid.org/

CLRC - **The Numerical Analysis Group at the Rutherford Appleton Laboratory has released HSL 2000**, a collection of Fortran packages for large scale scientific computation. The Library was started in 1963 and over the years it has evolved and has been extensively used on a wide range of computers. The latest release of the Library, HSL 2000, contains codes for Automatic Differentiation, Differential Equations, Eigenvalues and Eigenvectors, Mathematical Functions, Sorting, Linear Programming, Linear Algebra, Nonlinear Equations, Polynomials, Optimization and Non-linear Data Fitting. New packages include state-of-the-art routines for sparse linear programming, the solution of sparse linear systems, and optimization. While HSL 2000 is a commercial product, it is also available without charge to anyone working in an academic institution in the UK. This innovation is a direct result of a grant from the Engineering and Physical Sciences Research Council. Older Library codes are available in an HSL Archive Library for research purposes to anyone without charge. For details of both libraries, see http://www.cse.clrc.ac.uk/Activity/HSL/.

Commissioner Busquin visits CWI

ERCIM – The European Research Consortium for Informatics and Mathematics is an organisation dedicated to the advancement of European research and development, in information technology and applied mathematics. Its national member institutions aim to foster collaborative work within the European research community and to increase co-operation with European industry.

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