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ERCIM NEWS

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Special theme:

Big Data

Also in this issue:

ERCIM News is the magazine of ERCIM. Published quarterly, it reports on joint actions of the ERCIM partners, and aims to reflect the contribution made by ERCIM to the European Community in Information Technology and Applied Mathematics. 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. This issue has a circulation of about 8,500 copies. The printed version of ERCIM News has a production cost of €8 per copy. Subscription is currently available free of charge.

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A heavy ion collision event animation from the Large Ion Collider Experiment (ALICE) © CERN

Keynote

E-Infrastructures for Big Data: Opportunities and Challenges

The management of extremely large and growing volumes of data has since many years been a challenge for the large scientific facilities located in Europe such as CERN or ESA, without clear long term solutions. The problem will become even more acute as new ESFRI facilities come on-stream in the near future. The advent of "big data science", however, is not limited to large facilities or to some fields of science. Big data science emerges as a new paradigm for scientific discovery that reflects the increasing value of observational, experimental and computer-generated data in virtually all domains, from physics to the humanities and social sciences.

The volume of information produced by the "data factories" is a problem for sustainable access and preservation, but it is not the only problem. Diversity of data, formats, metadata, semantics, access rights and associated computing and software tools for simulation and visualization add to the complexity and scale of the challenge.

Big Data and e-Science: challenges and opportunities

ICT empowers science by making possible massive interdisciplinary collaboration between people and computers, on a global scale. The capacity and know-how to compute and simulate, to extract meaning out of vast data quantities and to access scientific resources are central in this new way of co-creating knowledge. Making efficient use of scientific data is a critical issue in this new paradigm and has to be tackled in different dimensions: creation of data, access and preservation for re-use, interoperability to allow cross-disciplinary exploration and efficient computation, intellectual property, etc.

ICT infrastructures for scientific data are increasingly being developed world-wide. However, many barriers still exist across countries and disciplines making interoperability and sustainability difficult to achieve. To cope with the extremely large or complex datasets generated and used in research, it is essential to take a global approach to interoperability and discoverability of scientific information resources. International cooperation to achieve joint governance, compatible legal frameworks and coordinated funding is also necessary.

Data-intensive science needs be reproducible and therefore requires that all research inputs and outcomes are made available to researchers. Open access to scholarly papers, trusted and secure access to data resources and associated software codes, and interlinking of resources with publications, they all support reproducible and verifiable e-science. In some areas the storage and processing of large datasets may have implications to data protection, which need to be investigated together with access to data by the public.

Kostas Glinos
European Commission, DG Information Society and Media
Head of GEANT and e- Infrastructure Unit

In all fields of science we can encounter similar technical problems when using extremely large and heterogeneous datasets. Data may have different structures or may not be well structured at all. Analytical tools to extract meaningful information from the huge amounts of data being produced are lagging. Technical problems are often more complex in interdisciplinary research which is the research paying the highest rewards. When the amounts of data to be processed are large they cannot easily move around the network. Novel solutions are therefore needed; and in some cases, storage and data analysis resources might need to move to where data is produced.

A significant part of the global effort should focus on increasing trust (eg through international certification) and enhancing interoperability so that data can be more readily shared across borders and disciplines. Second, we need to develop new tools that can create meaningful, high quality analytical results from large distributed data sets. These tools and techniques are also needed to select the data that is most valuable for future analysis and storage. This is a third focus of effort: financial and environmental systainability. The rate of global data production per year has already exceeded the rate of increase in global data storage capacity; this gap is widening all the time, making it increasingly more important to understand what data has an intrinsic value that should not be lost and what data is "transient" and we could eventually throw away [Richard Baraniuk, More is Less: Signal Processing and the Data Deluge Science 2011 (331): at p. 717].

European Commission activities in scientific data

Through the 7th Framework Programme for research, the Commission, in coordination with Member States, promotes and funds ICT infrastructures for research (e-infrastructures) enabling the transition to e-science. The Commission has invested more than 100 M€ in the scientific data infrastructure over the last few years, covering domains ranging from geospatial information and seismology to genomics, biodiversity and linguistics . The development of e-Infrastructures is part of the Digital Agenda flagship initiative, envisioned as means to connect researchers, instruments, data and computation resources throughout Europe. Furthermore, the 2009 Communication of the Commission on ICT infrastructures for e-science highlighted the strategic role of IT in the scientific discovery process and sought to increase adoption of ICT in all phases of this process. The Communication expressed the urgency to develop a coherent strategy to overcome the fragmentation in infrastructures and to enable research communities to better manage, use, share and preserve data. In its conclusions of December 2009, the Competitiveness Council of the European Union invited Member States and the Commission to broaden access to scientific data and open repositories and ensure coherent approaches to data access and curation.

More recently, in October 2010, the High Level Expert Group on Scientific Data submitted its final report to the Commission. The main conclusion of the report is that there is a need for a "collaborative data infrastructure" for science in Europe and globally. The vision this infrastructure would enable is described in the following terms:

"Our vision is a scientific e-infrastructure that supports seamless access, use, re-use, and trust of data. In a sense, the physical and technical infrastructure becomes invisible and the data themselves become the infrastructure a valuable asset, on which science, technology, the economy and society can advance."

A complementary vision was developed by the Commission co-funded project GRDI2020. It envisions a Research Data Infrastructure that enables integration between data management systems, digital data libraries, research libraries, data collections, data tools and communities of research.

These efforts are expected to create a seamless knowledge territory or "online European Research Area" where knowledge and technology move freely thanks to digital means. Furthermore, it is essential to take a global approach to promote interoperability, discoverability and mutual access of scientific information resources.

Financial support for this policy is expected to come from the next framework programme for research and innovation. The Commission has included data e-infrastructure as a priority in its proposals for the so-called Horizon 2020 programme, covering the period from 2014 to 2020. Coordination with funding sources and policy initiatives in Member States of the EU is also necessary as much of the e-infrastructure in Europe obtains financing and responds to needs at national level.

In summary, data should become an invisible and trusted e-infrastructure that enables the progress of science and technology. Beyond technical hurdles, this requires a European (and global) research communication system that enables and encourages a culture of sharing and open science, ensures long-term preservation of scientific information, and that is financially and environmentally sustainable.

The views expressed are those of the author and do not necessarily represent the official view of the European Commission on the subject.

RESEARCH AND INNOVATION

This section features news about research activities and innovative developments from European research institutes

EVENTS, BOOKS, IN BRIEF

Industrial Systems Institute/RC 'Athena' Joins ERCIM

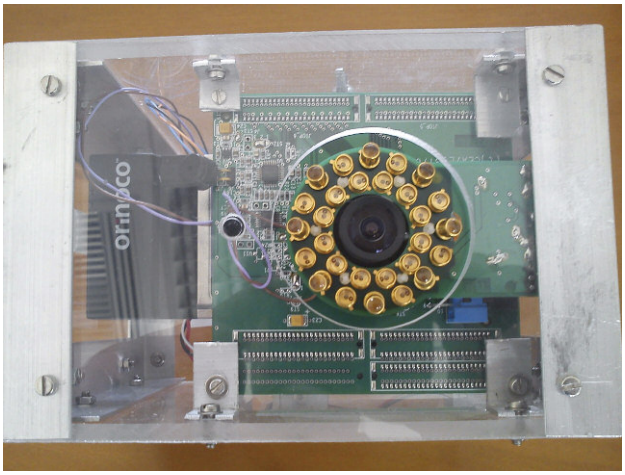
by Dimitrios Serpanos

The Industrial Systems Institute (ISI) of Research Centre ATHENA (RC 'Athena') is delighted to join ERCIM. ISI, a public research institute, was founded in Patras, Western Greece in 1998. Since 2003, ISI has been part of the 'Athena' Research and Innovation Centre in Information, Communication, and Knowledge Technologies, operating under the auspices of the General Secretariat of Research and Technology of the Greek Ministry of Education, Lifelong Learning and Religious Affairs.

ISI is the main research institute in Greece that focuses on cutting edge R&D that applies to the industrial and enterprise environment. Its main goal is sustainable innovation in information, communication and knowledge technologies for improving the competiveness of the Greek industry while applying environmentally friendly practices.

ISI is involved in a range of research areas such as industrial information and communication systems; enterprise systems and enterprise integration; embedded systems in several application areas, including transport, healthcare, and nomadic environments; enterprise and industrial process modelling; safety and security; reliability and cyber-security.

Our vision for ISI is to sustain a leading role in R&D of innovative industrial and enterprise technologies. ISI has made significant contributions at the regional, national, and European levels and has established strong relationships and collaboration with R&D and industrial stakeholders in Greece, Europe, and the USA.



System for earthquake monitoring and disaster rescue assistance developed by ISI

Research and development in ICT and applied mathematics is a strategic element for ISI's sustainable growth. We expect that ERCIM will enable ISI to increase its contribution through stronger networking and cooperation with important institutions, members of ERCIM, and dissemination of its results and achievements through joint activities. Three members of its staff will represent ISI in ERCIM, namely Professor Dimitrios Serpanos (Director of ISI), as the representative in the ERCIM general member assembly, with Dr Nikolaos Zervos (Researcher) as his substitute and Dr Artemios Voyiatzis (Researcher) represents ISI on the ERCIM News editorial board.

Link:
http://www.isi.gr/en/

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Research at ISI

ISI performs high-impact research in the following areas:

- information and communication systems for the industry and enterprise environment
  - high-performance communication systems and architectures
  - real-time communications
  - low-power hardware architectures for processing and communication
- embedded systems
  - design and architecture
  - interoperability
  - design tools
  - real-time cooperation and coordination
  - safety and reliability
- cyber-security
- electronic systems
  - RFID
- enterprise integration
  - next-generation control systems
  - software agents
  - ontologies for enterprise processes, resources, and products
  - service-Oriented Architecture
  - collaboration platforms, virtual and extended enterprise, enterprise clustering
  - collaborative manufacturing
- modelling and automation of industrial systems and processes
  - control of industrial robots
  - control of mobile robots and autonomous vehicles
  - control of distributed industrial systems
  - control of complex electromechanical systems
  - system modeling and fault prediction, detection, and isolation
  - intelligent and adaptive systems
- sustainable development
  - ICT for energy-efficient systems
  - ICT for increasing sustainable energy awareness
  - sustainable (multimodal) transport

The R&D activities of ISI draw upon many areas of mathematics, computer science and engineering including:

- hardware (memory structures, I/O and data communications, logic design, integrated circuit, performance and reliability)
- computer systems organization (processor architecture, computer communication networks, performance of systems, computer system implementation)
- software (software engineering, operating systems)
- mathematics of computing (discrete mathematics, probability and statistics)
- computing methodologies (artificial intelligence, image processing and computer vision, pattern recognition, simulation and modelling)
- computer applications (physical sciences and engineering, life and medical science, computer-aided engineering)
- computers and society (public policy issues, electronic commerce, security)

ISI has produced successful products and services such as:

- an innovative wireless network system for real-time industrial communications
- system for sea protection from ship wreckage oil spill
- system for earthquake monitoring and disaster rescue assistance
- integrated building management system
- a smart camera system for surveillance.

MUSCLE Working Group

International Workshop on Computational Intelligence for Multimedia Understanding

by Emanuele Salerno

The National Research Council of Italy in Pisa hosted the International Workshop on Computational Intelligence for Multimedia Understanding, organized by the ERCIM Working Group on Multimedia Understanding through Semantics, Computation and Learning (Muscle), 11-13 December 2011. The workshop was co-sponsored by CNR and Inria. Proceedings to come in LNCS 7252

Computational intelligence is becoming increasingly important in our households, and in all commercial, industrial and scientific environments. A host of information sources, different in nature, format, reliability and content are normally available at virtually no expense. Analyzing raw data to provide them with semantics is essential to exploit their full potential and help us manage our everyday tasks. This is also important for data description for storage and mining. Interoperability and exchangeability of heterogeneous and distributed data is an essential requirement for any practical application. Semantics is information at the highest level, and inferring it from raw data (that is, from information at the lowest level) entails exploiting both data and prior information to extract structure and meaning. Computation, machine learning, ontologies, statistical and Bayesian methods are tools to achieve this goal. They were all discussed in this workshop.

30 participants from eleven countries attended the workshop. With the help of more than 20 external reviewers, the program committee ensured a high scientific level, accepting 19 papers for presentation. Both theoretical and application-oriented talks, covering a very wide range of subjects, were given. Papers on applications included both the development of basic concepts towards the real-world practice and the actual realization of working systems. Most contributions focussed on still images, but there were some on video and text. Two presentations exploited results from studies on human visual perception for image and video analysis and synthesis. Two greatly appreciated invited lectures were given by Sanni Siltanen, VTT, former Muscle chair, and Bülent Sankur, Bogaziçi University, Istanbul. These dealt with emotion detection from facial images (Sankur) and advanced applications of augmented reality (Siltanen).

Ovidio Salvetti and Emanuele Salerno open the workshop.

The Muscle group has more than 50 members from research groups in 15 countries. Their expertise ranges from machine learning and artificial intelligence to statistics, signal processing and multimedia database management. The goal of Muscle is to foster international cooperation in multimedia research and carry out training initiatives for young researchers.

Links:
http://muscle.isti.cnr.it/pisaworkshop2011/
http://wiki.ercim.eu/wg/MUSCLE/

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The European Forum for ICST is Taking Shape

Since 2006 there has been discussion about creating a platform for cooperation among the European societies in Information and Communication Sciences and Technologies (ICST). The objective is to have a stronger, unified voice for ICST professionals in Europe. The forum will help to develop common viewpoints and strategies for ICST in Europe and, whenever appropriate or needed, a common representation of these viewpoints and strategies at the international level.

In 2006 and 2008, Keith Jeffery from STFC, UK, led expert groups on the topic at the request of the European Commission. The commission initiated a project to survey the views of ICST professionals in Europe; significantly this survey indicated that ERCIM was the best known and regarded organisation in Europe. Working closely with Informatics Europe and the European Chapter of the ACM, ERCIM has pushed steadily for progress. A meeting at the 2011 Informatics Europe annual conference confirmed a widespread desire to form such an association. An initial constellation of Informatics Europe, ERCIM, the European Chapter of ACM, CEPIS (Council of European Professional Informatics Societies), EATCS (European Association for Theoretical Computer Science), EAPLS (European Association for Programming Languages and Systems), and EASST (European Association of Software Science and Technology) was agreed, with Jan van Leeuwen, Utrecht University representing Informatics Europe, taking the chair, and ERCIM providing the coordinating website. On 2 February 2012, a meeting was hosted at Inria, Paris where the objectives and structure of the European Forum for ICST (EFICST) were defined and agreed, with the vice presidents Keith Jeffery, STFC representing ERCIM, and Paul Spirakis representing EATCS and ACM Europe.

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ERCIM Fellowship Programme: Eighty Postdoctoral Fellowships Co-funded to Date

Since September 2010, the ERCIM Alain Bensoussan Fellowship Programme has been supported by the 'FP7 Marie Curie Actions - People, Co-funding of Regional, National and International Programmes' (COFUND) of the European Commission. Many ERCIM member institutes have taken advantage of this opportunity and 80 fellowships have already been granted.

Benefits for hosting institutes

With the implementation of 'COFUND' , the European Commission recognized ERCIM's successful and long-lasting fellowship programme. As expected, the co-funding resulted in a considerable increase in the number of granted ERCIM Fellowships. The programme is now at mid-term and all ERCIM member institutes are strongly encouraged to participate. The advantages for a hosting institute are obvious: 30% of the costs for postdoctoral position can be co-funded. Additionally, the employment conditions are very flexible. Fellows can be hosted either with a working contract or a stipend agreement. With up to 250 applications for each round and an effective evaluation procedure, it should be easy for all institutes to find highly qualified post-docs for their labs.

Encouraging mobility

The programme places a high value on trans-national mobility for training and career development. ERCIM supports fellowships of one or two 12 month terms. The 2x12 months fellowships are spent in two different institutes to strengthen collaboration among ERCIM research teams. Fellowships comprising a single 12 month term include a 'Research Exchange Programme' where fellows spend at least one week in two different ERCIM institutes. In order to encourage mobility, an institute cannot host a fellow from the same country.

Testimonials

Marco Giunti
postdoctoral fellow at Inria

"My experience with the ABCDE programme is extremely positive. I had the chance to get in touch with top-level researchers and to contrast my background and ideas with those of students and professors of several nationalities. The richness of the environment contributed to stimulate my research; the period spent under the programme has been indeed very prolific. I have particularly enjoyed the possibility to meet other fellows in the seminar organized by the ERCIM office, which in my view was a complete success. It was an excellent occasion to exchange our experiences as well as to establish new connections. I would recommend this programme to everyone in love with serious and outstanding research."

Great opportunity for post-docs

The programme enables bright young scientists from all over the world to work on a challenging problem as fellows of leading European research centres. A fellowship helps widen and intensify the network of personal relations and understanding among scientists. The programme offers the opportunity to:

- achieve the status of a EU Marie Curie Fellow
- work with internationally recognized experts
- improve knowledge about European research structures and networks
- become familiarized with working conditions in leading European research centres
- build networks with research groups working in similar areas in different laboratories.

A novelty of the programme is the yearly 'ABCDE seminar' which offers fellows training in a range of non-scientific skills. The first seminar was held over two days in November 2010 in Berlin with an exciting programme covering topics such as media training, career management, 'from research to business', intellectual property rights, ethics in research. The seminar also provided an excellent opportunity for networking and community building.

Link:
http://fellowship.ercim.eu

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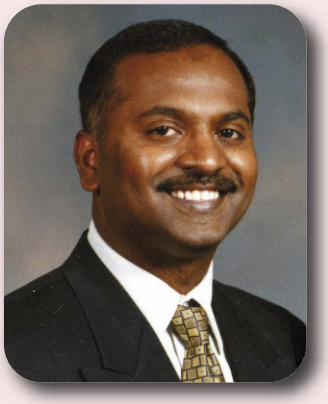
Valérie Issarny, Senior Research Scientist at Inria

"Alessandra Toninelli visited our group ARLES at Inria while she was a postdoc researcher at the University of Bologna. Seeing a great potential for collaborating in our research on socially-aware middleware and her great competence in semantic technologies and access control policies, we offered her a subsequent ERCIM Fellowship in Paris-Rocquencourt. Here, she spearheaded work on Yarta, a middleware for mobile social networks, which is currently one of the main areas of new work on our group, and has also been used by our collaborators at Trinity College, Dublin. She then remained with us as an Inria postdoc, before being hired by Engineering Inc. in Italy with the post of BI consultant. Alessandra is still in touch with the group members. This was a great experience for both the ERCIM fellow and host, and we will definitely be on the lookout for more such opportunities"



Ilangko Balasingham, Adjunct Professor, Department of Electronics and Telecommunications at the Norwegian University of Science and Technology

"I have hosted eight fellows at my group at NTNU since 2006, and my impression of all of them has been very positive! My research in signal processing and wireless communications for medicine requires a team that has a diverse research background to solve complex problems. The hosted fellows were specialists in signal processing, physical layer, MAC layer, network protocols, computer networks, optimization theory, and mathematics. Furthermore, they were genuinely interested in learning new skills and getting involved in complex research projects. Most of them contacted me before submitting their applications, which made the match-making process a bit easier. Their contributions have been very fruitful for us: each fellow, on average, has submitted three journal/conference papers during the tenure. I still have regular contact with many of them and will be looking for new fellows! I would also like to convey my sincere gratitude to the people working at the ERCIM offices at NTNU and in Nice for their professional way of handling and solving many practical issues."

Jean-Laurent Hippolyte, postdoctoral fellow at VTT Technical Research Centre of Finland

"My first experience as a young postdoctoral researcher was even better than I expected. I not only have enhanced my skills and learned new ones, but also met interesting people and discovered another culture and other ways of working and collaborating. The ERCIM Office addressed most annoying money matters so that I could focus on enjoying great scientific work with the help of my hosting supervisor. My personal research project has been greatly influenced by the collective projects in which I was involved, both international and national (inside my host country) thanks to the fellowship. The research exchange trips are particularly enriching: they gave us the opportunity to share experiences with other European research teams in a close and casual way. Overall, an ERCIM Fellowship is a gratifying adventure that I would recommend to any young researcher willing to establish long-term international collaborations."

Jason Frank, leader of CWI's research group MAC1 - Computational and Stochastic Dynamics

"Sergiy Zhuk visited my group at CWI while he was a fellow at Inria. We found his work on data assimilation and his individual enthusiasm so interesting that we offered him a subsequent ERCIM Fellowship in Amsterdam. Before the term of his appointment had passed, he was hired by IBM Research in Dublin, where he will direct a research group on assimilation of satellite data for deduction of ocean flows, and maintain collaborations with us. Overall this was a great opportunity for both fellow and host, and I will be sure to keep an eye open for future ERCIM applicants."

Introduction to the special theme

Big Data

by Costantino Thanos, Stefan Manegold and Martin Kersten

Big data' refers to data sets whose size is beyond the capabilities of the current database technology.

The current data deluge is revolutionizing the way research is carried out and resulting in the emergence of a new fourth paradigm of science based on data-intensive computing. This new data-dominated science will lead to a new data-centric way of conceptualizing, organizing and carrying out research activities which could lead to an introduction of new approaches to solve problems that were previously considered extremely hard or, in some cases, impossible to solve and also lead to serendipitous discoveries.

The recent availability of huge amounts of data, along with advanced tools of exploratory data analysis, data mining/machine learning and data visualization, offers a whole new way of understanding the world.

In order to exploit these huge volumes of data, new techniques and technologies are needed. A new type of e-infrastructure, the Research Data Infrastructure, must be developed to harness the accumulation of data and knowledge produced by research communities, optimize the data movement across scientific disciplines, enable large increases in multi- and interdisciplinary science while reducing duplication of effort and resources, and integrating research data with published literature.

Science is a global undertaking and research data are both national and global assets. A seamless infrastructure is needed to facilitate collaborative arrangements necessary for the intellectual and practical challenges the world faces.

Therefore, there is a need for Global Research Data Infrastructures to overcome language, policy, methodology, and social barriers and to reduce geographic, temporal, and national barriers in order to facilitate discovery, access, and use of data.

The next generation of global research data infrastructures is facing two main challenges:

- to effectively and efficiently support data-intensive science
- to effectively and efficiently support multidisciplinary/interdisciplinary science.

In order to build the next generation of Global Research Data Infrastructures several breakthroughs must be achieved. They include:

Data modelling challenges

There is a need for radically new approaches to research data modelling. Current data models (relational model) and management systems (relational database management systems) were developed by the database research community for business/commercial data applications. Research

data has completely different characteristics and thus the current database technology is unable to handle it effectively.
There is a need for data models and query languages that:

- more closely match the data representation needs of the several scientific disciplines;
- describe discipline-specific aspects (metadata models);
- represent and query data provenance information;
- represent and query data contextual information;
- represent and manage data uncertainty;
- represent and query data quality information.

Data management challenges

There is a clear need for extremely large data processing. This is especially true in the area of scientific data management where, in the near future, we expect data inputs in the order of multiple Petabytes. However, current data management technology is not suitable for such data sizes.
In the light of such new database applications, we need to rethink some of the strict requirements adopted by database systems in the past. For instance, database management systems (DBMS) see database queries as contracts carved in stone that require the DBMS to produce a complete and correct answer, regardless of the time and resources required. While this behaviour is crucial in business data management, it is counterproductive in scientific data management. With the explorative nature of scientific discovery, scientists cannot be expected to instantly phrase a crisp query that yields the desired (but a priori unknown) result, or to wait days to get a multi-megabyte answer that does not reveal what they were looking for. Instead, the DBMS could provide a fast and cheap approximation that is neither complete nor correct, but indicative of the complete answer. In this way, the user gets a 'feel' for the data that helps him/her to advance his/her exploration using a refined query.

The challenges faced include catching the user's intention and providing the users with suggestions and guidelines to refine their queries in order to quickly converge to the desired results, but also call for novel database architectures and algorithms that are designed with the intent to produce fast and cheap indicative answers rather than complete and correct answers.

Data Tools challenges

Currently, the available data tools for most scientific disciplines are inadequate. It is essential to build better tools in order to improve the productivity of scientists. There is a need for better computational tools to visualize, analyze, and catalog the available enormous research datasets in order to enable data-driven research.
Scientists need advanced tools that enable them to follow new paths, try new techniques, build new models and test them in new ways that facilitate innovative multidisciplinary/interdisciplinary activities and support the whole research cycle.

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Invited article

Data Stewardship in the Age of Big Data

by Daniel E. Atkins

As evidenced by a large and growing number of reports from research communities, research funding agencies, and academia, there is growing acceptance of the assertion that science is becoming more and more data-centric.

Data is pushed to the center by the scale and diversity of data from computational models, observatories, sensor networks, and the trails of social engagement in our current age of Internet-based connection. It is pulled to the center by technology and methods now called "the big-data movement" or by some a "fourth paradigm for discovery" that enables extracting knowledge from these data and then acting upon it. Vivid examples of data analytics and its potential to convert data to knowledge and then to action in many fields are found at http://www.cra.org/ccc/dan.php. Note that I am using the phrase "big data" to include both the stewardship of the data and the system of facilities and methods (including massive data centers) to extract knowledge from data.

The focus of these comments is the fact that our current infrastructure - technologies, organizations, and sustainability strategies - for the stewardship of digital data and codes is far from adequate to support the vision of transformative data-intensive discovery. I include both data and programming codes because to the extent that both are critical to research, both need to be curated and preserved to sustain the fundamental tradition of the reproducibility of science. See for example an excellent case study about reproducible research in the digital age at http://stanford.edu/~vcs/papers/RRCiSE-STODDEN2009.pdf.

The power of data mining and analytics increases the opportunity costs for not preserving data for reuse, particularly for inherently longitudinal research such as global climate change. Multi-scale and multi-disciplinary research often requires complex data federation and in some fields careful vetting and credentialing of data is critical. Appraisal and curation is, at present at least, expensive and labor intensive. Government research-funding agencies are declaring data from research to be a public good and requiring that it be made openly available to the public. But where will these data be stored and stewarded?

On the campuses of research universities there is widespread and growing demand by researchers to create university-level, shared, professionally managed data-storage services and associated services for data management. This is being driven by:

- the general increase in the scale of data and new methods for extracting information and knowledge from data, including that produced by other people
- policies by research funders requiring that data should be an open resource that is available at no or low cost to others over long periods of time
- privacy and export regulations on data that are beyond the capability of the researcher to be in compliance
- the growing need to situate data and computational resources together to make it easier for researchers to develop scientific applications, increasingly as web service, on top of the rich data store. They could potentially use their data, as well as shared data and tools from others to accelerate discovery, democratize resources, and yield more bang for the buck from research funding.

Although there are numerous successful repository services for the scholarly literature, most do not accommodate research data and codes. Furthermore, as noted by leaders of an emerging Digital Preservation Network (DPN) being incubated by Internet 2, a US-based research and education network consortium, even the scholarship that is being produced today is at serious risk of being lost forever to future generations. There are many digital collections with a smattering of aggregation but all are susceptible to multiple single points of failure. DPN aspires to do something about this risk, including archival services for research data.

No research funding agency, at least in the US, has provided or is likely to provide the enormous funding on a sustained basis required to create and maintain an adequate cyberinfrastructure for big data. We must approach it as a shared enterprise involving academia, government, for-profit and non-profit organizations, with multiple institutions playing complementary roles within an incentive system that is sustainable both financially and technically.

At the federal government level, major research funding agencies including the National Science Foundation, the National Institutes for Health, and the Department of Energy, together with several mission-based agencies are developing, with encouragement from the White House, a coordinated inter-agency response to "big data." Although details will not be available for several months, the goals will be strategic and will include four linked components: foundational research, infrastructure, transformative applications to research, and related training and education.

Commercial partners could play multiple roles in the big-data movement, especially by providing cloud-based platforms for storing and processing big data. The commercial sector has provided and will likely continue to provide resources at a scale well beyond what can be provided by an individual or even a university consortium. Major cloud service providers in the US have strategies to build a line of business to provide the cloud as a platform for big data, and there is growing interest within both universities and the federal government in exploring sustainable public-private partnerships.

Initial efforts at collaboration between academia, government, and industry are encouraging but great challenges remain to nurture the infrastructure necessary to achieve the promise of the big-data movement.

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Invited article

SciDB: An Open-Source DBMS for Scientific Data

by Michael Stonebraker

SciDB is a native array DBMS that combines data management and mathematical operations in a single system. It is an open source system that can be downloaded from SciDB.org

SciDB is an open-source DBMS oriented toward the data management needs of scientists. As such it mixes statistical and linear algebra operations with data management ones, using a natural nested multi-dimensional array data model. We have been working on the code for three years, most recently with the help of venture capital backing. Currently, there are 14 full-time professionals working on the code base.

SciDB runs on Linux and manages data that can be spread over multiple nodes in a computer cluster, connected by TCP/IP networking. Data is stored in the Linux file system on local disks connected to each node. Hence, it uses a "shared nothing" software architecture.

The data model supported by SciDB is multi-dimensional arrays, where each cell can contain a vector of values. Moreover, dimensions can be either the standard integer ones or they can be user-defined data types with non-integer values, such as latitude and longitude. There is no requirement that arrays be rectangular; hence SciDB supports "ragged" arrays.

Access is provided through an array-version of SQL, which we term AQL. AQL provides facilities for filtering arrays, joining arrays and aggregation over the cell values in an array. Moreover, Postgres-style user-defined scalar functions, as well as array functions are provided.

In addition, SciDB contains pre-built popular mathematical functions, such as matrix multiply, that operate in parallel on multiple cores on a single node as well as across nodes in a cluster.

Other notable features of SciDB include a no-overwrite storage manager that retains old values of updated data, and provides Postgres-style "time travel" on the various versions of a cell. Moreover, we have extended SciDB with support for multiple notions of "null". Using this capability, users can distinguish multiple semantic notions, such as "data is missing but it is supposed to be there" and "data is missing and will be present within 24 hours". Standard ACID transactions are supported, as is an interface to the statistical package R, which can be used to run existing R scripts as well as to visualize the result of SciDB queries.

Our storage manager divides arrays, which can be arbitrarily large, into storage "chunks" which are partitioned across the nodes of a cluster and then allocated to disk blocks. Worthy chunks are also cached in main memory for faster access.

We have benchmarked SciDB against Postgres on an astronomy-style workload that typifies the load provided by the Large Synoptic Survey Telescope (LSST) project. On this benchmark, SciDB outperforms Postgres by 2 orders of magnitude. We have also benchmarked SciDB analytics against those in R. On a single core, we offer comparable performance; however SciDB scales linearly with additional cores and additional nodes, a characteristic that does not apply to R.

Early users of SciDB include the LSST project mentioned above, multiple high-energy physics (HEP) projects, as well as commercial applications in genomics, insurance and financial services. SciDB has been downloaded by about 1000 users from a variety of scientific and commercial domains.

A fairly robust and performant version of the system is currently downloadable from our web site (SciDB.org). We plan a production-ready release of SciDB within the next six months. The system is supported by Paradigm4, Inc, a venture-capital backed company in Waltham, Massachusetts, which provides application consulting as well as a collection of enterprise-oriented extensions to SciDB.

SciDB is used by the Large Synoptic Survey Telescope (LSST) project. Its powerful data system will compare new with previous images to detect changes in brightness and position. Hundreds of images of each part of the sky will be used to construct a movie of the sky. This image from a pilot project called the Deep Lens Survey (DLS), gives a taste of what the sky will look like with LSST. But the LSST data will actually go deeper still, have better resolution and cover 50,000 times the area of this image, and in 6 different optical bands. In addition, LSST will also reveal changes in the sky by repeatedly covering this area multiple times per month, over 10 years. Image Courtesy of Deep Lens Survey / UC Davis / NOAO.

Link: http://www.scidb.org

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Invited article

Data Management in the Humanities

by Laurent Romary

Owing to the growing interest in digital methods within the humanities, an understanding of the tenets of digitally based scholarship and the nature of specific data management issues in the humanities is required. To this end the ESFRI roadmap on European infrastructures has been seminal in identifying the need for a coordinating e-infrastructure in the humanities - DARIAH - whose data policy is outlined in this paper.

Scholarly data in the humanities is a heterogeneous notion. Data creation, ie the transcription of a primary document, the annotation of existing sources or the compilation of observations across collections of objects, is inherent to scholarly activity and thus makes it strongly dependant upon the actual hypotheses or theoretical backgrounds of the researcher. There is little notion of data centre in the humanities since data production and enrichment are anchored on the individuals performing research.

DARIAH's goal is to create a sound and solid infrastructure to ensure the long-term stability of digital assets, as well as the development of a wide range of thus-far unanticipated services to carry out research on these assets. This comprises both technical aspects (identification, preservation), editorial (curation, standards) and sociological (openness, scholarly recognition).

This vision is underpinned by the notion of digital surrogates, information structures intended to identify, document or represent a primary source used in a scholarly work. Surrogates can be metadata records, a scanned image of a document, digital photographs, transcription of a textual source, or any kind of extract or transformation (eg the spectral analysis of a recorded speech signal) of existing data. Surrogates act as a stable reference for further scholarly work in replacement – or in complement – to the original physical source it represents or describes. Moreover, a surrogate can act as a primary source for the creation of further surrogates, thus forming a network that reflects the various steps of the scholarly workflow where sources are combined and enriched before being further disseminated to a wider community.

Such a unified data landscape for humanities research necessitates a clear policy on standards and good practices. Scholars should both benefit from strong initiatives such as the Text Encoding Initiative (TEI) and stabilize their experience by participating in the development of standards, in collaboration with other stakeholders (publishers, cultural heritage institutions, libraries).

The vision also impacts on the technical priorities for DARIAH, namely:

- deploying a repository infrastructure where researchers can transparently and trustfully deposit their productions, comprising permanent identification and access, targeted dissemination (private, restricted and public) and rights management, possibly in a semi-centralized way allowing efficiency, reliability and evolution (cf. http://hal.archives-ouvertes.fr/hal-00399881);
- defining standardized interfaces for accessing data through such repositories, but also through third-party data sources, with facilities such as threading, searching, selecting, visualizing and importing data;
- experimenting with the agile development of virtual research spaces based on such services, integrating community based research workflows (see http://hal.inria.fr/inria-00593677).

Beyond the technical aspects, an adequate licensing policy must be defined to assert the legal conditions under which data assets can be disseminated. This should be a compromise between making all publicly financed scholarly productions available in open access and preventing the adoption of heterogeneous reuse constraints and/or licensing models. We contemplate encouraging the early dissemination of digital assets in the scholarly process and recommend, when applicable, the use of a Creative Commons CC-BY license, that supports systematic attribution (and thus citation) of the source.

From a political point of view, we need to discuss with potential data providers (cultural heritage entities, libraries or even private sector stakeholders such as Google) methods of creating a seamless data landscape where the following issues should be jointly tackled:

- general reuse agreements for scholars, comprising usage in publications, presentation on web sites, integration (or referencing) in digital editions, etc.;
- definition of standardized formats and APIs that could make access to one or the other data provider more transparent;
- identification of scenarios by covering the archival version of records as well as scholarly created enrichments. For example, TEI transcriptions made by scholars could be archived in the library where the primary source is situated.

As a whole, DARIAH should contribute to excellence in research by being seminal in the establishment of a large coverage, coherent and accessible data space for the humanities. Whether acting at the level of standards, education or core IT services, we should keep this vision in mind when setting priorities in areas that will impact the sustainability of the future digital ecology of scholars.

Links:

ESFRI: ec.europa.eu/research/esfri/

DARIAH: www.dariah.eu/

European report on scientific data:
cordis.europa.eu/fp7/ict/e-infrastructure/docs/hlg-sdi-report.pdf

Text Encoding Initiative:
http://www.tei-c.org

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Managing Large Data Volumes from Scientific Facilities

by Shaun de Witt, Richard Sinclair, Andrew Sansum and Michael Wilson

One driver for the data tsunami is social networking companies such as Facebook™ which generate terabytes of content. Facebook for instance, uploads three billion photos monthly for a total of 3,600 terabytes annually. The volume of social media is large, but not overwhelming. The data are generated by a lot of humans, but each is limited in their rate of data production. In contrast, large scientific facilities are another driver where the data are generated automatically.

In the 10 years to 2008, the largest current astronomical catalogue, the Sloane Digital Sky Survey, produced 25 terabytes of data from telescopes.

By 2014, it is anticipated that the Large Synoptic Survey Telescope will produce 20 terabytes each night. By the year 2019, The Square Kilometre Array radio telescope is planned to produce 50 terabytes of processed data per day , from a raw data rate of 7000 terabytes per second. The designs for systems to manage the data from these next generation scientific facilities are being based on the data management used for the largest current scientific facility: the CERN Large Hadron Collider.

The Worldwide LHC Computing Grid has provided the first global solution to collecting and analyzing petabytes of scientific data. CERN produces data as the Tier0 site, which are distributed to 11 Tier1 sites around the world - including the GRIDPP Tier-1 at STFC's Rutherford Appleton Laboratory (RAL) in the UK. The CASTOR storage infrastructure used at RAL was designed at CERN to meet the challenge of handling the high LHC data rates and volume using commodity hardware. CASTOR efficiently schedules placement of files across multiple storage devices, and is particularly efficient at managing tape access. The scientific metadata relating science to data-files is catalogued by each experiment centrally at CERN. The Tier1 sites operate databases which identify on which disk or tape the data-file is stored.

In science the priority is to capture the data, because if it's not stored it may be lost, and the lost dataset may have been the one that would have lead to a Nobel Prize. Analysis is given secondary priority, since data can be analysed later, when it's possible. Therefore the architecture that meets the user priorities is based on effective storage, with a batch scheduler responsible for choosing compute locations, moving data and scheduling jobs.

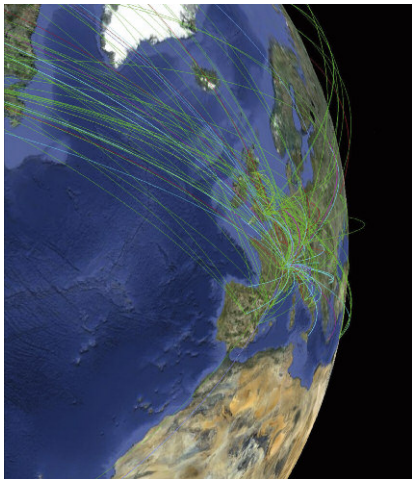

Figure 1: A snapshot of the monitor showing data analysis jobs being passed around the Worldwide LHC Computing Grid.

The data are made available to researchers who submit jobs to analyse datasets on Tier2 sites. They submit processing jobs to a batch processing scheduler that states which data to analyse, and what analysis to perform. The system schedules jobs for processing at the location that minimises data transfers. The scheduler will copy the data to the compute location before the analysis, but this transfer consumes considerable communication bandwidth, which reduces the response speed.

The Tier1 at RAL has 8PB of high bandwidth disk storage for frequently used data, in front of a tape robot with lower bandwidth, but a maximum capacity of 100PB for long term data archiving. In 2011, network rates between the Tier-1 and wide area network averaged 4.7Gb/s and peaked at over 20Gb/s; over 17PB of data was moved between the Tier-1 and other sites worldwide. Internally, over the same period, 5PB of data was moved between disk and tape and a further 28PB between disk and the batch farm. During intense periods of data reprocessing internal network rates exceeded 60Gb/s for many hours.

Storing and retrieving data is not that difficult - what's hard is managing the data, so that users can find what they want, and get it when they want. The limiting factor for Tier1 sites is the performance of the databases. The RAL database stores a single 20 gigabyte table, representing the hierarchical file structure, which performs about 500 transactions per second across six clusters. In designing the service it is necessary to reduce to a practical level the number of disk operations to the data tables and the log required for error recovery on each cluster. Multiple clusters are used, but that introduces a communications delay between clusters to ensure the integrity of the database, due to the passing of data locking information between them. Either the disk i/o or the inter-cluster communication becomes the limiting factor.

In contrast, Facebook users require immediate interactive responses, so batch schedulers cannot be used. They use a waterfall architecture which, in February 2011, ran 4,000 instances of MySQL, but also required 9,000 instances of a database memory caching system to speed up performance.

Whatever the application, for large data volumes the problem remains how to model the data and its usage so that the storage system can be appropriately designed to support the users performance demands.

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Revolutionary Database Technology for Data Intensive Research

by Martin Kersten and Stefan Manegold

The ability to explore huge digital resources assembled in data warehouses, databases and files, at unprecedented speed, is becoming the driver of progress in science. However, existing database management systems (DBMS) are far from capable of meeting the scientists' requirements. The Database Architectures group at CWI in Amsterdam cooperates with astronomers, seismologists and other domain experts to tackle this challenge by advancing all aspects of database technology. The group's research results are disseminated via its open-source database system, MonetDB.

The heart of a scientific data warehouse is its database system, running on a modern distributed platform, and used for both direct interaction with data gathered from experimental devices and management of the derived knowledge using workflow software. However, most (commercial) DBMS offerings cannot fulfill the demanding needs of scientific data management. They fall short in one or more of the following areas: multi-paradigm data models (including support for arrays), transparent data ingestion from, and seamless integration of, scientific file repositories, complex event processing, and provenance. These topics only scratch the surface of the problem. The state of the art in scientific data exploration can be compared with our daily use of search engines. For a large part, search engines rely on guiding the user from their ill-phrased queries through successive refinement to the information of interest. Limited a priori knowledge is required. The sample answers returned provide guidance to drill down, chasing individual links, or to adjust the query terms.

The situation in scientific databases is more cumbersome than searching for text, because they often contain complex observational data, eg telescope images of the sky, satellite images of the earth, time series or seismograms, and little a priori knowledge exists. The prime challenge is to find models that capture the essence of this data at both a macro- and micro-scale. The answer is in the database, but the 'Nobel-winning query' is still unknown.

Next generation database management engines should provide a much richer repertoire and ease of use experience to cope with the deluge of observational data in a resource-limited setting. Good is good enough as an answer, provided the journey can be continued as long as the user remains interested.

We envision seven directions of long term research in database technology:

- Data Vaults. Scientific data is usually available in self-descriptive file formats as produced by advanced scientific instruments. The need to convert these formats into relational tables and to explicitly load all data into the DBMS forms a major hurdle for database-supported scientific data analysis. Instead, we propose the data vault, a database-attached external file repository. The data vault creates a true symbiosis between a DBMS and existing file-based repositories, and thus provides transparent access to all data kept in the repository through the DBMS's (array-based) query language.

- Array support. Scientific data management calls for DBMSs that integrate the genuine scientific data model, multi-dimensional arrays, as first-class citizens next to relational tables, and unified declarative language as symbiosis of relational and linear algebra. Such support needs to be beyond 'alien' extensions that provide user defined functions. Rather, arrays need to become first-class DBMS citizens next to relational tables.

- One-minute database kernels. Such a kernel differs from conventional kernels by identifying and avoiding performance degradation by answering queries only partly within strict time bounds. Run the query during a coffee break, look at the result, and continue or abandon the data exploration path.

- Multi-scale query processing. Fast exploration of large datasets calls for partitioning the database based on science interest and resource availability. It extends traditional partitioning schemes by taking into account the areas of users' interest and the statistical stability in samples drawn from the archives.

- Post-processing result sets. The often huge results returned should not be thrown at the user directly, but passed through an analytical processing pipeline to condense the information for human consumption. This involves computation intensive data mining techniques and harnessing the power of GPUs in the software stack of a DBMS.

- Query morphing. Given the imprecision of the queries, the system should aid in hinting at proximity results using data distributions looked upon during query evaluation. For example, aside from the traditional row set, it may suggest minor changes to the query predicates to obtain non-empty results. The interesting data may be 'just around the corner'.

- Queries as answers. Standing on the shoulders of your peers involves keeping track of the queries, their results, and resource requirements. It can be used as advice to modify ill-phrased queries that could run for hours producing meaningless results.

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Zenith: Scientific Data Management on a Large Scale

by Esther Pacitti and Patrick Valduriez

Modern science disciplines such as environmental science and astronomy must deal with overwhelming amounts of experimental data. Such data must be processed (cleaned, transformed, analyzed) in all kinds of ways in order to draw new conclusions and test scientific theories. Despite their differences, certain features are common to scientific data of all disciplines: massive scale; manipulated through large, distributed workflows; complexity with uncertainty in the data values, eg, to reflect data capture or observation; important metadata about experiments and their provenance; and mostly append-only (with rare updates). Furthermore, modern scientific research is highly collaborative, involving scientists from different disciplines (eg biologists, soil scientists, and geologists working on an environmental project), in some cases from different organizations in different countries. Since each discipline or organization tends to produce and manage its own data in specific formats, with its own processes, integrating distributed data and processes gets difficult as the amounts of heterogeneous data grow.

In 2011, to address these challenges, we started Zenith (http://www-sop.inria.fr/teams/zenith/), a joint team between Inria and University Montpellier 2. Zenith is located at LIRMM in Montpellier, a city that enjoys a very strong position in environmental science with major labs and groups working on related topics such as agronomy, biodiversity, water hazard, land dynamics and biology. We are developing our solutions by working closely with scientific application partners such as CIRAD and INRA in agronomy.

Zenith adopts a hybrid P2P/cloud architecture. P2P naturally supports the collaborative nature of scientific applications, with autonomy and decentralized control. Peers can be the participants or organizations involved in collaboration and may share data and applications while keeping full control over some of their data (a major requirement for our application partners). But for very-large scale data analysis or very large workflow activities, cloud computing is appropriate as it can provide virtually infinite computing, storage and networking resources. Such hybrid architecture also enables the clean integration of the users' own computational resources with different clouds.

Figure 1 illustrates Zenith's architecture with P2P data services and cloud data services. We model an online scientific community as a set of peers and relationships between them. The peers have their own data sources. The relationships are between any two or more peers and indicate how the peers and their data sources are related, eg "friendship", same semantic domain, similar schema. The P2P data services include basic services (metadata and uncertain data management): recommendation, data analysis and workflow management through the Shared-data Overlay Network (SON) middleware. The cloud P2P services include data mining, content-based information retrieval and workflow execution. These services can be accessed through web services, and each peer can use the services of multiple clouds.

Let us illustrate two recent results obtained in this context. The first is the design and implementation of P2Prec (http://www-sop.inria.fr/teams/zenith/p2prec/), a recommendation service for P2P content sharing that exploits users' social data. In our approach, recommendation

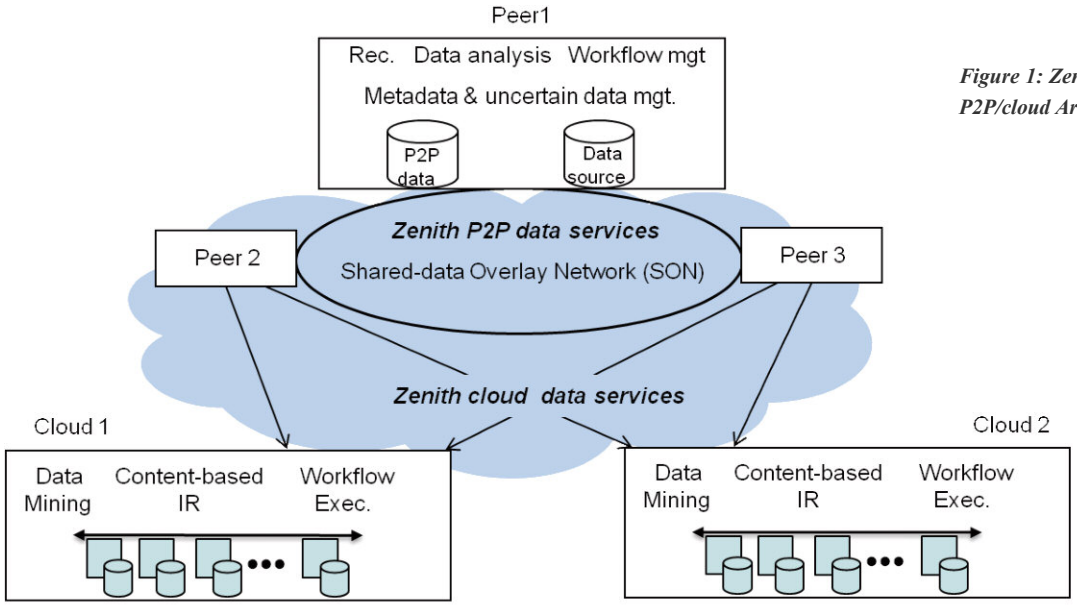

Figure 1: Zenith Hybrid P2P/cloud Architecture

is based on explicit personalization, by exploiting the scientists' social networks, using gossip protocols that scale well. Relevance measures may be expressed based on similarities, users' confidence, document popularity, rates, etc., and combined to yield different recommendation criteria. With P2Prec, each user can identify data (documents, annotations, datasets, etc.) provided by others and send queries to them. For instance, one may want to know which scientists are expert in a topic and get documents highly rated by them. Or another may look for the best datasets used by others for some experiment. To efficiently disseminate information among peers, we propose new semantic-based gossip protocols. Furthermore, P2Prec has the ability to get reasonable recall with acceptable query processing load and network traffic.

The second result deals with the efficient processing of scientific workflows that are computationally and data-intensive, thus requiring execution in large-scale parallel computers. We propose an algebraic approach (inspired by relational algebra) and a parallel execution model that enable automatic optimization of scientific workflows. With our algebra, data are uniformly represented by relations and workflow activities are mapped to operators that have data aware semantics. Our execution model is based on the concept of activity activation, which enables transparent distribution and parallelization of activities. Using both a real oil exploitation application and synthetic data scenarios, our experiments demonstrate major performance improvements compared to an ad-hoc workflow implementation.

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Performance Analysis of Healthcare Processes through Process Mining

by Diogo R. Ferreira

Process mining provides new ways to analyze the performance of clinical processes based on large amounts of event data recorded at run-time.

Hospitals and healthcare organizations around the world are collecting increasingly vast amounts of data about their patients and the clinical processes they go through. At the same time - especially in the case of public hospitals - there is growing pressure from governmental bodies to refactor clinical processes in order to improve efficiency and reduce costs. These two trends converge, prompting for the need to use run-time data in order to support the analysis of existing processes.

In the area of process mining, there are specialized techniques for the analysis of business processes according to a number of perspectives, including control-flow, social network, and performance. These techniques are based on the analysis of event data recorded in system logs. In general, any information system that is able to record the activities that are performed during process execution can provide valuable data for process analysis.

These event data become especially relevant for the analysis of clinical processes, which are highly complex, dynamic, multi-disciplinary, and ad-hoc in nature. Until recently one could only prescribe general guidelines for this kind of process, and expect that medical staff comply. Now, with process mining techniques, it is possible to analyze the actual run-time behaviour of such processes and obtain precise information about their performance in near real-time.

Such an endeavour, however, is made difficult by the fact that reality is inherently complex, so direct application of process mining techniques may produce very large and confusing models, which are quite difficult to interpret and analyze – in the parlance of process mining, these are known as "spaghetti" models.

While the area of process mining is being led by Wil van der Aalst at the Eindhoven University of Technology in The Netherlands, here at the Technical University of Lisbon, in Portugal, we have been developing techniques to address the problem of how to extract information from event logs such that the output models are more amenable to interpretation and analysis. To this end, we have spent the last six years developing a number of clustering, partitioning, and preprocessing techniques. Such techniques have matured to the point that they can be systematically applied to real-world event logs, according to a prescribed methodology, to produce understandable, useful, and often surprising results.

One of the latest developments in the field of process mining, introduced by Zhengxing Huang and others at Zhejiang University in China, concerns performance. Typically, a control-flow model must be extracted from the event log prior to performance analysis. However, to study the performance of healthcare processes, only a subset of the recorded activities is usually considered – these are the key activities that represent milestones in the process, and that are always present regardless of the actual path of the patient. The time span between these activities becomes a Key Performance Indicator (KPI).

The ability to measure this KPI directly from the event log is a major improvement with respect to previous performance analysis techniques which rely on a control-flow model that often includes too much behaviour. Here, we are interested in a predefined sequence of milestones and in retrieving the time span between any pair of milestones. Incidentally, this approach also provides the time span between the first and last activities, which can be used to

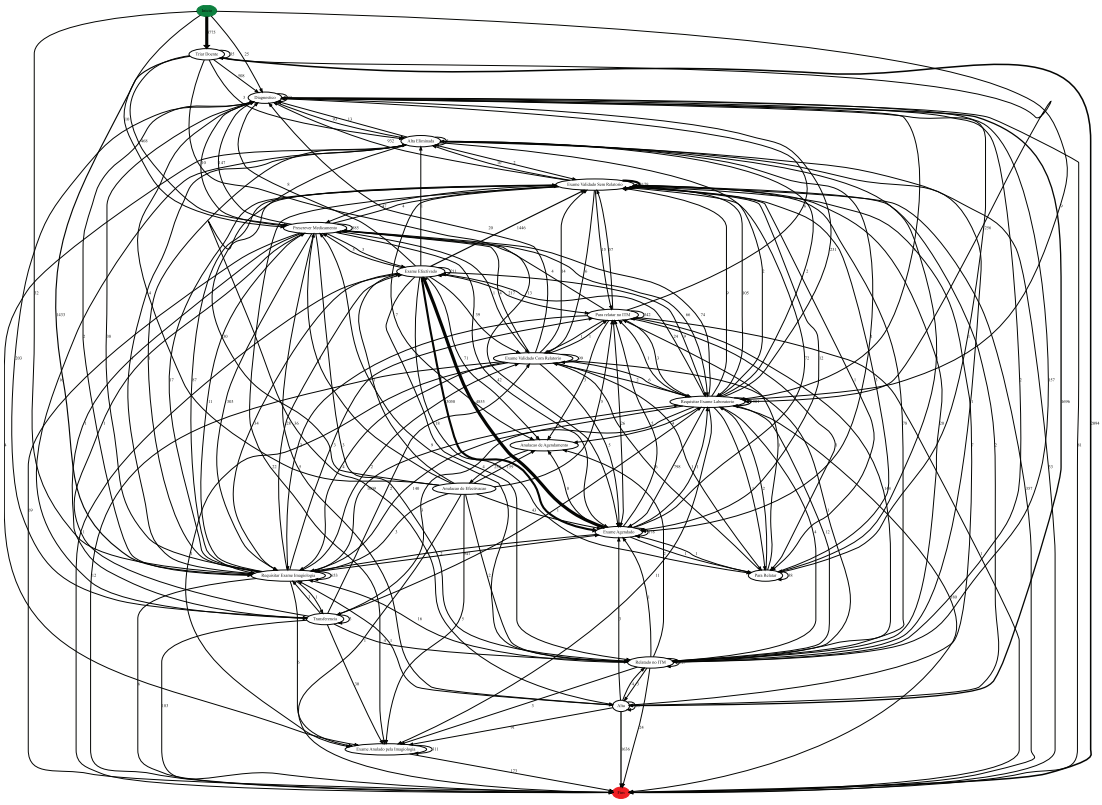

Figure 1: Control-flow model

determine the length of stay (LOS) of the patient in the hospital, one of the most sought-after KPIs in healthcare processes.

Back in Portugal, we applied this approach in a case study carried out in the emergency department of a mid-sized public hospital. The hospital has an Electronic Patient Record (EPR) system, which records the events that take place in several departments. The event log used in this experiment was collected over a period of 12 days. A total of 4851 patients entered the emergency department in that period, resulting in over 30 000 recorded events, although there are only 18 distinct activities.

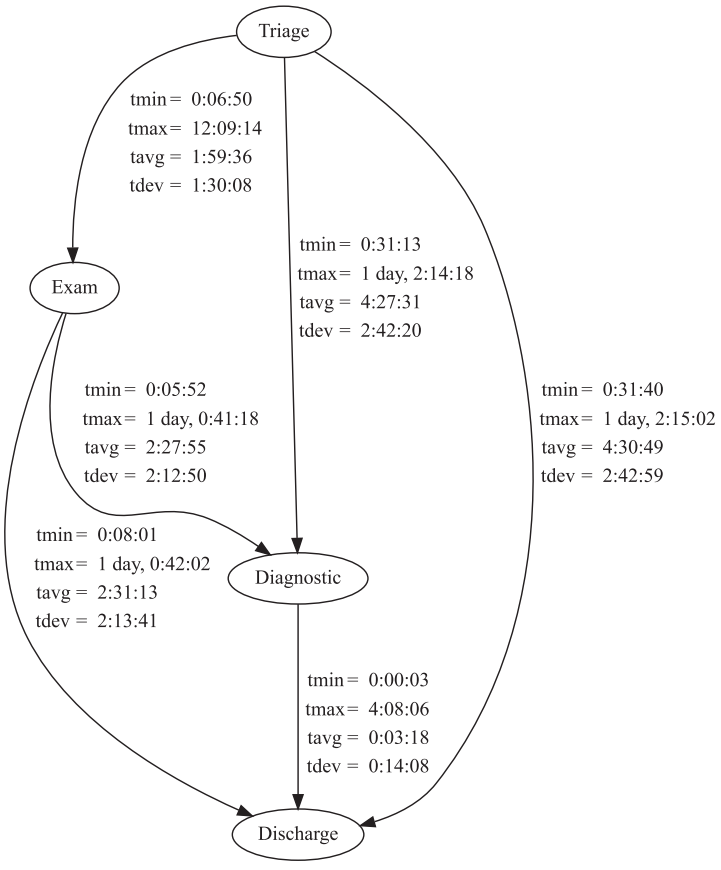

Figure 2: Performance analysis

Figure 1 depicts a control-flow model for these activities, illustrating the reason why such diagrams are often called "spaghetti" models. In Figure 2, we present the results for some key activities. The first step – triage – determines the priority of the patient and takes place once the patient enters the hospital. For patients who require medical examination, it takes on average two hours to perform the first exam. About two hours and 30 minutes later, the patient receives the diagnosis, and then is quickly discharged, on average within three minutes. The resulting LOS amounts to an average of four hours and 30 minutes.

Figure 2 shows minimum, maximum, and average times, and standard deviations. While these results were gathered for all patients that entered the emergency department, similar analysis can be conducted for patients with certain conditions or with particular clinical paths.

Link: http://www.processmining.org/

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A Scalable Indexing Solution to Mine Huge Genomic Sequence Collections

by Eric Rivals, Nicolas Philippe, Mikael Salson, Martine Leonard, Thérèse Commes and Thierry Lecroq

With High Throughput Sequencing (HTS) technologies, biology is experiencing a sequence data deluge. A single sequencing experiment currently yields 100 million short sequences, or reads, the analysis of which demands efficient and scalable sequence analysis algorithms. Diverse kinds of applications repeatedly need to query the sequence collection for the occurrence positions of a subword. Time can be saved by building an index of all subwords present in the sequences before performing huge numbers of queries. However, both the scalability and the memory requirement of the chosen data structure must suit the data volume. Here, we introduce a novel indexing data structure, called Gk arrays, and related algorithms that improve on classical indexes and state of the art hash tables.

Biology and its applications in other life sciences, from medicine to agronomy or ecology, is increasingly becoming a computational, data-driven science, as testified by the launch of the Giga Science journal (http://www.gigasciencejournal.com). In particular, the advent and rapid spread of High Throughput Sequencing (HTS) technologies (also called Next Generation Sequencing) has revolutionized how research questions are addressed and solved. To assess the biodiversity of an area, for instance, instead of patiently determining species in the field, the DNA of virtually all species present in collected environmental samples (soil, water, ice, etc.) can be sequenced in a single run of a metagenomic experiment. The raw output consists of up to several hundred million short sequencing reads (eg from 30 to 120 nucleotides with an Illumina sequencer). These reads are binned into classes corresponding to species, which allow to reliable estimation of their number and relative abundance. This becomes a computational question.

In other, genome-wide, applications, HTS serve to sequence new genomes, to catalogue active genes in a tissue, and soon in a cell, to survey epigenetic modifications that alter our genome, to search for molecular markers of diseases in a patient sample. In each case, the read analysis takes place in the computer, and users face scalability issues. The major bottleneck is memory consumption. To illustrate the scale, currently sequences accumulate at a faster rate than the Moore law, and large sequencing centres have outputs of gigabases a day, so large that even network transfer becomes problematic.

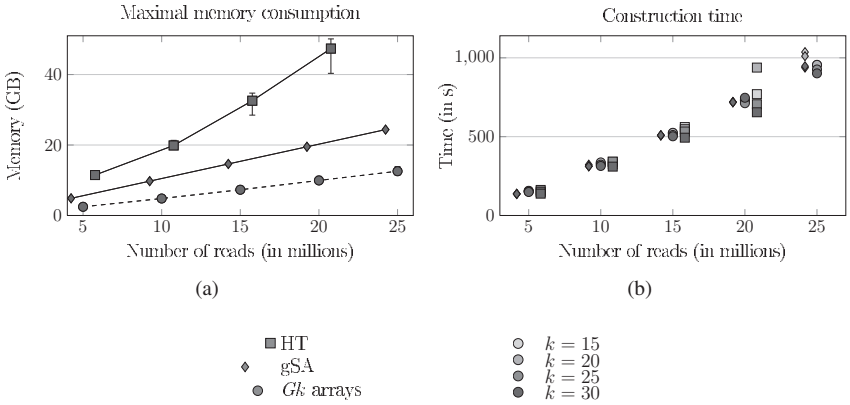

Figure 1: Comparison of Gk arrays with a generalised Suffix Array (gSA) and a Hash Table solutions on the construction time and memory usage.

Let us take an example. Consider the problem of assembling a genome from a huge collection of reads. Because sequencing is error prone and the sequenced DNA vary between cells, the read sequences are compared pairwise to determine regions of approximate matches. To make it feasible, potentially matching regions between any read pair are selected on the presence of identical subwords of a given length k (k-mer). For the sake of efficiency, it is advantageous, if not compulsory, to index once for all the positions of all distinct k-mers in the reads. Once constructed, the index data structure is kept in main memory and repeatedly accessed to answer queries like 'given a k-mer, get the reads containing this k-mer (once/at least once)'. The question of indexing k-mers or subwords has long been addressed for large texts, however classical solutions like the generalized suffix tree, or suffix array require too much memory for a read collection. Even state of the art implementations of sparse hash tables (Google sparse hash) hit their limits with such data volumes.

To address the increasing demand for read indexing, we have developed a compact and efficient data structure, dubbed Gk arrays, that is specialized for indexing huge collections of short reads (the term 'collection', rather than 'set', underlines that the same read sequence can occur multiple times in the input). An in-depth evaluation has shown that Gk arrays, can be constructed in a time similar to the best hash tables, but outperform all concurrent solutions in term of memory usage (Figure 1). The Gk arrays combine three arrays: one for storing the sorted positions where true k-mers start, an inverted array that allows finding the rank of any k-mer from a position in a read, and a smaller array that records the intervals of positions of each distinct k-mer in sorted order. Although reads are concatenated for construction, Gk arrays avoid storing the positions of (artificial) k-mers that overlap

two adjacent reads. For instance, the query for counting the read containing an existing k-mer takes constant time. Several types of queries have been implemented and Gk arrays accommodate fixed as well as variable length reads. Gk arrays are packaged in an independent C++ library with a simple and easy to use programming interface (http://www.atgc-montpellier.fr/ngs/). They are currently exploited in a read mapping and RNA-sequencing analysis program; their scalability, efficiency, and versatility made them adequate for read error correction, read classification, k-mer counting in assembly program, or other HTS applications. Gk arrays can be seen as an indexing layer that is accessed by higher level applications. Future developments are planned to devise direct construction algorithms, or a compressed version of Gk arrays that, like other index structures, stores only some sampled positions and reconstruct the others at runtime, hence enabling the user to control the balance between speed and memory usage.

Gk arrays library is available on the ATGC bioinformatics platform in Montpellier: http://www.atgc-montpellier.fr/gkarrays

Link:
Gk arrays library:
http://www.atgc-montpellier.fr/gkarrays

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A-Brain: Using the Cloud to Understand the Impact of Genetic Variability on the Brain

by Gabriel Antoniu, Alexandru Costan, Benoit Da Mota, Bertrand Thirion and Radu Tudoran

Joint genetic and neuroimaging data analysis on large cohorts of subjects is a new approach used to assess and understand the variability that exists between individuals. This approach, which to date is poorly understood, has the potential to open pioneering directions in biology and medicine. As both neuroimaging- and genetic-domain observations include a huge number of variables (of the order of 106), performing statistically rigorous analyses on such Big Data represents a computational challenge that cannot be addressed with conventional computational techniques. In the A-Brain project, researchers from Inria and Microsoft Research explore cloud computing techniques to address the above computational challenge.

Several brain diseases have a genetic origin, or their occurrence and severity is related to genetic factors. Genetics plays an important role in understanding and predicting responses to treatment for brain diseases like autism, Huntington's disease and many others. Brain images are now used to understand, model, and quantify various characteristics of the brain. Since they contain useful markers that relate genetics to clinical behaviour and diseases, they are used as an intermediate between the two. Currently, large-scale studies assess the relationships between diseases and genes, typically involving several hundred patients per study.

Imaging genetic studies linking functional MRI data and Single Nucleotide Polyphormisms (SNPs) data may face a dire multiple comparisons issue. In the genome dimension, genotyping DNA chips allow recording of several hundred thousand values per subject, while in the imaging dimension an fMRI volume may contain 100k-1M voxels. Finding the brain and genome regions that may be involved in this link entails a huge number of hypotheses, hence a drastic correction of the statistical significance of pair-wise relationships, which in turn results in a crucial reduction of the sensitivity of statistical procedures that aim to detect the association. It is therefore desirable to set up techniques that are as sensitive as possible to explore where in the brain and where in the genome a significant link can be detected, while correcting for family-wise multiple comparisons (controlling for false positive rate).

In the A-Brain project, researchers of the Parietal and KerData Inria teams jointly address this computational problem using cloud computing techniques on Microsoft Azure cloud computing environment. The two teams bring their complementary expertise: KerData (Rennes) in the area of scalable cloud data management and Parietal (Saclay) in the field of neuroimaging and genetics data analysis. The Map-Reduce programming model has recently arisen as a very effective approach to develop high-performance applications over very large distributed systems such as grids and now clouds. KerData has recently proposed a set of algorithms for data management, combining versioning with decentralized metadata management to support scalable, efficient, fine-grain access to massive, distributed Binary Large OBjects (BLOBs) under heavy concurrency. The project investigates the benefits of integrating BlobSeer with Microsoft Azure storage services and aims to evaluate the impact of using BlobSeer on Azure with large-scale application experiments such as the genetics-neuroimaging data comparisons addressed by Parietal. The project is supervised by the Joint Inria-Microsoft Research Centre.

Sophisticated techniques are required to perform sensitive analysis on the targeted large datasets. Univariate studies find an SNP and a neuroimaging trait

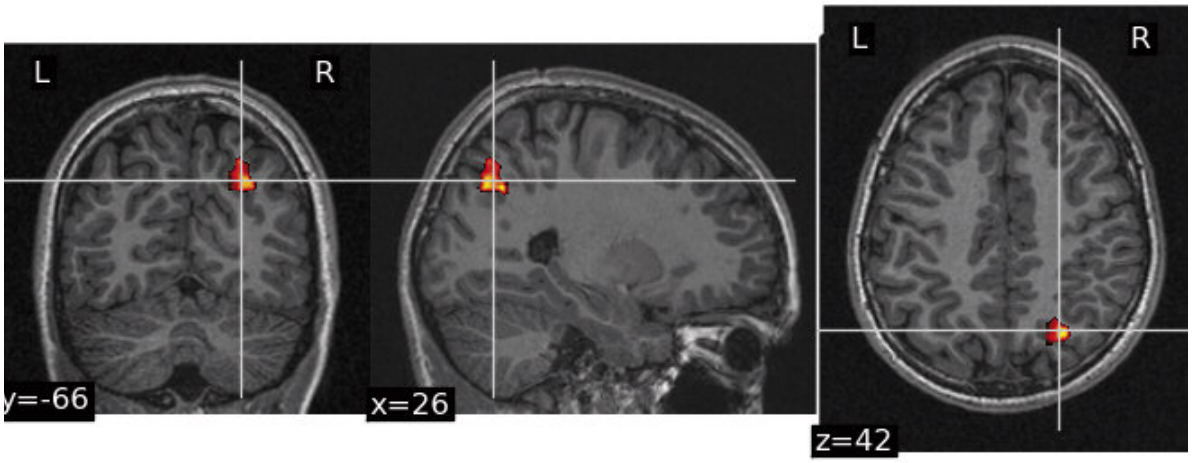

Figure 1: Identifying areas in the human brain (red and orange colors) in which activation is correlated with a given SNP data, using A-Brain.

that are significantly correlated (eg the amount of functional activity in a brain region is related to the presence of a minor allele on a gene). In regression studies, some sets of SNPs predict a neuroimaging/behavioural trait (eg a set of SNPs predict a given brain characteristic), while with multivariate studies, an ensemble of genetic traits predict a certain combination of neuroimaging traits. Typically, the data sets involved contain 50K voxels and 500K SNPs. Additionally, in order to obtain results with a high degree of confidence, a number of 10K permutations is required on the initial data, resulting in a total computation of 2.5 × 1014 associations. Several regressions are performed, each giving a set of correlations, and all these intermediate data must be stored in order to compare the values of each simulation and keep that which is most significant. The intermediate data that must be stored can easily reach 1.77 PetaBytes.

Traditional computing has shown its limitations in offering a solution for such a complex problem in the context of Big Data. Performing one experiment to determine if there is a correlation between one brain location and any of the genes on a single core would take about five years. The computational framework, however, can easily be run in parallel and with the emergence of the recent cloud platforms we could perform such computations in a reasonable time (days).

Our goal is to use Microsoft's Azure cloud to performing such experiments. For this purpose, two million hours per year and 10 TBytes of storage on the Azure platform are available for the duration of the project (three years). In order to execute the complex A-Brain application one needs a parallel programming framework (like MapReduce), supported by a high performance storage backend. We therefore developed TomusBlobs, an optimized storage service for Azure clouds, leveraging the high throughput under heavy concurrency provided by the BlobSeer library developed at KerData. TomusBlobs is a distributed storage system that exposes the local storage from the computation nodes in the cloud as a uniform shared storage to the application. Using this system as a storage backend, we implemented TomusMapReduce, a MapReduce platform for Azure. With these tools we were able to execute the neuro-imaging and genetic application in Azure and to create a demo for it. Preliminary results show that our solution brings substantial benefits to data intensive applications like A-Brain compared to approaches relying on state-of-the-art cloud object storage.

The next step will be to design a performance model for the data management layer, which considers the cloud's variability and provides some optimized deployment configurations. We are also investigating new techniques to make more efficient correlations between genes and brain characteristics.

Links:
http://www.msr-inria.inria.fr/Projects/a-brain
http://www.irisa.fr/kerdata/
http://parietal.saclay.inria.fr/
http://blobseer.gforge.inria.fr/

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Big Web Analytics: Toward a Virtual Web Observatory

by Marc Spaniol, András Benczúr, Zsolt Viharos and Gerhard Weikum

For decades, compute power and storage have become steadily cheaper, while network speeds, although increasing, have not kept up. The result is that data is becoming increasingly local and thus distributed in nature. It has become necessary to move the software and hardware to where the data resides, and not the reverse. The goal of LAWA is to create a Virtual Web Observatory based on the rich centralized Web repository of the European Archive. The observatory will enable Web-scale analysis of data, will facilitate large-scale studies of Internet content and will add a new dimension to the roadmap of Future Internet Research – it's about time!

Flagship consumers of extreme large computational problems are the 'Web 3.0' applications envisioned for the next 10-year period of Web development: fast and personalized applications accessible from any device, aided by data mining solutions that handle distributed data by cloud computing.

Academically, longitudinal data analytics – the Web of the Past – is challenging and has not received due attention. The sheer size and content of such Web archives render them relevant to analysts within a range of domains. The Internet Archive currently holds more than 150 billion versions of Web pages, captured since 1996. Currently the same coverage cannot be maintained as a few years ago as Web content has become so diverse and dynamic. A high-coverage archive would have to be an order of magnitude larger.

In our applications, the size of the data itself forms the key challenge. Scalability issues arise from two main sources. Certain problems such as Web or log processing are data intensive where reading vast amounts of data itself forms a bottleneck. Others, such as machine learning or network analysis, are computationally intensive as they require complex algorithms run on large data that may not fit into the internal memory of a single machine.

Within the scope of the LAWA project – as part of the Future Internet Research and Experimentation (FIRE) initiative founded by the European Commission – we investigate temporal Web analytics with respect to semantic and scalability issues by creating a Virtual Web Observatory (VWO). The consortium consists of six partners: Max Planck Institute for Informatics (Germany), Hebrew University (Israel), SZTAKI (Hungary), University of Patras (Greece), Internet Memory Foundation (France) formerly called European Archive, and Hanzo Archives Ltd. (UK). The latter two are professional archival organizations.

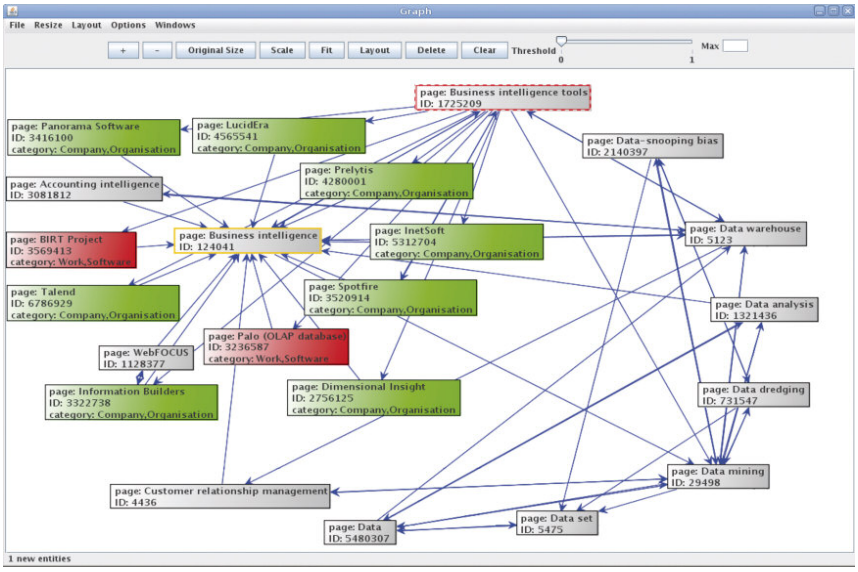

Figure 1: Screenshot of the relevant subgraph visualization demo

As a central functionality of the VWO, specific parts of the entire data collection can be defined and selected by the use of machine learning. As an example we may classify different Web domains for spam or genre, quality, objectivity,

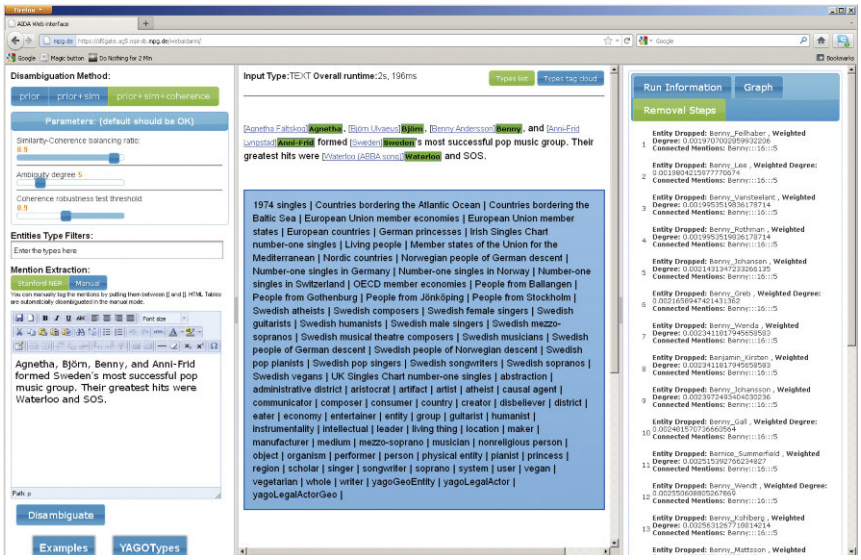

Figure 2: Screenshot of the AIDA user interface in a browser window

trustworthiness or personally sensitive social content. The VWO will provide graphical browsing to aid the user in discovering information along with its relationships. Hyperlinks constitute a type of relationship that, when visualized, provides insight into the connection of terms or documents and is useful for determining their information source, quality and trustworthiness. Our main goal is to present relevant interconnections of a large graph with textual information, by visualizing a well-connected small subgraph fitting the information needs of the user.

A Web archive of timestamped versions of Web sites over a long-term time horizon opens up great opportunities for analysts. By detecting named entities in Web pages we raise the entire analytics to a semantic rather than keyword-level. Difficulties here arise from name ambiguities, thus requiring a disambiguation mapping of mentions (noun phrases in the text that can denote one or more entities) onto entities. For example, "Bill Clinton" might be the former US president William Jefferson Clinton, or any other William Clinton contained in Wikipedia. Ambiguity further increases if the text only contains "Clinton" or a phrase like "the US president". The temporal dimension may further introduce complexity, for example when names of entities have changed over time (eg people getting married or divorced, or organizations that undergo restructuring in their identities).

As part of our research on entity disambiguation we have developed the AIDA system (Accurate Online Disambiguation of Named Entities), which includes an efficient and accurate NED method, suited for online usage. Our approach leverages the YAGO2 knowledge base as an entity catalog and a rich source of relationships among entities. We cast the joint mapping into a graph problem: mentions from the input text and candidate entities define the node set, and we consider weighted edges between mentions and entities, capturing context similarities, and weighted edges among entities, capturing coherence.

Figure 2 shows the user interface of AIDA. The left panel allows the user to select the underlying disambiguation methods and to insert an input text. The panel in the middle shows for each mention (in green) the disambiguated entity, linked with the corresponding Wikipedia articles. In addition, a clickable type cloud allows the user to explore the types of the named entities contained. Finally, the rightmost panel provides statistics about disambiguation process.

In conclusion, supercomputing software architectures will play a key role in scaling data and computational intensive problems in business intelligence, information retrieval and machine learning. In the future we will be identifying new applications such as Web 3.0, and considering the combination of distributed and many-core computing for problems that are both data and computational intensive.

Our work is supported by the 7th Framework IST programme of the European Union through the focused research project (STREP) on Longitudinal Analytics of Web Archive data (LAWA) under contract no. 258105.

Links:
LAWA project website:
http://www.lawa-project.eu/

AIDA webinterface:
https://d5gate.ag5.mpi-sb.mpg.de/webaida/

YAGO2 webinterface:
https://d5gate.ag5.mpi-sb.mpg.de/webyagospotlx/WebInterface

Visualization demo:
http://dms.sztaki.hu/en/letoltes/wimmut-searching-and-navigating-wikipedia

FIRE website:
http://cordis.europa.eu/fp7/ict/fire/

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Computational Storage in Vision Cloud

by Per Brand

Vision Cloud is an ongoing European project on cloud computing. The novel storage and computational infrastructure is designed to meet the challenge of providing for tomorrow's data-intensive services.

The two most important trends in information technology today are the increasing proliferation of data-intensive services and the digital convergence of telecommunications, media and ICT. A growing number of services aggregate, analyze and stream rich data to service consumers over the Internet. We see the inevitability of media, telecommunications and ICT services becoming merged into one operating platform, where content and ICT resources (including storage, network, and computing) are integrated to provide value-added services to users. The growing number, scale, variety and sophistication of data-intensive services impose demanding requirements that cannot be met using today's computing technologies. There is the need to simultaneously service millions of users, accommodate the rapid growth of services and the sheer volume of data, while at the same time providing high availability, low maintenance costs and efficient resource utilization.

The two critical ingredients to deliver converged data-intensive services are the storage infrastructure and the computational infrastructure. Not only must the storage offer unprecedented scalability, good and tunable availability, it must also provide the means to structure, categorize, and search massive data sets. The computational framework

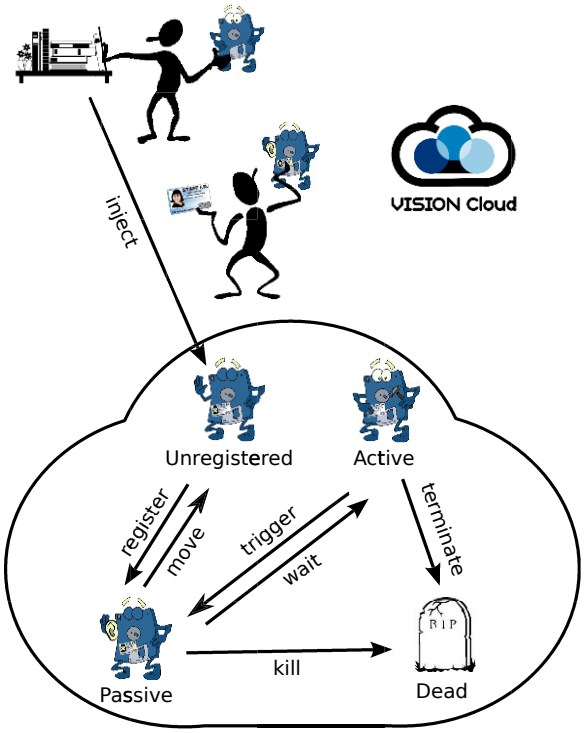

Figure 1: Example of computational storage Vision Cloud.

needs to provide user-friendly programming models capable of analyzing and manipulating large data sets in a resource-aware and efficient manner.

The ongoing European IP project Vision Cloud (October 2010-September 2013) addresses these issues and is developing a distributed and federated cloud architecture as well as a reference implementation. Use cases are taken from the domains of telecommunication (with Telenor, France Telecom, and Telefonica as partners), media (with Deutsche Welle, and RAI), health (Siemens) and enterprise (SAP). In addition to SICS, other partners include IBM, Engineering, National Technical University of Athens, Umeå University, the University of Messina and SNIA.

An important principle of the Vision Cloud architecture is that storage and computation are tightly coordinated and designed to work together. Indeed, one could say there is no clear dividing line between the two. We will illustrate with two examples taken from Vision Cloud use cases, but first we briefly describe the storage service and computational model.

The storage service encapsulates objects together with their metadata. Metadata is used by many different actors at various levels, ranging from end-user metadata, organizational metadata, metadata belonging to PaaS services, to system metadata. The metadata of a data object characterizes the object from different points of view. For example, one metadata field might specify that a document is 'type: text' and 'subject: computer_science', while another (system) field gives the creation time of the object. The storage service also offers search facilities whereby objects with given metadata tags and values may be found.

In Vision Cloud the units of computation are called storlets. Storlets may be seen as a computation agent that lives, works and eventually dies in the cloud. The storlet is an encapsulated computation where all interaction with other cloud services is given in the storlet parameters. The storlet programming model specifies the format for these storlet parameters. Parameters include credentials, the identity of objects it will access, constraints it must obey during operation, and most importantly, its triggers; the conditions that will cause the storlet to become active and actually perform some computation. The objects that the storlet will work on are either provided by the data object parameters or given by the triggering event that activates the storlet. An important aspect of the runtime system is that storlets execute close to the data they access. Some examples follow.

In a perfect world a user, organization might define an appropriate metadata scheme for object classification; each and every user will appropriately tag each and every object they inject into the cloud. However, experience tells us that this is not the case, users forget and make mistakes. Hence it is useful to have analysis programs that automatically annotate and check objects as they are injected.

Another example addresses the proliferation of different media formats. One possibility is that upon ingestion data is automatically converted by appropriate storlets to all the formats that might be needed upon access for all devices. Another possibility is to, transparent to the user, perform on-the-fly transcoding from a given standard format to one suitable for the particular accessing device being used. Note that if one data item can be transcoded from another, the best choice depends on the relative costs of computation and storage. With storlets this choice can be done automatically, transparently, and even dynamically.

In Figure 1 a user copies a storlet from a storlet library, which could also be in the cloud. The user provides the storlet with the necessary additional parameters, which would typically include user credentials – as the storlet is acting as an extension of the user with the same rights and privileges. The storlet is injected into Vision Cloud. The system places the storlet appropriately (eg close to the data it will need to access (if known). The system will also extract the trigger conditions from the storlet, and register the storlet so when and if the appropriate trigger event occurs this information is propagated. The storlet becomes active and performs some computation, possibly modifying data objects or their metadata. When the computation has finished the storlet generally returns to the passive state waiting for a new trigger event.

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http://www.visioncloud.eu

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Large-Scale Data Analysis on Cloud Systems

by Fabrizio Marozzo, Domenico Talia and Paolo Trunfio

The massive amount of digital data currently being produced by industry, commerce and research is an invaluable source of knowledge for business and science, but its management requires scalable storage and computing facilities. In this scenario, efficient data analysis tools are vital. Cloud systems can be effectively exploited for this purpose as they provide scalable storage and processing services, together with software platforms for developing and running data analysis environments. We present a framework that enables the execution of large-scale parameter sweeping data mining applications on top of computing and storage services.

The past two decades have been characterized by an exponential growth of digital data production in many fields of human activity, from science to enterprise. In the biological, medical, astronomic and earth science fields, for example, very large data sets are produced daily from the observation or simulation of complex phenomena. Unfortunately, massive data sets are hard to understand, and models and patterns hidden within them cannot be identified by humans directly, but must be analyzed by computers using knowledge discovery in database (KDD) processes and data mining techniques.

Data analysis applications often need to run a data mining task several times, using different parametric values before getting significant results. For this reason, parameter sweeping is widely used in data mining applications to explore the effects of using different values of the parameters on the results of data analysis. This is a time consuming process when a single computer is used to mine massive data sets since it can require very long execution times. Cloud systems can be effectively employed to handle this class of application since they provide scalable storage and processing services, as well as software platforms for developing and running data analysis environments on top of such services.

We have worked on this topic by developing Data Mining Cloud App, a software framework that enables the execution of large-scale parameter sweeping data analysis applications on top of Cloud computing and storage services. The framework has been implemented using Windows Azure and has been used to run large-scale parameter sweeping data mining applications on a Microsoft Cloud data centre.

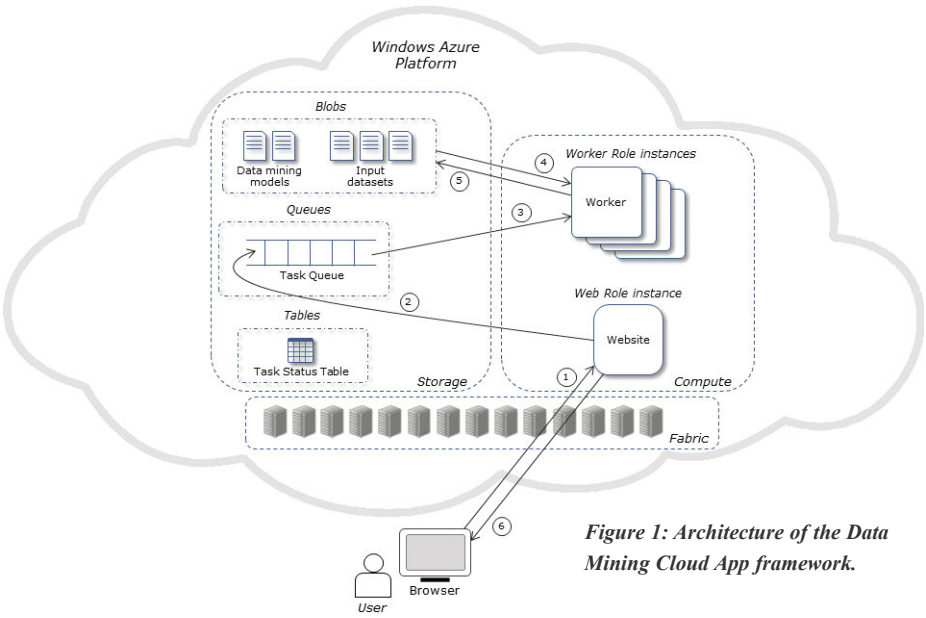

Figure 1: Architecture of the Data Mining Cloud App framework.

Figure 1 shows the architecture of the Data Mining Cloud App framework, as it is implemented on Windows Azure. The framework includes the following components:

- a set of binary and text data containers (Azure blobs) used to store data to be mined (input datasets) and the results of data mining tasks (data mining models)
- a task queue that contains the data mining tasks to be executed
- a task status table that keeps information about the status of all tasks
- a pool of k workers, where k is the number of virtual servers available, in charge of executing the data mining tasks submitted by the users
- a website that allows users to submit, monitor the execution, and access the results of data mining tasks.

The website includes three main sections: i) task submission that allows users to submit data mining tasks; ii) task status that is used to monitor the status of submitted tasks and to access results; iii) data management that allows users to manage input data and results.

Figure 2 shows a screenshot of the task submission section of the website, taken during the execution of a parameter sweeping data mining application. An application can be configured by selecting the algorithm to be executed, the dataset to be analyzed, and the relevant parameters for the algorithm. For parameter sweeping applications, the system submits to the Cloud a number of independent tasks that are executed concurrently on a set of virtual servers.

The user can monitor the status of each single task through the task status section of the website, as shown in Figure 3. For each task, the current status (submitted, running, done or failed) and status update time are shown. Moreover, for each task that has completed its execution, the system enables two links: the first (Stat) gives access to a file containing some statistics about the amount of resources consumed by the task; the second (Result) visualizes the task result.

We evaluated the performance of the Data Mining Cloud App through the execution of a set of long-running

Figure 2: Data Mining Cloud App website: A screenshot from the task submission section.

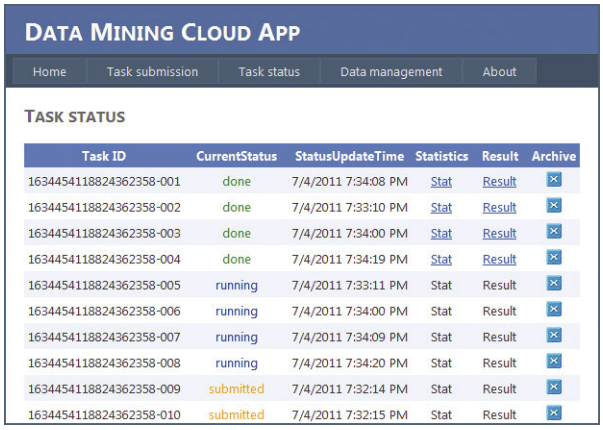

Figure 3: Data Mining Cloud App website: A screenshot from the task status section.

parameter sweeping data mining applications on a pool of virtual servers hosted by a Microsoft Cloud data center. The experiments demonstrated the effectiveness of the Data Mining Cloud App framework, as well as the scalability that can be achieved through the parallel execution of parameter sweeping data mining applications on a pool of virtual servers. For example, the classification of a large dataset (290,000 records) on a single virtual server required more than 41 hours, whereas it was completed in less than three hours on 16 virtual servers. This corresponds to an execution speedup equal to 14.

Other than supporting users in designing and running parameter sweeping data mining applications on large data sets, we intend to exploit Cloud computing platforms for running knowledge discovery processes designed as a combination of several data analysis steps to be run in parallel on Cloud computing elements. To achieve this goal, we are currently extending the Data Mining Cloud App framework to also support workflow-based KDD applications, in which complex data analysis applications are specified as graphs that link together data sources, data mining algorithms, and visualization tools.

Links:
http://www.microsoft.com/windowsazure
http://grid.deis.unical.it

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Big Software Data Analysis

by Mircea Lungu, Oscar Nierstrasz and Niko Schwarz

In today's highly networked world, any researcher can study massive amounts of source code even on inexpensive off-the-shelf hardware. This leads to opportunities for new analyses and tools. The analysis of big software data can confirm the existence of conjectured phenomena, expose patterns in the way a technology is used, and drive programming language research.

The amount and variety of available external information associated with evolving software systems is staggering: data sources include bug reports, mailing list archives, issue trackers, dynamic traces, navigation information extracted from the IDE, and meta-annotations from the versioning system. All these sources of information have a time dimension, which is tracked in versioning control systems.

Software systems, however, do not exist in isolation but co-exist in larger contexts known as software ecosystems. A software ecosystem is a group of software systems that is developed and co-evolves together in the same environment. The usual environments in which ecosystems exist are organizations (companies, research centres, universities) or communities (open source communities, programming language communities). The systems within an ecosystem usually co-evolve, depend on each other, have intersecting sets of developers as authors, and use similar technologies and libraries. Analyzing an entire ecosystem entails dealing with orders of magnitude more data than analyzing a single system. As a result, analysis techniques that work for the individual system no longer apply.

Recently, we have seen the emergence of a new type of large repository of information associated with software systems which can be orders of magnitude larger than an ecosystem: the super-repository. Super-repositories are repositories of project repositories. The existence of super-repositories provides us with an even larger source of information to analyze, exceeding ecosystems again by orders of magnitude.

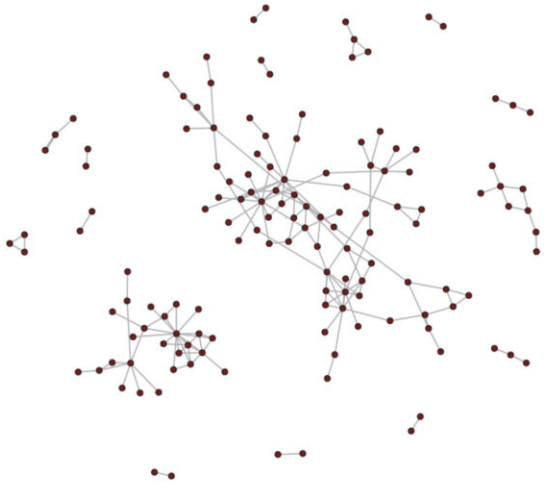

Figure 1: A decade of evolution in a subset of the systems in the Gnome ecosystem shows the size of source code monotonically increasing.

Research has been empowered by increased network bandwidth and raw computation power to analyze all of these artifacts at possibly massive scales. Therefore it shouldn't surprise us that current software engineering research uses the new wealth of information to improve the lives of software developers. Analysis of software ecosystems and super-repositories enters the realm of big software data.

In our research, we have been working towards discovering opportunities and challenges associated with big software data. We summarize three of the problems that we are working on, which we believe exemplify distinct directions in the big-software data analysis:

1. *Studying Ripple Effects in Software Ecosystems.* A change in a software system can propagate to other parts of the system. The same effect can also be observed at the ecosystem level, as we have shown in previous work. By data mining all versions of all the software systems that are available in the SqueakSource ecosystem, we were able to show that due to the tight network of compile-time dependencies between systems (see Figure 2), changes in a project can propagate to many other projects and can impact many developers. There is usually no way for the developers of a library to know which projects are impacted by a change. This presents an opportunity to assist the developer: By keeping track of all dependencies between systems in an ecosystem — an application of Big Software Data — a developer can identify all systems that will be impacted by a change.

2. *Code Cloning as a Means of Reuse.* We have studied the occurrence of code cloning in Ohloh, a large corpus of Java programs, and in SqueakSource, which tracks versions of almost the entire Squeak Smalltalk ecosystem. We have discovered that reuse by code duplication is very widespread in the Java and Smalltalk worlds - between 14 and 18%. Based on the empirical study of the evolution of clones, the consensus in the software engineering community has shifted from 'code clones considered harmful' to 'code clones considered harmful is harmful'. Indeed, cloning is often a necessary first step towards divergent evolution. It furthermore helps developers deal with problems of code ownership: it is often easier to fork code than to modify it in its project of origin. As a result, current code cloning research is about cloning management and awareness, such as by linking cloned source code snippets to the original site and informing both ends in the event of a change. Big Data means that it is now possible to keep track of all source code in all public repositories everywhere. This opens exciting opportunities to track software clones and try and help developers cope with them.

3. *Programming Language Comparisons.* New programming languages and language features are often announced with exaggerated claims of increased productivity. We believe that the analysis of big software data can enable an evidence-based analysis of the various claims regarding programming languages. We are currently running a study in which we compare the use of polymorphism in Java and Smalltalk. This will allow us to understand whether there is any significant difference in how people use object-oriented design in classical static and dynamic languages. The fact that we can run the study on hundreds of Java systems and hundreds of Smalltalk systems allows us to have confidence in the results and their significance.

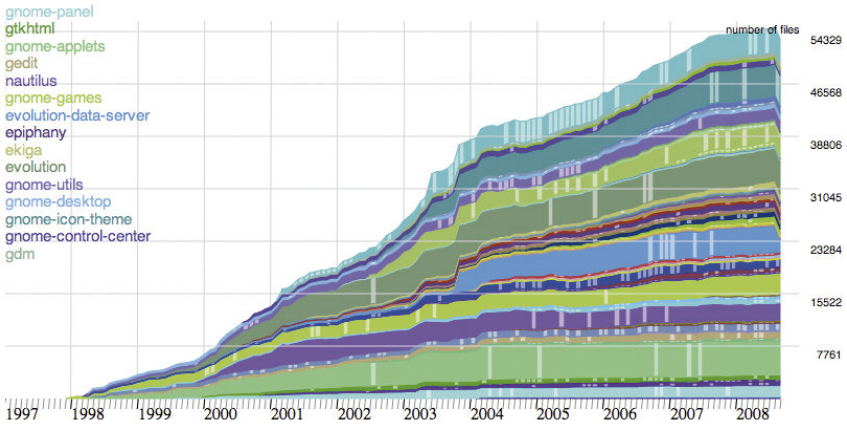

Figure 2: A subset of the software systems in the SqueakSource ecosystem shows a tight network of compile-time dependencies.

We believe that we are witnessing the beginning of big software data analysis, a field which will influence both software engineering practice and programming language design. In fact it might be a good place for the two fields to meet.

Link:
http://scg.unibe.ch/bigsoftwaredata

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Scalable Management of Compressed Semantic Big Data

by Javier D. Fernández, Miguel A. Martínez-Prieto and Mario Arias

The potential of Semantic Big Data is currently severely underexploited due to their huge space requirements, the powerful resources required to process them and their lengthy consumption time. We work on novel compression techniques for scalable storage, exchange, indexing and query answering of such emerging data.

The Web of Data materializes the basic principles of the Semantic Web. It is a collective effort for the integration and combination of data from diverse sources, allowing automatic machine-processing and reuse of information. Data providers make use of a common language to describe and share their semi-structured data, hence one person, or a machine, can move through different datasets with information about the same resource. This common language is the Resource Description Framework (RDF), and Linked Open Data is the project that encourages the open publication of interconnected datasets in this format.

Meanwhile, the world has entered a data deluge era in which thousands of exabytes (billion gigabytes) are created each year. Human genome data, accurate astronomical information, stock exchanges worldwide, particle accelerator results, logs of Internet use patterns and social network data are just a few examples of the vast diversity of data to be managed. This variety, together with the volume and the required velocity in data processing, characterize the "big data" and its inherent scalability problems. With the current data deluge transforming businesses, science and human relationships, to succeed in Semantic Big Data management means to convert existing scattered data into profitable knowledge.

A new paradigm for such large scale management is emerging, and new techniques to store, share, query, and analyze these big datasets are required. Our research is focused on scalable RDF management within a typical Create-Publish-Exchange-Consume scenario, as shown in Figure 1. To date, big RDF datasets are created and serialized, in practice, using traditional verbose syntaxes, still conceived under a document-centric perspective of the Web. Efficient interchange of RDF is limited, at best, to compress these plain formats using universal compression algorithms. The resultant file lacks logical structure and there is no agreed way to efficiently publish such data, ie to make them (publicly) available for diverse purposes and users. In addition, the data are hardly usable at consumption; the consumer has to decompress the file and, then, to use an appropriate external management tool. Similar problems arise when managing RDF in mobile devices; although the amount of information could be potentially small, these devices have even more restrictive requirements, not only for transmission costs/latency, but also for post-processing due to their inherent memory and CPU constraints.

We address the scalability drawbacks depicted in the previous workflow by proposing novel compressed structures optimized for the storage, exchange, indexing and querying of big RDF. We firstly design an efficient (binary) RDF serialization format, called HDT (Header-Dictionary-Triples). In this proposal, we called for the need to move forward RDF syntaxes to a data-centric view. HDT modularizes the data and uses the skewed structure of big RDF graphs to achieve large spatial savings. In addition, it includes metadata describing the RDF dataset which serves as an entrance point to the information on the dataset and leads to clean, easy-to-share publications. Our experiments show that big RDF is now exchanged and processed 10-15 times faster than traditional solutions, being rapidly available for final consumption.

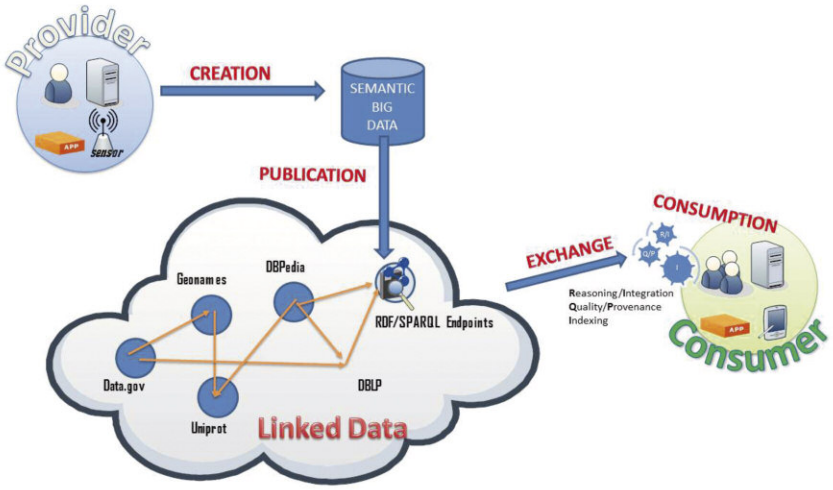

Figure 1: Create-Publish-Exchange-Consume scenario in the Web of Data

RDF datasets are typically consumed through a specific query language, called SPARQL. Several RDF stores provide SPARQL resolution both for local consumption or facilitating an online query service for third parties through SPARQL Endpoints. We have developed a lightweight post-processing which enhances the exchanged HDT with additional structures to provide full SPARQL resolution in compressed space. Furthermore, we were one of the first groups to empirically analyse SPARQL usage logs. These results provide valuable feedback to our work as well as other RDF store designers, especially in the tasks of

query evaluation and index construction.

The HDT format has recently been accepted as a W3C Member Submission, highlighting the relevancy of 'efficient interchange of RDF graphs'. We are currently working on our HDT-based store. In this sense, compression is not only useful for exchanging big data, but also for distribution purposes, as it allows bigger amounts of data to be managed using fewer computational resources. Another research area where we plan to apply these concepts is on sensor networks, where data throughput plays a major role. In a near future, where RDF exchange together with SPARQL query resolution will be the most common daily task of Web machine agents, our efforts will serve to alleviate current scalability drawbacks.

Links:
DataWeb Research Group:
http://dataweb.infor.uva.es
RDF/HDT: http://www.rdfhdt.org
HDT W3C Member Submission:
http://www.w3.org/Submission/2011/03/

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SCAPE: Big Data Meets Digital Preservation

by Ross King, Rainer Schmidt, Christoph Becker and Sven Schlarb

The digital collections of scientific and memory institutions – many of which are already in the petabyte range – are growing larger every day. The fact that the volume of archived digital content worldwide is increasing geometrically, demands that their associated preservation activities become more scalable. The economics of long-term storage and access demand that they become more automated. The present state of the art fails to address the need for scalable automated solutions for tasks like the characterization or migration of very large volumes of digital content. Standard tools break down when faced with very large or complex digital objects; standard workflows break down when faced with a very large number of objects or heterogeneous collections. In short, digital preservation is becoming an application area of big data, and big data is itself revealing a number of significant preservation challenges.

The EU FP7 ICT Project SCAPE (Scalable Preservation Environments), running since February 2011, was initiated in order to address these challenges through intensive computation combined with scalable monitoring and control. In particular, data analysis and scientific workflow management play an important role. Technical development is carried out in three sub-projects and will be validated in three Testbeds (refer to Figure 1).

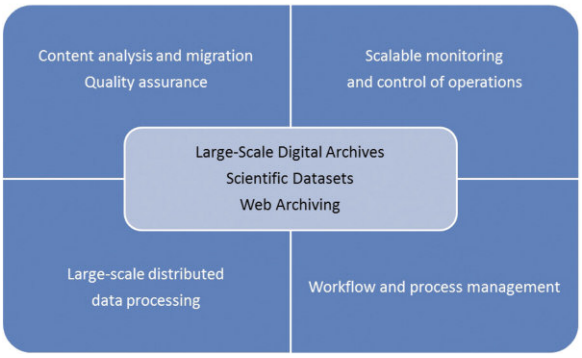

Figure 1: Challenges of the SCAPE project

Testbeds

The SCAPE Testbeds will examine very large collections from three different application areas: Digital Repositories from the library community (including nearly two petabytes of broadcast audio and video archives from the State Library of Denmark, who are adding more than 100 terabytes every year), Web Content from the web archiving community (including over a petabyte of web harvest data), and Research Data Sets from the scientific community (including millions of objects from the UK Science and Technology Facilities Council's Diamond Synchrotron source and ISIS suite of neutron and muon instruments). The Testbeds provide a description of preservation issues with a special focus on data sets that imply a real challenge for scalable solutions. They range from single activities (like data format migration, analysis and identification), to complex quality assurance workflows. These are supported at scale by solutions like the SCAPE Platform or Planning and Monitoring services detailed below. SCAPE solutions will be evaluated against defined institutional data sets in order to validate their applicability in real life application scenarios, such as large scale data ingest, analysis, and maintenance.

Data Analysis and Preservation Platform

The SCAPE Platform will provide an extensible infrastructure for the execution of digital preservation workflows on large volumes of data. It is designed as an integrated system for content holders employing a scalable architecture to execute preservation processes on archived content. The system is based on distributed and data-centric systems like Hadoop and HDFS and programming models like MapReduce. A suitable storage abstraction will provide integration with content repositories at the storage level for fast data exchange between the repository and the execution system. Many SCAPE collections consist of large binary objects that must be pre-processed before they can be expressed using a structured data model. The Platform will therefore implement a storage hierarchy for processing, analysing and archiving content, relying on a combination of distributed database and file

system storage. Moreover, the Platform is in charge of on-demand shipping and deploying the required preservation tools on the cluster nodes that hold the data. This is being facilitated by employing a software packaging model and a corresponding repository. The SCAPE vision is that preservation workflows, based on assembling components using the Taverna graphical workbench, may be created on desktop computers by end-users (such as data curators). The Platform's execution system will support the transformation of these workflows into programs that can be executed on a distributed data processing environment.

Scalable Planning and Monitoring

Through its data-centric execution platform, SCAPE will substantially improve scalability for handling massive amounts of data and for ensuring quality assurance without human intervention. But fundamentally, for a system to be truly operational on a large scale, all components involved need to scale up. Only scalable monitoring and decision making enables automated, large-scale systems operation by scaling up the control structures, policies, and processes for monitoring and action. SCAPE will thus address the bottleneck of decision processes and information processing required for decision making. Based on well-established principles and methods, the project will automate now-manual aspects such as constraints modelling, requirements reuse, measurements, and continuous monitoring by integrating existing and evolving information sources and measurements.

Conclusions

At the end of the first project year, the SCAPE project can already offer real solutions to some of the big data challenges outlined above, in the form of a scalable platform design and infrastructure, initial tools and workflows for large-scale content analysis and quality assurance, and an architecture for scalable monitoring and control of large preservation operations. Initial results in the form of deliverables, reports and software are publicly available on the project website, wiki, and Github repository. We are confident that the project will have significant impact over the remaining two and one-half years.

This work was partially supported by the SCAPE Project. The SCAPE project is co-funded by the European Union under FP7 ICT-2009.4.1 (Grant Agreement number 270137).

Links:
http://www.scape-project.eu/
http://wiki.opf-labs.org/display/SP/Home
https://github.com/openplanets/scape

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Brute Force Information Retrieval Experiments using MapReduce

by Djoerd Hiemstra and Claudia Hauff

MIREX (MapReduce Information Retrieval Experiments) is a software library initially developed by the Database Group of the University of Twente for running large scale information retrieval experiments on clusters of machines. MIREX has been tested on web crawls of up to half a billion web pages, totaling about 12.5 TB of data uncompressed. MIREX shows that the execution of test queries by a brute force linear scan of pages, is a viable alternative to running the test queries on a search engine's inverted index. MIREX is open source and available for others.

Research in the field of information retrieval is often concerned with improving the quality of search systems. The quality of a search system crucially depends on ranking the documents that match a query. To get the best documents ranked in the top results for a query, search engines use numerous statistics on query terms and documents, such as the number of occurrences of a term in the document, the number of occurrences of a term in the collection, the number of hyperlinks pointing at a document, the number of occurrences of a term in the anchor texts of hyperlinks pointing at a document, etc. New ranking ideas are tested off-line on query sets with human rated documents. If such ideas are radically new, experimentally testing them might require a non-trivial amount of coding to change an existing search engine. If, for instance, a new idea requires information that is not currently in the search engine's inverted index, then the researcher has to re-index the data or even recode parts of the system's indexing facilities, and possibly recode the query processing facilities that access this information. If the new idea requires query processing techniques that are not supported by the search engine (for instance sliding windows, phrases, or structured query expansion) even more work has to be done.

Instead of using the indexing facilities of the search engine, we propose to use MapReduce to test new retrieval approaches by sequentially scanning all documents. Some of the advantages of this method are: 1) Researchers spend less time on coding and debugging new experimental retrieval approaches; 2) It is easy to include new information in the ranking algorithm, even if that information would not normally be included in the search engine's inverted index; 3) Researchers are able to oversee all or most of the code used in the experiment; 4) Large-scale experiments can be done in reasonable time.

MapReduce was developed at Google as a framework for batch processing of large data sets on clusters of commodity machines. Users of the framework implement a mapper function that processes a key/value pair to generate a set of intermediate key/value pairs, and

a reducer function that processes intermediate values associated with the same intermediate key. For the example of simply counting the number of terms occurring across the entire collection of documents, the mapper takes as input a document URL (key) and the document content (value) and outputs pairs of term and term count in the document. The reducer then aggregates all term counts of a term together and outputs the number of occurrences of each term in the collection. Our experiments are made of several such MapReduce programs: We extract anchor texts from web pages, we gather global statistics for terms that occur in our test queries, we remove spam pages, and we run a search experiment by reading web pages one at a time, and on each page we execute all test queries. Sequential scanning allows us to do almost anything we like, for instance sophisticated natural language processing. If the new approach is successful, it will have to be implemented in a search engine's indexing and querying facilities, but there is no point in making a new index if the experiment is unsuccessful. Researchers at Google and Microsoft have recently reported on similar experimental infrastructures.

When implementing a MapReduce program, users do not need to worry about partitioning of the input data, scheduling of tasks across the machines, machine failure, or interprocess communication and logging: All of this is automatically handled by the MapReduce runtime. We use Hadoop: an open source implementation of Google's file system and MapReduce. A small cluster of 15 low cost machines suffices to run experiments on about half a billion web pages, about 12.5 TB of data if uncompressed. To give the reader an idea of the complexity of such an experiment: An experiment that needs two sequential scans of the data requires about 350 lines of code. The experimental code does not need to be maintained: In fact, it should be retained in its original form to provide data provenance and reproducibility of research results. Once the experiment is done, the code is filed in a repository for future reference. We call our code repository MIREX (MapReduce Information Retrieval EXperiments), and it is available as open source software from http://mirex.sourceforge.net

Proud researchers and their cluster.

MIREX is sponsored by the Netherlands Organization for Scientific Research NWO, and Yahoo Research, Barcelona.

Links:
MIREX: http://mirex.sourceforge.net
Database Group:
http://db.cs.utwente.nl
Web Information Systems Group:
http://wis.ewi.tudelft.nl

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A Big Data Platform for Large Scale Event Processing

by Vincenzo Gulisano, Ricardo Jimenez-Peris, Marta Patiño-Martinez, Claudio Soriente and Patrick Valduriez

To date, big data applications have focused on the store-and-process paradigm. In this paper we describe an initiative to deal with big data applications for continuous streams of events.

In many emerging applications, the volume of data being streamed is so large that the traditional 'store-then-process' paradigm is either not suitable or too inefficient. Moreover, soft-real time requirements might severely limit the engineering solutions. Many scenarios fit this description. In network security for cloud data centres, for instance, very high volumes of IP packets and events from sensors at firewalls, network switches and routers and servers need to be analyzed and should detect attacks in minimal time, in order to limit the effect of the malicious activity over the IT infrastructure. Similarly, in the fraud department of a credit card company, payment requests should be processed online and need to be processed as quickly as possible in order to provide meaningful results in real-time. An ideal system would detect fraud during the authorization process that lasts hundreds of milliseconds and deny the payment authorization, minimizing the damage to the user and the credit card company.

In this context, researchers have proposed a new computing paradigm called Complex Event Processing. A complex event processor (CEP) is a system designed to process continuous streams of data in near real-time. Data flows in streams that are not stored, but are rather processed on-the-fly.

Similar to database management systems (DBMS), a CEP processes queries over tuples. However, while in the context of DMBS the set of tuples to be processed is fairly static, CEP deals with an infinite sequence of events. Data processing is performed through continuous queries based on the sliding window model. This approach differs from queries in traditional DBMS because a continuous query is constantly 'standing' over the streaming events and results are output any time the actual data satisfies the query predicate. A continuous query is modelled as a graph where edges identify data flows and nodes represent operators that process input data.

Centralized CEPs suffered from single node bottlenecks and were quickly replaced by distributed CEPs where the query was distributed across several nodes, in order to decrease the per-node tuple processing time and increase the overall throughput. Nevertheless, each node of a distributed CEP must process the whole input flow, which severely limits scalability and application scope.

The real research challenge is how to build a parallel-distributed CEP where data is partitioned across processing nodes that (i) does not require any node to process the whole input and (ii) provides the same results of an ideal centralized execution (ie without any delay due to input tuples queuing up).

The gist of the problem is how to distribute input tuples, so that tuples that must be aggregated or joined together are actually received by the same processing node.

Moreover, a parallel CEP should also feature elasticity in order to adapt the amount of computing resources to the actual workload and achieve cost-effectiveness. Indeed, any parallel system with a static number of processing nodes might experience under-provisioning (ie the overall computing power is not enough to handle the input load) or over-provisioning (ie the current load is lower than the system maximum throughput and some nodes are running below their capacity).

With those goals in mind, we are developing StreamCloud, a parallel-distributed and elastic CEP that delivers unmatched performance in terms of throughput and allows for cost-effective resource utilization. The StreamCloud project is carried out by the Distributed System Lab at Universidad Politecnica de Madrid in collaboration with the Zenith team at Inria and LIRMM, Montpellier. The system is being exercised for a Security Information and Event Management system in the MASSIF project.

StreamCloud leverages a novel parallelization strategy that allows splitting the logical input stream in multiple physical streams that are pushed towards processing nodes. The logical stream is never concentrated in a single node, in order to avoid bottlenecks. Communication between nodes is minimized and only used to guarantee semantic transparency, ie that the outcome of the computation matches the one of a traditional centralized solution. With this parallelization, StreamCloud is able to aggregate the computing power of hundreds of nodes to process millions of events per second.

Further, StreamCloud is elastic and continuously monitors its processing nodes and makes autonomous decisions on whether to add or remove nodes to cope with the incoming load with the minimal set of resources. This is crucial in cloud environments with a pay-per-use model. Node provisioning and decommissioning is complemented by dynamic load balancing so that StreamCloud can re-distribute the load among processing node in case of uneven load distribution.

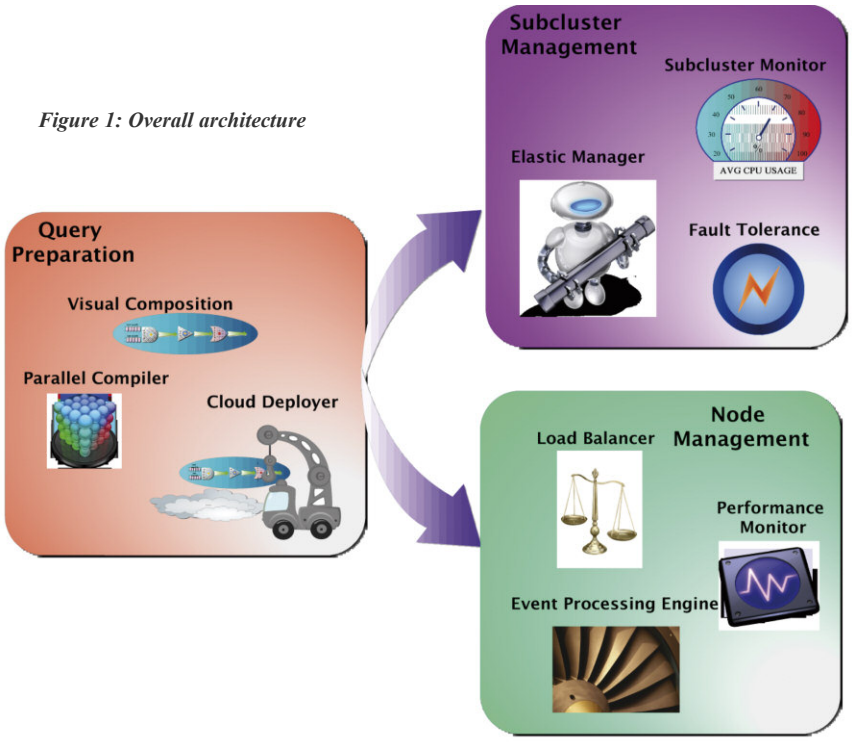

Figure 1: Overall architecture

Link:
http://www.massif-project.eu

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CumuloNimbo: A Highly-Scalable Transaction Processing Platform as a Service

by Ricardo Jimenez-Peris, Marta Patiño-Martinez, Kostas Magoutis, Angelos Bilas and Ivan Brondino

One of the main challenges facing next generation Cloud platform services is the need to simultaneously achieve ease of programming, consistency, and high scalability. Big Data applications have so far focused on batch processing. The next step for Big Data is to move to the online world. This shift will raise the requirements for transactional guarantees. CumuloNimbo is a new EC-funded project led by Universidad Politécnica de Madrid (UPM) that addresses these issues via a highly scalable multi-tier transactional platform as a service (PaaS) that bridges the gap between OLTP and Big Data applications.

CumuloNimbo aims at architecting and developing an ultra-scalable transactional Cloud platform as a service (PaaS). The current state of the art in transactional PaaS is to scale by resorting to sharding or horizontal partitioning of data across database servers, sacrificing consistency and ease of programming. Sharding destroys transactional semantics since it is applied to only subsets of the overall data set. Additionally, it forces modifications to applications and/or requires rebuilding them from scratch, and in most cases also changing the business rules to adapt to the shortcomings of current technologies. Thus it becomes imperative to address these issues by providing an easily programmable platform with the same consistency levels as current service-oriented platforms.

The CumuloNimbo PaaS addresses these challenges by providing support for familiar programming interfaces such as Java Enterprise Edition (EE), SQL, as well as No SQL data stores, ensuring seamless portability across a wide range of application domains. Simultaneously the platform is designed to support Internet-scale Cloud services (hundreds of nodes providing service to millions of clients) in terms of both data processing and storage capacity. These challenges require careful consideration of architectural issues at multiple tiers, from the application and transactional model all the way to scalable communication and storage.

CumuloNimbo improves the scalability of transactional systems, enabling them to process update transaction rates in the range of one million update transactions per second in a fully transparent way. This transparency is both syntactic and semantic. Syntactic transparency means that existing applications will be able to run totally unmodified on top of CumuloNimbo and benefit automatically from the underlying ultra-scalability, elasticity and high availability. Semantic transparency means that applications will continue to work exactly as they did on centralized infrastructure, with exactly the same semantics and preserving the same coherence they had. The full transparency will remove one of the most important obstacles to migration of applications to the cloud, ie the need to heavily modify, or even fully rebuild, them.

CumuloNimbo adopts a novel approach for providing SQL processing. Its main breakthrough lies in the scalability of transactional management, which is achieved by decomposing the different functions required for transactional processing and scaling each of them separately in a composable manner (refer to

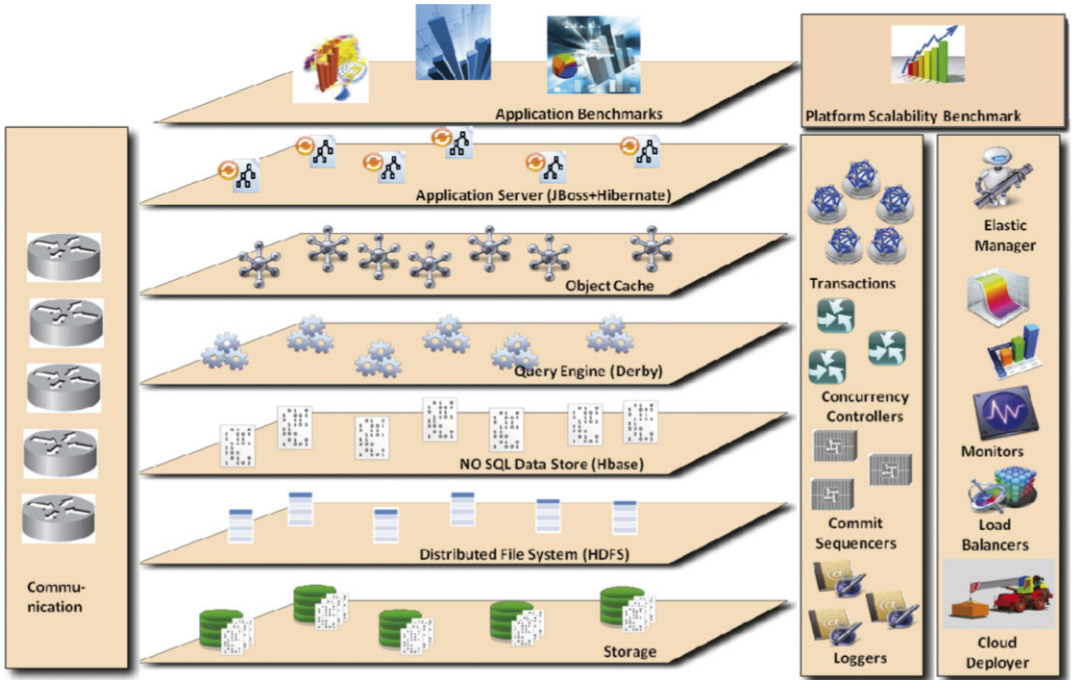

Figure 1: CumuloNimbo architecture

Figure 1). In contrast to many of the current approaches that constrain the query language to simple key-value stores, CumuloNimbo provides full SQL support based on the snapshot isolation transaction model and scaling to large update transaction rates. The SQL engines use a No-SQL data store (Apache HBase) as an underlying storage layer, leveraging support for scalable data access and version management. The project is optimizing this data store to operate over indexed block-level storage volumes in direct-attached or network-accessible storage devices.

Currently, the project has completed the specification of the architecture and the development of a first version of the core components, which have been successfully integrated. CumuloNimbo is expected to have a very high impact by enabling scalability of transaction processing over Cloud infrastructures without changes for OLTP and bridge the gap between Big-Data applications and OLTP. The project is carried out by Universidad Politécnica de Madrid (UPM), Foundation for Research and Technology – Hellas (FORTH), Yahoo Iberia, University of Minho, McGill University, SAP, and Flexiant. The CumuloNimbo project is part of the portfolio of the Software & Service Architectures and Infrastructures Unit – D3, Directorate General Information Society (http://cordis.europa.eu/fp7/ict/ssai).

Link:
http://cumulonimbo.eu

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ConPaaS, an Integrated Cloud Environment for Big Data

by Thorsten Schuett and Guillaume Pierre

ConPaaS makes it easy to write scalable Cloud applications without worrying about the complexity of the Cloud.

ConPaaS is the platform as a service (PaaS) component of the Contrail FP7 project. It provides a runtime environment that facilitates deployment of end-user applications in the Cloud. The team encompasses developers and researchers from the Vrije Universiteit in Amsterdam, the Zuse Institute in Berlin, and XLAB in Ljubljana.

In ConPaaS, applications are organized as a collection of services. ConPaaS currently provide services for web hosting (PHP and Java), SQL and NoSQL databases (MySQL and Scalaris), data storage (XtreemFS) and for large scale data processing (Task Farming and MapReduce). Using these services a bioinformatics application could, for example, be composed of a MapReduce service backend to process genomic data, as well as a Web hosting and SQL database service to provide a Web-based graphical interface to the users. Each service can be scaled on demand to adjust the quantity of computing resources to the capacity needs of the application.

ConPaaS contains two services specifically dedicated to Big Data: MapReduce and TaskFarming. MapReduce provides users with the well-known parallel programming paradigm. TaskFarming allows the automatic execution of a large collection of independent tasks such as those issued by Monte-Carlo simulations. The ability of these services to dynamically vary the number of Cloud resources they use makes it well-suited to very large computations: one only needs to scale services up before a big computation, and scale them down afterwards. This organization provides all the benefits of Cloud computing to application developers -- without having to worry about Cloud-specific details.

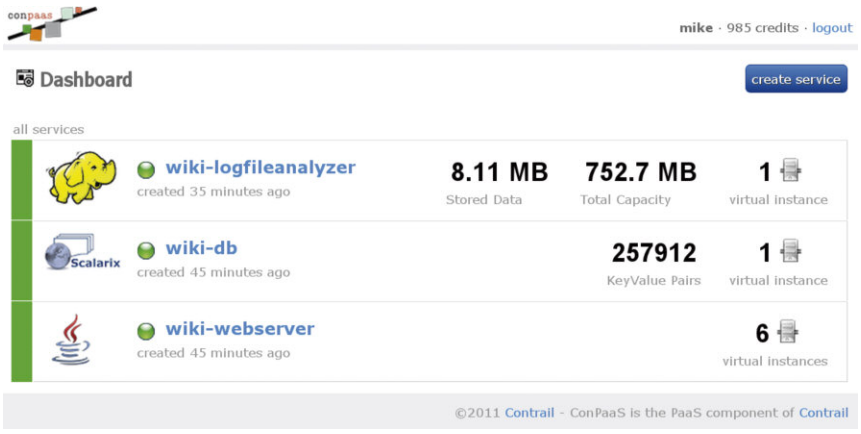

Figure 1: The main ConPaaS dashboard with three services running

An important element in all Big Data applications is the requirement for a scalable file system where input and output data can be efficiently stored and retrieved. ConPaaS comes together with the XtreemFS distributed file system for clouds. Like ConPaaS services, XtreemFS is designed to be highly available and fully scalable. Unlike most other file systems for the Cloud, XtreemFS provides a POSIX API. This means that an XtreemFS volume can be mounted locally, giving transparent access to files in the Cloud.

One of our demonstrator applications is a Wikipedia clone. It can load database dumps of the official Wikipedia and store their content in the Scalarix NoSQL database service. The business logic is written in Java and runs in the Web hosting service. Deploying Wikipedia in

the Cloud takes about 10 minutes. Increasing the processing capacity of the application requires two mouse clicks.

One of ConPaaS's Big Data use cases is a bioinformatics application that analyses large datasets across distributed computers. It uses large amounts of data from a Chip-Seq analysis, a type of genomic analysis methodology, and an application that can be parallelized in order to make use of multiple instances or processors to analyse data faster. The application stores its data in XtreemFS and makes extensive use of ConPaaS's MapReduce, TaskFarming, and Web hosting services. Users will use the application either directly through an API or through a web interface.

Although ConPaaS is already sufficiently mature to support challenging applications, we have many plans for further developments. In the near future, instead of manually choosing the number of resources each service should use, a user will be able to specify the performance she expects. ConPaaS will dimension each service such that the system meets its performance guarantees, while using the smallest possible number of computing resources. In the wiki example, for instance, one may want to request that user requests are processed on average in no more than 500 milliseconds.

We plan to allow users to upload complex applications in a single operation. Instead of starting and configuring multiple ConPaaS services one by one, a user will be able to upload a single manifest file describing the entire application organization. Thanks to this manifest, ConPaaS will be able to orchestrate the deployment and configuration of entire applications automatically.

Finally, we plan to provide an SDK for external users to implement their own services. For example, one could write a new service for demanding statistical analysis, for video streaming, or for scientific workflows. The platform will allow third-party developers to upload their own service as a plugin to the existing ConPaaS system.

In conclusion, ConPaaS is a runtime environment for Cloud applications. It takes care of the complexity of Cloud environments, letting application developers focus on what they do best: program great applications to satisfy their customers' needs.

Links:
http://www.conpaas.eu/
http://contrail-project.eu/
http://scalaris.googlecode.com/
http://xtreemfs.org/

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Crime and Corruption Observatory: Big Questions behind Big Data

by Giulia Bonelli, Mario Paolucci and Rosaria Conte

Can we have information in advance on organized crime movements? How can fraud and corruption be fought? Can cybercrime threats be tackled in a safe way? The Crime and Corruption Observatory of the European Project FuturICT will work at answering these questions. Starting from Big Data, it will face big challenges, and will propose new ways to analyse and understand social phenomena.

The cost of crime in the United States is estimated to be more than $1 trillion annually. The cost of corruption ranges from 2 to 5 per cent of global Gross Domestic Product (GDP), ie from $800 billion to $2 trillion US dollars. The cost of war on terrorism in the US since 9/11 is over $1 trillion.

These are just a few examples of the huge impact of crime on social, legal and economic systems. The situation in Europe is similarly dramatic. To face the problem in a new way, the "Crime and Corruption Observatory" is being set up in order to develop new technology to study and predict the evolution of phenomena that threaten the security of our society. The Observatory aims at building a data infrastructure to support crime prevention and reduce the costs of crime.

The starting point is Big Data: the huge amount of digital information now available enables the development of virtual techno-socio-economic models from existing and new information technology systems. The Observatory will collect huge data sets and run massive data mining and large-scale computer simulations of social dynamics related to criminal activities. It will be built using innovative technological instruments. This approach requires an internationally recognized scientifically grounded strategy, able to embrace different national policies, since global threats such as crime and corruption require global answers.

The Observatory will be built as a European network, with a central node probably in Italy. A large number of important European universities and research institutions will cooperate to develop the necessary components. Scientists from many different fields - from cognitive and social science to criminology, from artificial intelligence to complexity science, from statistics to economics and psychology - will be involved, establishing a pool of varied expertise. The method will thus be strongly interdisciplinary: this is the only way to promote a real paradigm shift in our approach to policy and decision-making. On the one hand, the way policies are designed can be enhanced through innovative "what-if" analyses developed by complex models and simulations. On the other hand, the goal is to create new tools to support police and security agencies and services with more effective instruments for law enforcement.

The Crime and Corruption Observatory is part of a broader European project called FuturICT, which was the first of six "FET Flagship"pilots selected by the European Commission as part of the Framework 7 Programme.

The mission of FuturICT is to unleash the power of information for a sustainable future: a Living Earth Simulator will be built to understand and manage complex social systems, with a focus on sustainability and resilience. Within this framework, the Crime and Corruption Observatory will identify the underlying economical, social and cultural mechanisms that influence illegal phenomena, in order to control them at European level.

Addressing important issues, such as fighting against terrorism and organized crime, fraud detection, and maintaining internal and external security, certainly requires the use of modern technology, but this is not enough. Data must be transformed into information and then into knowledge, to reveal the real meaning of the billions of bits gathered worldwide. For this reason, behind Big Data lie Big Questions: the Crime and Corruption Observatory will identify fundamental issues about the dynamics of crime and their implications, developing solutions and innovative theories at the same time.

From BigData to virtual models of our society (image by courtesy of FuturICT)

Data technology will thus become both responsive and responsible: it will provide not only practical answers but also reliable theoretical tools, since Big Data should always have underlying Big Questions.

Link: http://www.futurict.eu

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Managing Big Data through Hybrid Data Infrastructures

by Leonardo Candela, Donatella Castelli and Pasquale Pagano

Long-established technological platforms are no longer able to address the data and processing requirements of the emerging data-intensive scientific paradigm. At the same time, modern distributed computational platforms are not yet capable of addressing the global, elastic, and networked needs of the scientific communities producing and exploiting huge quantities and varieties of data. A novel approach, the Hybrid Data Infrastructure, integrates several technologies, including Grid and Cloud, and promises to offer the necessary management and usage capabilities required to implement the 'Big Data' enabled scientific paradigm.

A recent study, promoted by The Royal Society of London in cooperation with Elsevier, reviewed the changing patterns of science highlighting that science is increasingly a global, multidisciplinary and networked effort performed by scientists that dynamically collaborate to achieve specific objectives. The same study also indicated that data-intensive science is gaining momentum in many domains. Large-scale datasets come in all forms and shapes from huge international experiments to cross-laboratory, single laboratory, or even from a multitude of individual observations.

The management and processing of such datasets is beyond the capacity of traditional technological approaches based on local, specialized data facilities. They require innovative solutions able to simultaneously address the needs imposed by multidisciplinary collaborations and by the new data-intensive pattern. These needs are characterized by the well known three V's: (i) Volume – data dimension in terms of bytes is huge, (ii) Velocity – data collection, processing and consumption is demanding in terms of speed, and (iii) Variety – data heterogeneity, in terms of data types and data sources requiring integration, is high.

Recent approaches, such as Grid and Cloud Computing, can only partially satisfy these needs. Grid Computing was initially conceived as a technological platform to overcome the limitations in volume and velocity of single laboratories by sharing and re-using computational and storage resources across laboratories. It offers a valid solution in specific scientific domains such as High Energy Physics. However, Grid Computing does not handle

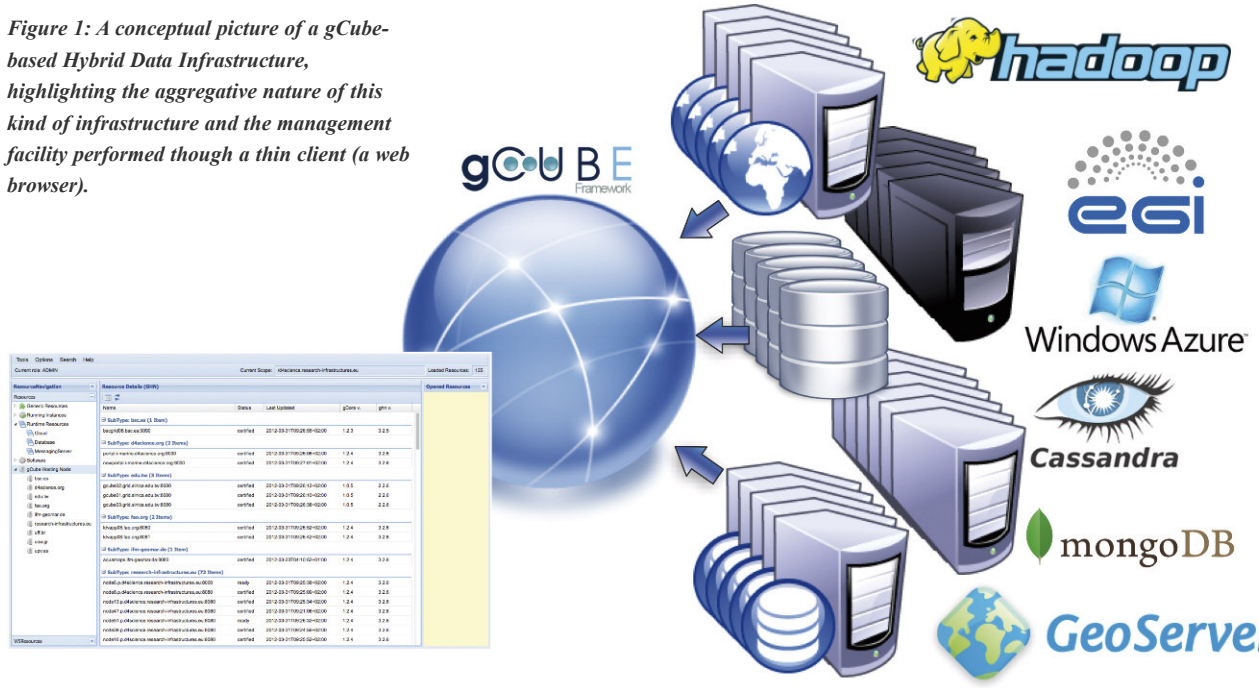

Figure 1: A conceptual picture of a gCube-based Hybrid Data Infrastructure, highlighting the aggregative nature of this kind of infrastructure and the management facility performed though a thin client (a web browser).

'variety' well. It supports a very limited set of data types and needs a common software middleware, dedicated hardware resources and a costly infrastructure management regulated by rigid policies and procedures.

Cloud Computing, instead, provides an elastic usage of resources that are maintained by third-party providers. It is based on the assumption that the management of hardware and middleware can be centralized, while the applications remain in the hands of the consumer. This considerably reduces application maintenance and operational costs. However, as it is a technology based on an agreement between the resource provider and the consumer, it is not suitable to manage the integration of resources deployed and maintained by diverse distributed organizations.

The Hybrid Data Infrastructure (HDI) is a new, more effective solution for managing the new types of scientific dataset. It assumes that several technologies, including Grid, private and public Cloud, can be integrated to provide an elastic access and usage of data and data-management capabilities.

The gCube software system, whose technological development has been coordinated by ISTI-CNR, implements the HDI approach. It was initially conceived to manage distributed computing infrastructures. It has evolved to operate large-scale HDIs enabling a data-management-capability-delivery model in which computing, storage, data and software are made accessible by the infrastructure and are exploited by users using a thin client (namely a web browser), through dedicated on-demand Virtual Research Environments.

gCube operates a large federation of computational and storage resources by relying on a rich and open array of mediator services for interfacing with Grid (eg European Grid Infrastructure), commercial cloud (eg Microsoft Azure, Amazon EC2), and private cloud (eg OpenNebula) infrastructures. Relational databases, geospatial storage systems (eg Geoserver), nosql databases (eg Cassandra, MongoDB), and reliable distributed computing platforms (eg Hadoop) can all be exploited as infrastructural resources. This guarantees a technological solution suitable for the volume, velocity, and variety of the new science patterns.

gCube is much more than a software integration platform; it is also equipped with software frameworks for data management (access and storage, integration, curation, discovery, manipulation, mining, and visualization) and workflow definition and execution. These frameworks offer traditional data management facilities in an innovative way by taking advantage of the plethora of integrated and seamlessly accessible technologies. The supported data types cover a wide spectrum ranging from tabular data – eg observations, statistics, records – to research products – eg diagrams, maps, species distribution models, enhanced publications. Datasets are associated with rich metadata and provenance information which facilitate effective re-use. These software frameworks can be configured to implement different policies ranging from the enforcement of privacy via encryption and secure access control to the promotion of data sharing while guaranteeing provenance and attribution.

The infrastructure enabled by gCube is now exploited to serve scientists operating in different domains, such as biologists generating model-based large-scale predictions of natural occurrences of species and statisticians managing and integrating statistical data.

gCube is a collaborative effort of several research, academic and industrial centres including ISTI-CNR (IT), University of Athens (GR), University of Basel (CH), Engineering Ingegneria Informatica SpA (IT), University of Strathclyde (UK), CERN (CH). Its development has been partially supported by the following European projects: DILIGENT (FP6-2003-IST-2), D4Science (FP7-INFRA-2007-1.2.2), D4Science-II (FP7-INFRA-2008-1.2.2), iMarine (FP7-INFRASTRUCTURES-2011-2), and EUBrazilOpenBio (FP7-ICT-2011-EU-Brazil).

Link:
gCube website:
http://www.gcube-system.org

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Cracking Big Data

by Stratos Idreos

A fundamental and emerging need with big amounts of data is data exploration: when we are searching for interesting patterns we often do not have a priori knowledge of exactly what we are looking for. Database cracking enables such data exploration features by bringing, for the first time, incremental and adaptive indexing abilities to modern database systems.

Source: Shutterstock

Good performance in state of the art database systems relies largely on proper tuning and physical design. Typically, all tuning choices happen up front, assuming sufficient workload knowledge and idle time. Workload knowledge is necessary in order to determine the appropriate tuning actions, ie to decide which proper indexes should be created, while idle time is required in order to actually perform those actions. In other words, we need to know what kind of queries we are going to ask and we need to have enough time to prepare the system for those queries.

However, in dynamic environments with big data, workload knowledge and idle time are scarce resources. For example, in scientific databases, new data arrive on a daily or even hourly basis, while query patterns follow an exploratory path as the scientists try to interpret the data and understand the patterns observed; there is no time and knowledge to analyze and prepare a different physical design every hour or even every day; even a single index may take several hours to create.

Traditional indexing presents three fundamental weaknesses in such cases: (a) the workload may have changed by the time we finish tuning; (b) there may be no time to finish tuning properly; and (c) there is no indexing support during tuning.

In this project, we propose a new approach to the physical design problem, called database cracking. Cracking introduces the notion of continuous, incremental, partial and on demand adaptive indexing. Thereby, indexes are incrementally built and refined during query processing. The net effect is that there is no need for any upfront tuning steps. In turn, there is no need for any workload knowledge and idle time to set up the database system. Instead, the system autonomously builds indexes during query processing, adjusting fully to the needs of the users. For example, as a scientist starts exploring a big data set, query after query, the system follows the exploration path of the scientist, incrementally building and refining indexes only for the data areas that seem interesting for the exploration path. After a few queries, performance adaptively improves to the level of a fully tuned system.

From a technical point of view cracking relies on continuously physically reorganizing data as the users pose more and more queries. Every query is used as a hint on how data should be stored. For example a data column referenced in queries is continuously reorganized (partitioned) as part of processing those queries. The actual query selection bounds are used for partitioning. This brings structure and partitioning information, allowing future queries to access data faster. Future queries exploit the partitioning information gained from the previous queries but they also introduce even more partitioning, bringing the continuous adaptation property. From a performance point of view cracking imposes a minimal overhead compared to the default performance of using no indexes, while at the same time it continuously converges at the optimal performance of using full indexes even though it requires zero initialization cost.

Cracking was proposed in the context of modern column-stores and has been hitherto applied for boosting the select operator performance, joins, maintenance under updates, and arbitrary multi-attribute queries. In addition, more recently these ideas have been extended to exploit a partition/merge-like logic as well as workload robustness is achieved via stochastic cracking. Future and ongoing research aims to tackle concurrency control, disk based cracking, maintenance under long query sequences and holistic indexing.

This project takes place primarily at the Database Architectures group of CWI in Amsterdam, The Netherlands and is part of the MonetDB column-oriented database system research projects. Other labs involved include HP Labs, Palo Alto, USA, National University of Singapore (NUS) and Rutgers University, USA. Several researchers are involved: Stratos Idreos (CWI), Eleni Petraki (CWI), Stefan Manegold (CWI), Martin Kersten (CWI), Goetz Graefe (HP Labs), Harumi Kuno (HP Labs), Panagiotis Karras (Rutgers U.), Felix Halim (NUS), and Roland C Yap (NUS).

CWI and Stratos Idreos won several awards for this research, including the 2011 ERCIM Cor Baayen Award and the 2011 ACM SIGMOD Jim Gray Dissertation award.

Links:
http://homepages.cwi.nl/~idreos/
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Massively Multi-Author Hybrid Artificial Intelligence

by John Pendlebury, Mark Humphrys and Ray Walshe

There is an emerging consensus in much of AI and cognitive science that "intelligence" is most likely the product of thousands of highly specialised subsystems collaborating in some kind of 'Network of Mind'. In 2001, Mark Humphrys proposed that if Artificial Intelligence (AI) is to "scale up", it will require a collaborative effort involving researchers from diverse disciplines, across multiple laboratories (http://computing.dcu.ie/~humphrys/WWM/). Until now there has never been an easy system to facilitate the construction of hybrid AI from the work of multiple laboratories. The World-Wide-Mind is the latest in a series of prototype systems, which enables the construction of hybrid AI systems from multiple laboratories.

The World-Wide-Mind server (http://w2mind.computing.dcu.ie) allows developers to pose software problems, (whether related to AI or not), for others to pose solutions to. Problems, such as a game of chess, or maze to be solved, are known as "worlds". Solutions to these problems are known as "minds". Both worlds and minds can be developed off-line and uploaded to the World-Wide-Mind server. As facilitated by many video hosting websites, such as Youtube, authors can upload their work and be assured that it will be hosted indefinitely.

Any web user can run a mind by selecting it from a list of minds displayed in a web browser. A new instance of the world and a new instance of the mind are created and run together, after which the world will assign a score to the mind.

This score can be used by mind authors to choose the most successful minds as components in their own hybrid minds, without the need to consult the original mind's author, or install anything. It then becomes possible to create entire

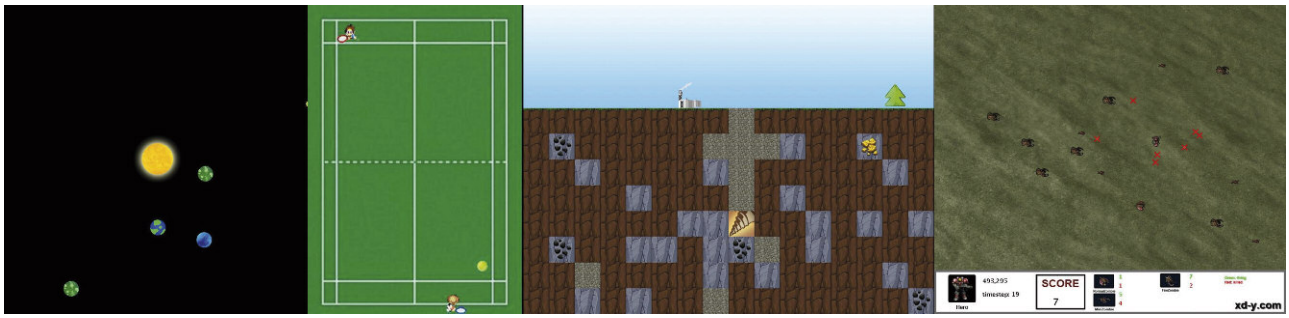

Figure 1: Some worlds currently hosted on the World-Wide-Mind server, including a space simulation, a tennis game, a mining game and a battle simulation.

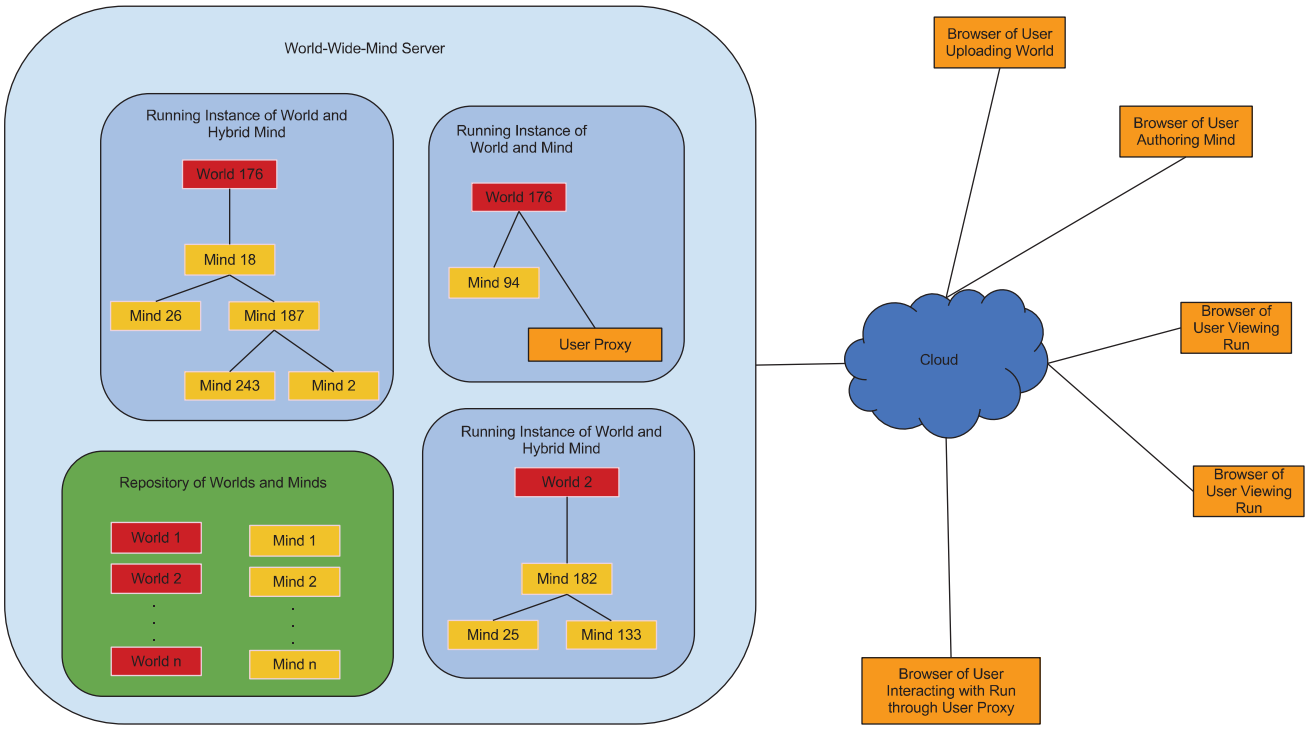

Figure 2: An Architecture for the World-Wide-Mind showing the World-Wide-Mind server running three instances of worlds with minds; two of which are running with hybrid minds and one running with an individual mind and a user proxy, allowing a user to interact with the world and mind.

hierarchies of minds with one mind at the top of the hierarchy arbitrating between the actions of minds below it, which might themselves be arbitrators of minds below them, and so on. During a run worlds can opt to output images. The system also has the facility to generate a video using these images.

In late 2011 funding was secured from the Irish Research Council for Science, Engineering & Technology (IRCSET) to enhance the World-Wide-Mind over three years. Current work in scaling up this platform is to move image generation to the client. This will allow the system to update the user's view of a run in real-time.

Distributed games frequently use artificial intelligent agents to enhance the user experience. As the user will be viewing the state of a world in real-time, there is no technical reason why they cannot interact with minds in real-time during a run. The advantage to our system would be to allow minds to learn from direct interaction with human agents. With this enhancement the system will resemble a generic MMOG (Massively Mutli-player Online Game) platform capable of running any game that a user may upload.

Many worlds and minds have been written for the World-Wide-Mind. A selection of the best of these can be found at http://w2mind.computing.dcu.ie. Some minds on the current system are individuals; others are hybrids consisting of several, or even dozens of individual minds. In the future, instead of developing solutions consisting of dozens of specialised minds, potentially we could develop solutions consisting of thousands, or hundreds of thousands of minds.

The World-Wide-Mind already resembles an ecology, where unsuccessful minds are ignored and successful minds are reused constantly. If this is indeed the case then what kinds of problems will these new hybrids be capable of solving? We hope that this system will harness an unexploited creativity for creating hybrid AIs that until now has been almost entirely dormant.

Links:
http://computing.dcu.ie/~humphrys/WWM/
http://w2mind.computing.dcu.ie
http://computing.dcu.ie/~humphrys/wwmdev/selected.worlds.html

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Bionic Packaging: A Promising Paradigm for Future Computing

by Patrick Ruch, Thomas Brunschwiler, Werner Escher, Stephan Paredes and Bruno Michel

The spectacular progress in the development of computers has been following Moore's Law for at least six decades. Now we are hitting a barrier. While neuromorphic computing architectures have been touted as a promising basis for low-power bio-inspired microprocessors down the road, imitating the packaging of mammalian brains is a new concept which may open new horizons independent of novel transistor technologies or non-Van Neumann architectures.

If one looks at the transistor count in microprocessors over the last four decades we have gone from 2500 to 2,500,000,000, a gain of six decades.

But today, two major roadblocks to further progress have arisen: power density and communication delays. The currently fastest computer was built by Fujitsu and is at the Riken Institute in Japan; it has a capacity of 8 petaflops and a power consumption of more than twelve megawatts --- enough for some ten thousand households. As to communication, while pure on-chip processing tasks can be completed in shorter and shorter times as technology improves, the transmission delays between processors and memory or other processors grow as a percentage of total time and severely limit overall task completion.

Energy considerations

A processor architecture that imitates the mammalian brain promises a revolution. Compared with the mammalian brain, today's computers are terribly inefficient and wasteful of energy, with the number of computing operations per unit energy of the best man-made machines being in the order of ~0.01% of the human brain depending on the workload. This inefficiency occurs not only in the processing chips themselves but also in the energy-hungry air conditioners that are needed to remove the heat generated by the processors.

In the October 2009, No. 79, issue of ERCIM News the Aquasar project was described. In Aquasar, the individual semiconductor chips are water cooled, with water being 4,000 times more effective than air in removing heat. Aquasar uses micro-fluidic channels in chip-mounted water coolers to transport the heat. This result is achieved with relatively hot coolant so that the recovered thermal energy is used for heating a building. Aquasar is installed and running at the ETH in Zurich; a successor machine with a three petaflop capacity is currently being installed in Munich. The integration of microchannels into the semiconductor chips themselves promises to sustain very high power dissipation as the industry strives to increase integration density further and also move to 3D chip stacks.

Going further in the new paradigm, another cause of energy inefficiency is the loss (in power and in space) in delivering

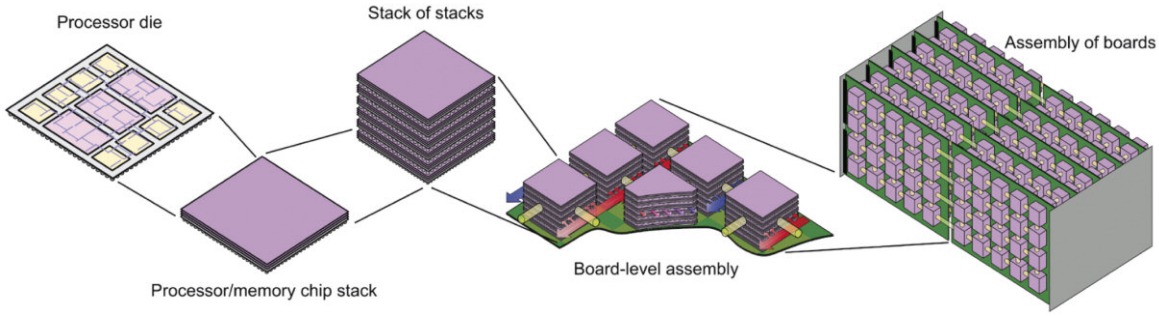

Figure 1: Vision of an ultra-dense assembly of chip stacks in a 3D computer with fluidic heat removal and power delivery.

the required electrical energy to the chips. The pins dedicated to power supply in a chip package easily outnumber the pins dedicated to signal I/O in high-performance microprocessors, and the number of power pins has been growing faster than the total number of pins for all processor types. This power problem is essentially a wiring problem, which is aggravated by the fact that wiring for signal I/O has a problem of its own. The energy needed to switch a 1 mm interconnect is more than an order of magnitude larger than the energy needed to switch one MOSFET; 25 years ago, the switching energies were roughly equal. This disparate evolution of communication and computation is even more pronounced for another vital performance metric, latency. The reason behind this trend is simply that transistors have become smaller while the chip size has not followed suit, leading to substantially longer total wire lengths. A proposed new solution to this two-fold wiring problem, again patterned after the mammalian brain, is to use the coolant fluid as the means of delivering energy to the chips. Probably it is easiest to think of this in terms of a kind of electrochemical, distributed battery where the cooling electrolyte is constantly "recharged" while the heat is removed. This is how energy is delivered to the mammalian brain and with great effectiveness.

Using the example of the human brain as the best low-power density computer we use technological analogs for sugar as fuel and the trans-membrane proton pumps which evolution has brought about as the chemical to electrical energy converters. These analogs are inorganic redox couples which have been mainly studied for grid-scale energy storage in the form of redox flow batteries. These artificial electrochemical systems offer superior power densities than their biological counterparts, but would still be pressed to meet the weighty challenge of satisfying the energy need of a fully loaded microprocessor. However, future high-performance computers which could be built around this fluidic power delivery scheme would be much less power-intensive due to their reduced communication cost.

Integration density and communication

The number of communication links between logic blocks in a microprocessor depends on the complexity of the interconnect architecture and on the number of logic blocks in a way that can be described by a power-law known as Rent's Rule. Today, all microprocessors suffer from a break-down of Rent's Rule for high logic block counts because the number of interconnects does not scale smoothly beyond the chip edge. The limited number of package pins is one of the main reasons behind the performance limitation faced by modern computing systems known as the memory wall, in which it takes several hundred to thousand CPU clock cycles to fetch data from main memory. A dense, three-dimensional physical arrangement of semiconductor chips would allow much shorter communication paths and a corresponding reduction in internal-delay roadblocks. Such a dense packaging of chips is physically possible were it not for the problems of heat removal and energy delivery using today's architecture. Using the techniques just described for handling electrical energy delivery and heat removal, this dense packaging can be achieved and communication bottlenecks with associated delay avoided.

The fluidic means of removing heat allows huge increases in packaging density while the fluidic delivery of power with the same medium saves the space used by conventional hard-wired energy delivery. The savings in space allow much denser architectures, not to mention the sharply reduced energy needs and improved latency as communication paths are chopped up into much shorter fragments

Conclusion

Using this new paradigm, the hope is that a petaflop supercomputer could eventually be built in the space taken by today's desktop PC. This is only a factor of eight smaller in performance than the above-mentioned fastest computer in the world today! The second reference below describes the paradigm in detail.

Links:

Gerhard Ingmar Meijer, Thomas Brunschwiler, Stephan Paredes, and Bruno Michel, "Using Waste Heat from Data Centres to Minimize Carbon Dioxide Emission", ERCIM News, No. 79, October, 2009: http://ercim-news.ercim.eu/en79/special/using-waste-heat-from-data-centres-to-minimize-carbon-dioxide-emission

P. Ruch, T. Brunschwiler, W. Escher, S. Paredes, and B. Michel, IBM J. Res. Develop.,"Toward 5-Dimensional Scaling: How Density Improves Efficiency in Future Computers", Vol. 55 (5), 15:1-15:13, October 2011: http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=6044603

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NanoICT: A New Challenge for ICT

by Mario D'Acunto, Antonio Benassi, Ovidio Salvetti

Nanotechnology is the manipulation or self-assembly of individual atoms, molecules or molecular clusters into structures to create material and devices through an exact control of size and form in the nanometer scale. The immense potential of this field is presenting a challenge for the ICT world.

A nanometer (nm) is a billionth of a meter ($1nm=10^{-9}m$), ie about 1/80,000 of the diameter of a human hair, or 10 times the diameter of a hydrogen atom. The term nanotechnology is generally used when referring to materials of size 0.1nm to 100nm. Materials with nanometric structures often exhibit quite different properties- mechanical, optical, chemical, magnetic or electronic - compared with traditional bulk materials made from the same chemical composition. Two principal factors cause the properties of nanomaterials to differ significantly from other materials: increased relative surface area, and quantum effects. These factors can change or enhance properties such as reactivity, strength and electricity, or optical characteristics, because the deviation of surface and interface properties from the bulk properties of larger amounts of material sometimes leads to unexpected surface effects.

Information and Communications Technology (ICT) is one of the areas that has most benefited from nanotechnologies, where it has been traditionally associated with nanoelectronics, in the efficient development and miniaturization of items such as computer chips, information storage, and sensors. Certain ICT procedures, such as distributed calculus and smart processing can be considered suitable for the implementation of bottom-up nanotechnology procedures. The self-assembly of nanostructures is the clearest evidence of a bottom-up processing (as opposed to miniaturization that can be considered the basic top-down procedure). Self-assembly is the art of building by mixing. Chemists have been doing this for centuries. The challenge today is to make such systems smart. In order to successfully use self-assembly to build micro- and nano-devices it is important to use building blocks that can be programmed to assemble in certain, pre-determined ways. If all the components that are being assembled are of the same kind, a simple over-scale structure will be the result. Using building blocks with differentiated binding sites that only fit together in certain patterns is a way to program the assembly process and makes it possible to build far more advanced structures than just periodic ones. Such processes are known as programmable self-assembly.

One important example of programmable self-assembly is the mechanism of single stranded DNA hybridization on different surfaces, gold nanoparticles surfaces, carbon nanotubes, etc. DNA is an excellent self-assembly glue since it is specific in its bonding interactions and can be used in various nanotechnology applications, see Figure 1. Recently, we showed that the hybridization of DNA on a single-wall carbon nanotube (SWNT) is accomplished by a band-gap fluorescent shift due to changes in the exciton population (M. D'Acunto, S. Colantonio, D. Moroni, O. Salvetti, Journal of Modern Optics, 57, 1695-1699, 2010). An exciton is a bond state between an electron crossed on the conduction band and its corresponding hole in the valence band connected by the electrostatic Coulomb force. The possibility to tune the exciton population during the self-assembling process opens the road for the production of smart biosensors with many possible applications (genetic diagnosis, screening of genetically modified food, etc.). The smart biosensors, engineered by our simulations, will implement DNA sequences that are complementary to the carbon nanotubes and are compatible with specific biosensor enzymes for many different compounds. In turn, it will be a self-assembling guided procedure for biosensors at the biomolecular level. Such smart sensors could be strongly improved using graphene sheets instead of carbon nanotubes, because of the large area for single strand DNA functionalization made available by graphene sheets, see Figure 2. The construction of a smart nano-biosensor based on the self-assembly of DNA on graphene sheets is a future exciting challenge for scientists bridging the gap between the behavior of matter on the nanoscale and the ICT world. Another possible application that we are studying is to use electrospun nanofiber for hybridizing single stranded DNA. Electrospinning is a well-developed process used to produce nanofibers from a variety of materials. In electrospinning, a

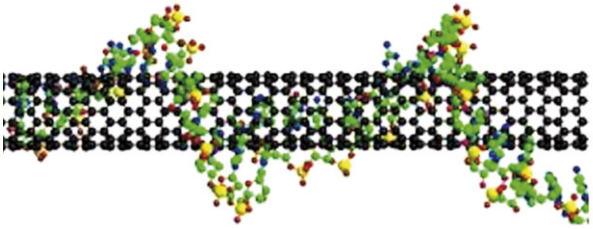

Figure 1. Example of DNA wrapping a carbon nanotube. The chemical bonding of nanotubes is composed entirely of sp2-bonds, similar to those of graphite. These bonds provide nanotubes with their unique strength, and other specific physical-chemical properties, selectively changed by the bonding with DNA filament.

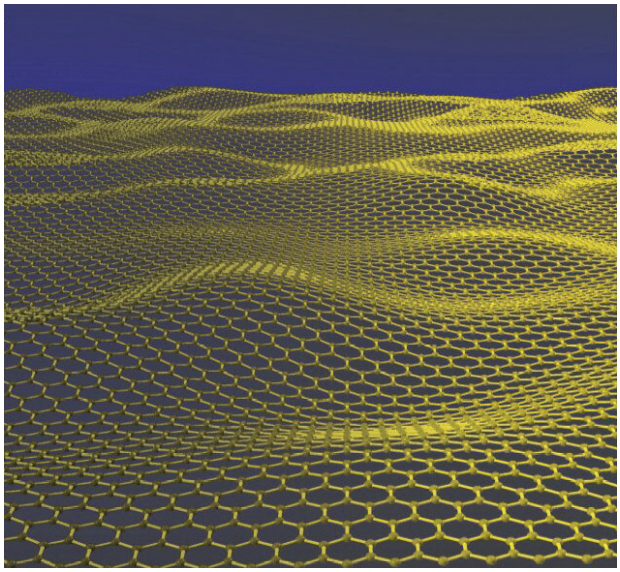

Figure 2: A graphene sheet: a one-atom-thick planar sheet of sp^2-bonded carbon atoms densely packed in a honeycomb crystal lattice. The crystalline or flake form of graphite consists of many graphene sheets stacked together.

high voltage is applied to viscous solution on a sharp conducting tip, causing it to form a Taylor cone. As the electric field is increased, a fluid jet is extracted from the Taylor cone and accelerated toward a grounded collecting substrate. Nanofibers (having at least one dimension of 100 nanometer (nm) or less) exhibit special properties mainly due to extremely high surface to weight ratio. Within this main nanoICT challenge, we are now working on simulating possible improvements of DNA-functionalized nanofibers to be used as smart nanobiosensors through a combination of selective DNA chemical bonding with nanofiber surface.

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Information Extraction from Presentation-Oriented Documents

by Massimo Ruffolo and Ermelinda Oro

The Web is the largest knowledge repository ever. In recent years there has been considerable interest in languages and approaches providing structured (eg XML) and semantic (eg Semantic Web) representation of Web content. However, most of the information available is still accessed via Web pages in HTML and documents in PDF, both of which have internal encoding conceived to present content on screen to human users. This makes automatic information extraction problematic.

In Presentation-Oriented Documents (PODs) content is laid out to provide visual patterns that help human readers to make sense of it. A human reader is able to look at an arbitrary document and intuitively recognize its logical structure and understand the various layout conventions and complex visual patterns that have been used in its presentation. This aspect is particularly evident, for instance, in Deep Web pages where Web designers arrange data records and data items with visual regularity, and in PDF documents where tables are used to meet the reading habits of humans. However, the internal representations of PODs are often very intricate and not expressive enough to allow the associated meaning to be extracted, even though it is clearly evidenced by the presentation.

In order to extract data from such documents, for purposes such as information extraction, it is necessary to consider their internal representation structures as well as the spatial relationships between presented elements. Typical problems that must be addressed, especially in the case of PDF documents, are incurred by the separation between document structure and spatial layout. Layout is important as it often indicates the semantics of data items corresponding to complex structures that are conceptually difficult to query, eg in western languages, the meaning of a cell entry in a table is most easily defined by the leftmost cell of the same row and the topmost cell of the same column. Even when the internal encoding provides fine-grained annotation, the conceptual gap between the low level representation of PODs and the semantics of the elements is extremely wide. This makes it difficult:

- for human and applications attempting to manipulate POD content. For example, languages such as XPath 1.0 are currently not applicable to PDF documents;
- for machines attempting to learn of extraction rules automatically. In fact, existing wrapper induction approaches infer the regularity of the structure of PODs only by analyzing their internal structure.

The effectiveness of manual and automated wrapper construction is thus limited by the need to analyze the internal encoding of PODs with increasing structural complexity. The intrinsic print/visual oriented nature of PDF encoding poses many issues in defining 'ad hoc' information extraction approaches.

In the literature a number of spatial query languages for Web pages, query languages for multimedia databases and presentations, visual Web wrapping approaches, and PDF wrapping approaches, have been proposed. However, so far, these proposals provide limited capabilities for navigating and querying PODs for information extraction purposes. In particular, existing approaches are not able to generate extraction rules that are reusable when the internal structure changes, or for different documents in which information is presented by the same visual pattern. Information extraction approaches are needed that can exploit the presentation features of PODs.

ICAR-CNR is addressing these problems through the definition of spatial and semantic wrapper induction and querying approaches that allow users to query PODs by exploiting the visual patterns provided in the presentation. These approaches are grounded on document layout analysis and page segmentation algorithms combined with techniques for automatic wrapper induction and spatial languages like SXPath, a spatial extension of XPath 1.0. The innovative approaches for information extraction from PODs now being studied at ICAR-CNR permit: (i) the analysis of document layout and recognition of complex content structures like tables, sections, titles, data records, page columns, etc.; (ii) the automatic learning of extraction rules and creation of wrappers that enable relevant information to be extracted from documents such as records and objects belonging to specific classes; (iii) the navigation and querying of both Web and PDF documents by spatial primitives that exploit the spatial arrangement of content elements resulting from documents presentation.

A CNR spin-off and start-up company, Altilia srl, will implement the approaches defined at ICAR-CNR. Altilia will provide semantic content capture technologies for the content management area of the IT market.

Link: http://www.altiliagroup.com

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Region-based Unsupervised Classification of SAR Images

by Koray Kayabol

Many applications in remote sensing, varying from crop and forest classification to urban area extraction, use Synthetic Aperture Radar (SAR) image classification. As ERCIM Fellows, we have studied the classification of land covers for a year. Our results on the classification of water, land and urban areas can be used by city administrators and planners to automatically classify related land covers in order to control the development of the city, while preserving its resources like forests and waters.

The aim of image classification is to assign each pixel of the image to a class with regard to a feature space. These features can be the basic image properties as intensity and colours. Moreover, some more advance abstract image descriptors as textures can also be exploited as feature. Radar images are preferred in remote sensing because the acquisition of the images is not affected by light and weather conditions.

The developments in forming SAR images took place in the years 1950-1975 and the studies on processing and understanding SAR images started in the late 1970s. By the technological developments, we are now able to work with high resolution SAR images. For example, the images used in our studies have ground resolutions varying from 2.5 to 8.2 meters. The scope of our work is high resolution SAR image classification. As a feature, we use the amplitudes of the SAR images. As a model density for SAR image amplitudes, we use the Nakagami density, since it is a basic multi-look amplitude model for SAR images. Multi-look SAR images are formed by scanning the same region multiple times and consequently have less noise than the single-look SAR images. Beside the amplitudes, we must take into consideration the spatial neighborhood of the pixels to obtain some smooth and connected components in the class label map. We introduce the spatial interactions adopting the Multinomial Logistic model to obtain a smooth classification map.

In this work, we follow the model based classification approach to reach a novel unsupervised classification algorithm for SAR images. The Finite Mixture Model (FMM) is a suitable statistical model to represent the SAR image histogram and to perform a model based classification. Fitting a mixture model to some data can be realized by using the Expectation-Maximization algorithm. We use a computationally less expensive version of the EM algorithm, namely Classification EM (CEM), for both parameter estimation and classification, using the advantage of categorical random variables. Determining the necessary number of classes and initialization are some drawbacks of the EM type algorithms. First time in this study, we combine hierarchical agglomeration, CEM and a model order selection criterion to get rid of the drawbacks of CEM in order to obtain an unsupervised SAR image classification algorithm. In this way, we are able to determine the necessary number of land covers in a given area. We start the CEM algorithm with a large number of classes and then reduce the number of classes iteratively by merging the weakest class in probability to the one that is most similar to it with respect to a distance measure. Figure 1 demonstrates the algorithm where a SAR image is classified to three regions namely, urban, land and water areas.

This work started in November 2010 and major parts were completed in the Ariana/Ayin research group at Inria, France, lead by Josiane Zerubia. Koray Kayabol carried out this work during the tenure of an ERCIM 'Alain Bensoussan' Postdoctoral Fellowship Programme. He is currently pursuing his works in the Probability and Stochastic Networks (PNA2) group at CWI, The Netherlands, with Marie-Colette van Lieshout as part of the ERCIM MUSCLE Working Group. We presented this research during the MUSCLE International Workshop on Computational Intelligence for Multimedia Understanding held in Pisa, Italy, organized by the Working Group. The study is planned to be finalized in April 2012. The Italian Space Agency (ASI) provided the COSMO-SkyMed images. The TerraSAR-X images are provided by Astrium Services (Infoterra) from http://www.infoterra.de/. The papers written during the study can be found in the links below.

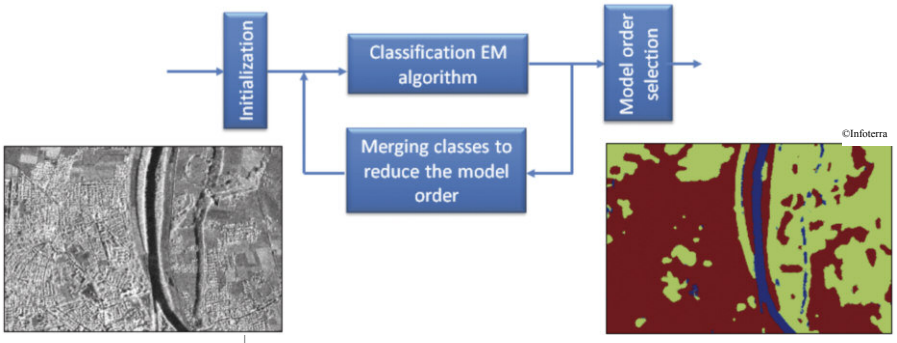

Figure 1: Region based classification of a TerraSAR-X image by hierarchical agglomeration based unsupervised algorithm. The TerraSAR-X image was acquired over the city of Rosenheim in Germany.

Links:

http://www-sop.inria.fr/ariana/en/lequipe.php?name=Kayabol
http://hal.archives-ouvertes.fr/hal-00612491/fr/
http://www.cwi.nl/pna2
http://repository.cwi.nl/search/searchrepository.php?cwi=2457
http://muscle.isti.cnr.it/pisaworkshop2011/index.html

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Computer-Aided Diagnostics

by Peter Zinterhof

In a joint project, scientists at University Salzburg and SALK (Salzburger Landeskrankenanstalten) explore how to apply machine-learning techniques to assess the huge amount of image data generated by computed tomography.

Modern radiology offers a wide range of imaging tools for diagnosis and for planning of treatments of various severe illnesses. As techniques such as MRI and CT (computed tomography) are employed on a large scale, clinicians all over the world are confronted with an increasing amount of imaging data. These data have to be analysed and assessed by trained radiologists in a mostly manual process, which requires high levels of concentration for long periods of time. Also, the intrinsic power of modern medical imaging technology opens up the possibility of detecting conditions in a patient that weren't even on the scope of the physician who initiated the diagnostic run in the first place. As a consequence, in addition to concentrating on the initial diagnostic directions, the assessing radiologist is also responsible for detecting and correctly reporting other medical issues revealed by a patient's data. As a result, the overall diagnostic process is very demanding and sometimes even error-prone.

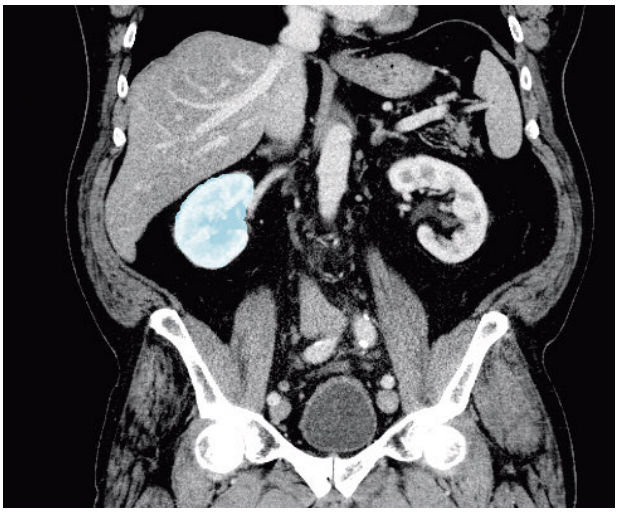

Figure 1: Raw segmentation of the right kidney

In a joint research project with the department for radiology at SALK (Salzburger Landeskrankenanstalten), we aim to explore the application of certain machine-learning techniques for image segmentation in the field of computed tomography. One such approach is based on principle component analysis (PCA), also known as Karhunen-Loeve transform. This method derives statistically uncorrelated components of some given input data set, allowing robust recognition of patterns in new datasets. Our algorithm works on image patches of 64 x 64 pixels, allowing us to detect image details up to this size within a single CT frame.

During an initial setup phase we semi-automatically generate and label a large number – usually millions – of patches that stem from a training sample of some 500 patients' data.(50 GB DICOM)

An auto-correlation matrix of the pixel intensities of the patches is made up and in a second step both the Eigenvalues and Eigenvectors of that matrix are computed and the Eigenvectors corresponding to the 32 largest Eigenvalues are retained for further processing. Based on these Eigenvectors we are able to build a codebook that holds the necessary information for recognizing medically relevant features later on.

Such codebooks are composed of millions of short vectors of length 32 (also being called feature vectors), which are assigned specific class labels, eg 'kidney', 'tissue', 'bone'. New data (ie image patches) will then also be decomposed into feature vectors by means of the very same Eigenvectors. At the core of the recognition algorithm we take a previously unknown feature vector, 'look up' its corresponding entry in the codebook, and assign that vector the same class label as the entry found in the codebook. The look-up process is based on finding the entry with minimal Euclidean distance to the unknown vector.

As we deal with a high-dimensional vector space model, the lookup process itself is not suitable for typical optimizations, such as kD-trees or clustering. This is a direct consequence of the 'curse of dimensionality', which basically limits us to a standard linear search operation within the codebook as the space- and execution-time optimal approach to solve the retrieval problem.

For a new patient, the whole set of CT data is then checked frame by frame at the 'regions of interest', which consist of some 64 000 pixels per frame (see picture 1 with marked area of the left kidney). On average 2 PB (2 million GB) of data have to be processed per patient. Fortunately, this computationally complex process lends itself very well to distributed parallel hardware, eg clusters of general purpose graphics units (GPU) that are especially powerful in the field of high-throughput computing.

In our cluster setup of 16 distributed NVIDIA GPUs (Fermi and GT200 class) we achieve high recognition rates for the complete segmentation of the kidney area in a patient's CT data in a time frame of 10-12 minutes (wall-time), based on 10 million codebook entries. One of the charms of PCA is its relative resilience against over-fitting of the model data, so increasing the amount of training data in general will not reduce its generalization capability (as can be the case in artificial neural networks). Hence, the approach is easily extendible both in terms of additional compute nodes and additional training data, which will help us to sift relevant information from this vast data space even faster and at higher quality.

Our developments aid both clinicians as well as patients by enabling automatic assessment of large amounts of visual data on massively parallel computing machinery.

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Computer-Aided Maritime Search and Rescue Operations

by Salvatore Aronica, Massimo Cossentino, Carmelo Lodato, Salvatore Lopes, Umberto Maniscalco.

Information and communications technologies promise to have a significant impact on safety at sea. This is particularly true for smaller ships and boats that rarely have active on board safety systems. We are currently developing a system for computer-aided maritime search and rescue operations within the ICT-E3 Project (ICT excellence programme of Western Sicily funded by the Sicilian Regional Government).

A successful conclusion of a maritime search and rescue (SAR) operation depends on several factors. Some, like the weather and sea conditions, are uncontrollable; others can be optimized and made more effective by the employment of information and communications technologies. A system able to localize a vessel in trouble and to define the most efficient plan for search and rescue activities is of great importance for safety at sea.

The first step in building such a system is an accurate localization of vessels in trouble. Normally, the last known position (LKP) of a vessel is communicated to the rescuers by the people on board. This apparently simple action can become extremely difficult with adverse weather and sea conditions. To add to the difficulty, those on board may only know their positions approximately or, at worst, not at all. The vessel may not be equipped with a global positioning system or even a suitable compass to obtain at least some bearings. Thus the localization provided by the people on board of a vessel in trouble may generate imprecise or useless information.

However, if a rescue request is received by radio, localization can be achieved in a few seconds with good precision and without any specific information communicated by the vessel in trouble. As a rule, a couple (or a net) of radio direction finders (RDFs) can detect the direction of an incoming radio signal via voice on VHF channel 16 or by digital selective calling (a distress signal on VHF). Hence, automatic localization is possible via a simple triangulation if at least two or more RDFs, placed in different points, get a bearing from a radio signal. If the people awaiting rescue continue to communicate via radio, our system can track the vessel by successive localizations. With an accurate localization of the vessel, search and rescue operations (SAROPs) have a higher probability of success.

SAROPs are regulated at the international level by a set of standard procedures defined and described in the IAMSAR volume II (International Aeronautical and Maritime Search and Rescue). IAMSAR procedures require many meteorological parameters, they employ many data tables and curve plots in order to evaluate the datum (a geographic point, line or area used as reference in the search planning). However, such procedures involve several complex computations and require a lot of valuable time thus delaying the start of a SAROP.

The use of a computer system implementing all the procedures involved in SAROPs can reduce errors and the time needed to define a SAR plan; it can also improve on the probability of success of the rescue mission.

IAMSAR procedures were originally developed for manual calculation and they do not include the support for a computer implementation. Hence, they avoid the adoption of complex and effective algorithms for defining the search action plan; such algorithms are a viable solution when the support of a computer is available. For the same reason, the IAMSAR manual only suggests two simple search paths for the navigation of SAR units; furthermore, the handling and the allocation of these units over the search area, is quite rigid.

Starting from these considerations, we have developed an enhanced implementation of IAMSAR procedures and have integrated it with the automatic localization system outlined above. An enhanced statistical processing method (the Monte Carlo simulation technique) has been introduced in this implementation. It determines the search area instead of the prefixed probability maps suggested by the IAMSAR manual. Crucial data, like wind force, state of the sea and

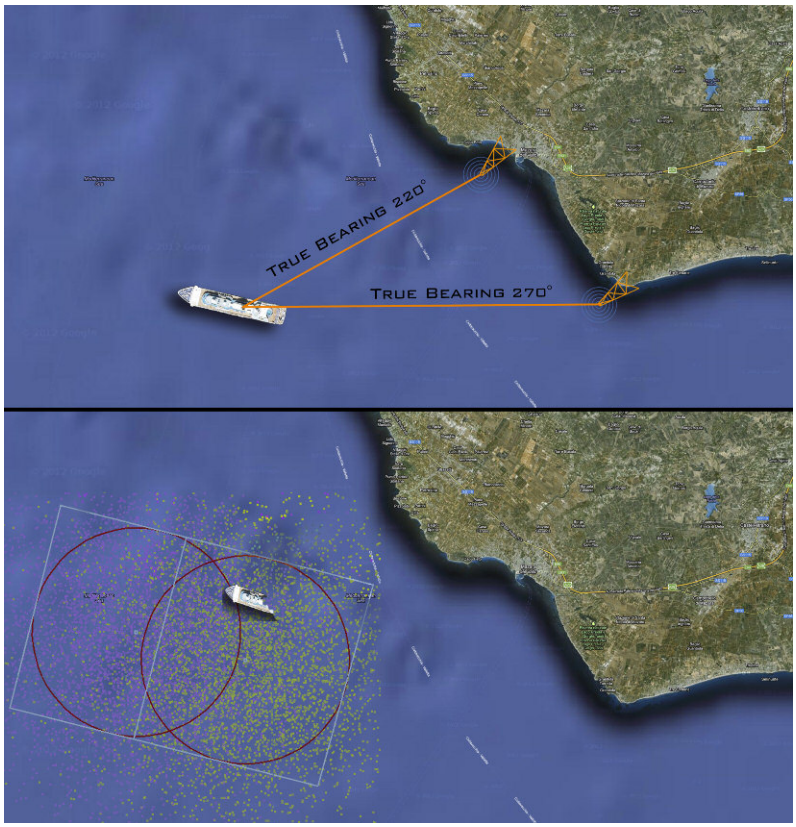

Figure 1: Upper side: a simple scenario with two stations detecting an emergency call. Lower side: datum, search area and probability distribution obtained by the Monte Carlo simulation.

water current models from SOAP messages, can also be integrated. The system includes a database in which all SAR units at disposal of a Coast Guard Station are stored with details of their salient features. A friendly graphic user interface has been designed, where several graphic layers of information can be overlaid or hidden in visualization.

Other significant and innovative extensions of the IAMSAR procedures have been carried out during the development of the ICT-E3 project, and are now subject to a patent application. We wish to acknowledge the collaboration with the personnel of the Mazara del Vallo Coast Guard Station, their invaluable help and stimulating suggestions have been fundamental to the success of the activity.

Link: http://ceur-ws.org/Vol-621/paper21.pdf

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Wikipedia as Text

by Máté Pataki, Miklós Vajna and Attila Csaba Marosi

When seeking information on the Web, Wikipedia is an essential source: its English version features nearly four million articles. Studies show that it is the most frequently plagiarized information source, so when KOPI, a new translational plagiarism checker was created, it was necessary to find a way to add this vast source of information to the database. As it is impossible to download the whole database in an easy-to-handle format, like HTML or plain text, and all the available Mediawiki converters have some flaws, a Mediawiki XML dump to plain text converter has been written, which runs every time a new database dump appears on the site with the text version being published for everybody to use.

The KOPI Plagiarism Search Portal was developed by the Department of Distributed Systems (DSD) of MTA SZTAKI in 2004 as a plagiarism checker tool for carbon copy plagiarism cases. In 2010, the system improved by adding a unique feature to the search engine, the capability to find translated plagiarism. For this function it was necessary to include the whole English Wikipedia, as the number one source of potential plagiarism, into the database.

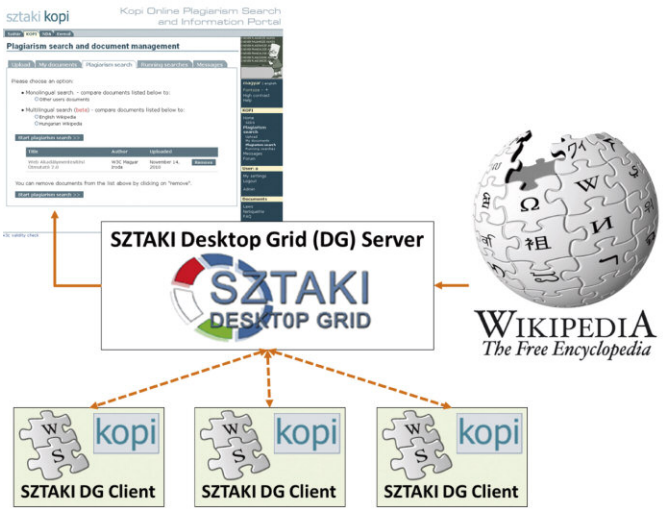
When the Wikipedia dumps were first downloaded from the server, all possibilities of converting them easily and quickly to plain text were examined, as plain text is easy to manipulate. Consequently, the whole content had to be run through a series of language processing steps. In most cases the available converters were not suitable for handling a larger chunk of XML dump, or the output was error prone and in many cases – when using, for example, a Mediawiki instance as a converter – the conversion was slow.

Consequently a new converter needed to be written based on the following features:

- article boundaries have to be kept
- only the textual information is necessary
- infoboxes – as they are duplicated information – are filtered out
- comments, templates and math tags are dismissed
- other pieces of information, like tables, are converted to text.

Wikipedia dumps are published regularly and, as the aim is to be up-to-date, the system needed an algorithm which is able to process the whole English Wikipedia in a fast and reliable way. As the text is also subject to a couple of language processing steps to facilitate plagiarism search, these steps were included and the whole processing moved to the SZTAKI Desktop Grid service (operated by the Laboratory of Parallel and Distributed Systems), where more than 40,000 users have donated their free computational resources to scientific and social issues. Desktop grids are usually suited for parameter study or "bag-of-tasks" type of applications and have other minor requirements for the applications in exchange for the large amount of "free" computing resources made available through them. SZTAKI Desktop Grid, established in 2005, utilizes mostly volatile and non-dedicated resources (usually the donated computation time of desktop computers) to solve compute intensive tasks from different scientific domains like mathematics and physics. Donors run a lightweight client in the background which downloads and executes tasks. The client also makes sure that only the excess resources are utilized so there is no slowdown for the computer and the donor is not affected in any other way.

The Mediawiki converter was written in PHP to support easy development and compatibility with the existing codebase of the KOPI Portal. The main functionality could be implemented with less than 400 lines of code. The result was adapted to the requirements of the desktop grid with the help of GenWrapper, a framework specially created for porting existing scientific applications to desktop grids.



Wikipedia to text conversion process

GenWrapper's primary goal is lowering the porting effort required for 'legacy applications', which either have no source code available or making changes to them is infeasible. In case of KOPI it allowed the development of the converter independently from the desktop grid and the result could be effortlessly deployed.

This new arrangement allows Wikipedia in any language to be converted and preprocessed in a couple of days. As these text versions can be used for several other purposes as well, they are shared and made available to everybody. Currently one can download the English (5.7 GB), Hungarian (300 MB), German (2.2 GB) and French (1.5 GB) versions (sizes are gz compressed size). Based on the project work and plans, other languages will follow shortly.

Links:
Wikipedia as text download link:
http://kopiwiki.dsd.sztaki.hu
KOPI portal: http://kopi.sztaki.hu
SZTAKI Desktop Grid: http://szdg.lpds.sztaki.hu
GenWrapper: http://genwrapper.sourceforge.net

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Genset: Gender Equality for Science Innovation and Excellence

by Stella Melina Vasilaki

GenSET was an innovative project aiming to improve the excellence of European science through inclusion of the gender dimension in research and science knowledge making. It functioned as a forum for sustainable dialogue between European science leaders, science stakeholder institutions, gender experts, and science strategy decision-makers, to help implement effective overall gender strategies. The goal was to develop practical ways in which gender knowledge and gender mainstreaming expertise can be incorporated within European science institutions in order to improve individual and collective capacity for action to increase women's participation in science.

Between March and June 2010, three genSET Consensus Seminars brought together 14 European science leaders to share knowledge and experience and arrive at a consensus view on the gender dimension in science and on the priorities for gender action in scientific institutions. The Science Leaders Consensus Panel represents extensive knowledge of different scientific fields and sectors, with over 500 years of scientific and leadership experience; involvement in appointing over 4000 researchers; direction of over 300 major research programmes and research funding of over €500 million; executive decision making through over 100 Executive Board positions; and research publication record exceeding 1000 peer reviewed research papers. They collaborated with a group of equally high-ranking gender experts, who provided expertise through lectures and research evidence during the Consensus Seminars.

The consensus recommendations call for action in four priority areas of the gender dimension in science: science knowledge making, deployment of human capital, institutional practices and processes, and regulation and compliance with gender□related processes and practices. All of these recommendations are meant to be included within an overall institutional science strategy. The work of the Science Leaders Panel has highlighted only the beginning of an important dialogue between gender experts and leaders of scientific institutions.

Here below there is a summary of the consensus recommendations:

- *Recommendation 1:*
  Leaders must be convinced that there is a need to incorporate methods of sex and gender analysis into basic and applied research; they must "buy into" the importance of the gender-dimension within knowledge making.
- *Recommendation 2:*
  Scientists should be trained in using methods of sex and gender analysis. Both managerial levels and researchers should be educated in such sex and gender analysis. Training in methods in sex and gender analysis should be integrated into all subjects across all basic and applied science curricula
- *Recommendation 3:*
  In all assessments – paper selection for journals, appointments and promotions of individuals, grant reviews, etc. – the use and knowledge of methods for sex and gender analysis in research must be an explicit topic for consideration. Granting agencies, journal editors, policy makers at all levels, leaders of scientific institutions, and agencies responsible for curricula accreditation, should be among those responsible for incorporating these methods into their assessment procedures.
- *Recommendation 4:*
  Research teams should be gender diverse. Institutions should promote gender diversity of research teams through a variety of incentives (eg quality recognition and allocation of resources) and through transparency in hiring.
- *Recommendation 5:*
  Gender balancing efforts should be made in all committees, with priority given to key decision-making committees. Panels for selection of grants and applicants must be gender diverse. This must be the goal for management teams as well.
- *Recommendation 6:*
  Institutions should seek to improve the quality of their leadership by creating awareness, understanding, and appreciation of different management styles. This can be achieved through training, self-reflection, and various feedback mechanisms. Diversity training, specifically, is essential in this process.
- *Recommendation 7:*
  Women already within scientific institutions must be made more visible. All public relations activities from scientific

institutions should be gender□proofed (represent women appropriately), while avoiding tokenism. This could be done by including women in all promotional campaigns for scientific careers, by leaders nominating women for prizes, and by recognizing women's achievements appropriately.

- *Recommendation 8:*
  Assessment procedures must be re-defined to focus on the quality, rather than quantity, of individuals' publications and research output. This must be consistently applied in individual, departmental, and other levels of assessment.
- *Recommendation 9:*
  Persons with disproportionate committee and administrative duties should be provided with additional support staff or reduced teaching assignments to ensure that their research does not suffer.
- *Recommendation 10:*
  Policies and procedures specifically affecting working conditions that differentially impact men and women in scientific institutions must be reviewed and revised, ensuring positive benefits for personal and professional development for both men and women.
- *Recommendation 11:*
  Specific strategies should be employed for attracting women to apply for scientific positions. Announcements for recruitment should be formulated so that they encourage women to apply. That is, announcements should be broad, rather than narrowly focused. Job criteria for employment should be objective and transparent. Additionally, leaders should not just rely on self-initiated promotion but also encourage and promote applications, not just accept them. Finally, if there are no women in the applicant pool, the positions should be re-advertised.
- *Recommendation 12:*
  Explicit targets to improve gender balance and action plans to reach them must be included in the overarching gender strategy of scientific institutions. The progress must subsequently be regularly monitored and be made public.
- *Recommendation 13:*
  Gender issues must be an integral part of internal and external evaluation of institutions. Policies at all levels must require this inclusion. This should begin with a critical review of gender mainstreaming processes within each institution, identifying current successes and failures. A member of the leadership team should be responsible for gender-related issues, such as following up on the gender action strategy for the institution.

genSET was a project funded by the Science in Society Programme of the European Commission's 7th Framework, in the area of Capacity Support Action.

Link:
The full report 'The Consensus Report: Recommendations for Action on the Gender Dimension in Science' is found on the project website:
http://www.genderinscience.org/resources.html

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Recommending Systems and Control as a Priority for the European Commission's Work Programme

by Sebastian Engell and Françoise Lamnabhi-Lagarrigue

In a recently published position paper, members of the HYCON2 Network of Excellence ('Highly-Complex and Networked Control Systems') demonstrate that control is at the heart of the information and communication technologies of complex systems. As a consequence, control should be supported as a priority in the coming European Commission's work programmes, both at the level of enabling technologies and at application level, including 'public private partnerships' (PPPs) on Energy-efficient buildings, Factories of Future and European Green Cars Initiatives. The recommendations for a 'European Research Agenda towards Horizon 2020' are supported by major European enterprises and academia.

Systems and control science provides the scientific foundations and technology to analyse and design complex, dynamically evolving systems, in particular systems in which feedback plays an important role. Feedback means that the effect of actions is monitored and future actions are planned taking this information into account. Feedback is ubiquitous in technical systems where it enables automation and autonomy, and in social, socio-technical, economic and biological systems.

Systems and control science is both a scientific core discipline and a crucial part of application areas such as automotive, aeronautics and aerospace, manufacturing, generation and distribution of electric energy, heating, ventilation and air conditioning, production of chemicals, paper, food and metals, robotics, supply chains and logistics.

Systems and control science provides tools for modelling dynamic physical, chemical, biological, economic and social systems and develops concepts and tools for their analysis and design. It integrates contributions from mathematics, signal processing, computer science, and from the application domains. Systems and control science is indispensable to analyse, design, simulate, optimize, validate, and verify the technological and socio-technical systems that will be characterized by massive interconnection, the processing of huge amounts of data, new forms of synergy between humans and technical systems, and challenging requirements for substantially improved performance, reliability, and energy efficiency.

The basic roles of systems and control science are thus the following:

- model physical phenomena and artefacts to understand and predict their dynamic behaviour and the interactions among their components

- develop control strategies and algorithms to optimize the behaviour of systems so that they accomplish certain intended functions, satisfy constraints, and minimize negative effects, eg consumption of resources
- implement the control strategies by selecting sensing devices, computing elements and actuators and integrating them into a system with maximum performance under cost constraints
- validate and verify that the implementation of control strategies acting on the physical systems satisfies constraints and performance requirements.

Systems and control science has played an important enabling role in all major technological evolutions, from the steam engine to rockets, high-performance aircrafts, space ships, high-speed trains, 'green' cars, digital cameras, smart phones, modern production technology, medical equipments, and many others. It provides a large body of theory that enables the analysis of dynamic systems in order to better understand their behaviour, improve their design, and augment them by advanced information processing, leading to qualitative leaps in performance. Over the last fifty years the field of systems and control has seen huge advances, leveraging technology improvements in sensing and computation with breakthroughs in the underlying principles and mathematics. Motivated by this record of success, control technologists are addressing contemporary challenges as well, examples of which include:

- The automotive industry is focusing on active safety technologies, which may ultimately lead to partially autonomous driving, where humans will become passengers of automated vehicles governed by automatic control algorithms for substantial parts of their trips, leading to improved safety, better fuel economy, and better utilization of the available infrastructure.

- Automatic control will help improve surgery. Robots are already used to support surgeons to minimize invasive procedures and increase accuracy of operations. It is conceivable that semi-autonomous robots, remotely supervised by surgeons, will be capable of carrying out unprecedentedly complex operations.

- Automatic control will play a fundamental role in the energy landscape of the future, both in the efficient use of energy from various sources in industry and in buildings, and in the management of the generation, distribution and consumption of electrical energy with increased use of renewable and decentralized generation. The management of important schedulable loads (eg the recharging of electric cars) and of distributed sources (eg at customers' homes) calls for completely new large-scale control structures.

- Systems and control science is important in all kinds of maintenance tasks for large infrastructures. Robotic sensor and actuator networks will be employed for autonomous surveillance and maintenance in large buildings, distribution networks, etc.

- Control is ubiquitous in the biological mechanisms that govern life. An improved understanding of the dynamic behaviour of these complex biological systems will provide new opportunities for biotechnology and medicine and support the design of such systems ('synthetic biology').

- In the defence and security domains, besides the interest in improved performance of equipment of all kinds, there is an increasing demand for highly autonomous devices and, in particular in coordinated sets of devices and vehicles that cooperate to carry out a particular task, asking for distributed multi-agent control.

The Systems and Control position paper outlines ten crucial areas in which control will make a strong impact in the next decade: Ground and air smart traffic management; green electricity and Smart Grid; improved energy efficiency in production systems; security in decentralized automation; mechatronics and control co-design and automation; analysis, control and adaptation of large infrastructures; autonomous systems; neurosciences; health care (from open medication to closed loop control) and cellular and biomolecular research.

Then the main overarching challenges behind these applications are summarized: 1) System-wide coordination control of large-scale systems 2) Distributed networked control systems 3) Autonomy, cognition and control 4) Model-based systems engineering 5) Human-machine interaction. This is followed by a discussion of new sectors where control will have a major role to play: control and health; control and social and economic phenomena and markets; control and quantum engineering.

Finally some operational recommendations are listed in order to provide the means to develop this extremely important scientific and technological discipline whose critical role in ICT is essential to meet European Policies in the future.

Link:
Systems and Control position paper, 30 pages:
http://www.hycon2.eu/extrafiles/CONTROL_position_paper_FP8_28_10_2011.pdf

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First 'NetWordS' Workshop on Understanding the Architecture of the Mental Lexicon: Integration of Existing Approaches

by Claudia Marzi

A workshop, held 24-26 November 2011 at the CNR Research Campus in Pisa, was organised within the framework of "NetWordS", the European Science Foundation Research Networking Programme on the Structure of Words in the languages of Europe.

The ambitious goal of the workshop was to lay the foundations for an interdisciplinary European research agenda on the Mental Lexicon for the coming 10 years, with particular emphasis on three main challenges:

- Lexicon and Rules in the grammar
- Word knowledge and word use
- Words and meanings

Leading scholars were invited to address three basic questions:

- In the speaker's area of expertise, what are the most pressing open issues concerning the architecture of the Mental Lexicon?
- What and how can progress in other research areas contribute to addressing these issues?
- How can advances in our understanding of these issues contribute to progress in other areas?

The Workshop brought together 37 participants (Scholars, Post-Docs, PhD students) from a number of European countries. Eighteen speakers, from diverse scientific domains, presented cross-disciplinary approaches to the understanding of the architecture of Mental Lexicon, reflecting the interdisciplinarity and synergy fostered by NetWordS. Contributions were devoted to understanding the ontogenesis of word competence, creative usage of words in daily conversation, the architecture of the mental lexicon and its brain substrates. In all these research areas NetWordS intends to encourage multidisciplinarily informed integration and synthesis of existing approaches.

More than 40 research institutions from 16 European countries participate in NetWordS. Scientists involved in NetWordS are playing a leading role in the following areas:

- Theoretical issues in morphology and its interfaces
- Typological, variationist and historical aspects of word structure
- Cognitive issues in lexical architecture
- Short-term and long-term memory issues
- Neuro-physiological correlates of lexical organization and processing
- Psycho-linguistic evidence on lexical organization and processing
- Machine-learning approaches to morphology induction
- Psycho-computational models of the mental lexicon
- Distributional Semantics

NetWordS promotes development of interdisciplinary transnational scientific partnerships through short-visit grants, that are assigned yearly on the basis of open calls for short-term project proposals. Scholars taking part in interdisciplinary activities funded through NetWordS grants convene periodically to discuss and disseminate results. Short-visit grants are also geared towards planning focused collaborative work, with a view to catalysing credible large-scale proposals within more application-oriented European projects and initiatives.

NetWordS organises yearly Workshops on interdisciplinary issues in word structure, usually between late November and early December. A major conference is planned to take place in 2015.

NetWordS is pleased to announce the first Summer School on Interdisciplinary Approaches to Exploring the Mental Lexicon - 2nd-6th July 2012 – Dubrovnik (Croatia). The school offers a broad and intensive range of interdisciplinary courses on methodological and topical issues related to the architecture of the mental lexicon, its level of organisation, content and functioning, and a series of key-note lectures on recent advances in this area. The school targets doctoral students and junior researchers from fields as diverse as Cognition, Computer Science, Brain Sciences and Linguistics, with a strong motivation to advance their awareness of theoretical, typological, psycholinguistic, computational and neuro-physiological aspects of word structure and processing.

Link: http://www.networds-esf.eu

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IEEE Winter School on Speech and Audio Processing organized and hosted by FORTH-ICS

by Eleni Orphanoudakis

The Signal Processing Laboratory of the Institute of Computer Science (ICS) of the Foundation for Research and Technology – Hellas (FORTH) organized the international Winter School on Speech and Audio Processing for Immersive Environments and Future Interfaces of the IEEE Signal Processing Society, which took place from 16-20 January at FORTH, in Heraklion Crete, Greece.

The Winter School involved a series of lectures from distinguished researchers from all over the world and was focused on current research trends and applications in the areas of audio and speech signal processing. More specifically, current trends were presented in areas such as automatic speech recognition, speech synthesis, speech and audio modeling and coding, speech capture in noisy environments using one or more microphones, and 3D audio rendering using two or more loudspeakers. The Winter School also involved "hands-on" sessions, where students were able to work on practical aspects of speech and audio signal processing, as well as "demo" sessions where researchers from

FORTH and other institutes demonstrated their implemented systems in these fields.

Many of the technologies that were presented in the school will be implemented and demonstrated in the context of the Ambient Intelligence (AmI) Program of FORTH-ICS. Specifically, sound-related technologies, which are a natural means of human-computer interaction in AmI environments, will be developed and demonstrated in a new laboratory space for 3D sound rendering and recording, to be included in an under-construction building on the FORTH campus which will be dedicated to AmI technologies.

This Winter School was the 4th in the Series of "Seasonal Schools in Signal Processing" (S3P Program) of the IEEE Signal Processing Society. Previous Seasonal Schools were organized in The Netherlands, Austria, and Taiwan. In the Winter School at FORTH, forty students and professionals participated from all around the world, with the opportunity to attend lectures taught by world-renowned researchers and to have a close interaction with them, but also to meet each other to strengthen the audio and speech research community.

More information:
http://www.s3p-saie.eu/

Annual workshop of the ERCIM Working Group on Software Evolution

Research Challenges in Software Complexity

Brussels, 6 September 2012

In 2012, the annual workshop of the ERCIM Working Group on Software Evolution will be co-located with the European Conference on Complex Systems. The one-day workshop will explore the research challenges and recent advances in software complexity, ranging from theoretical insights to practical applications, and focusing on all aspects surrounding software development that potentially impact its complexity. Interdisciplinary research to tackle software complexity problems is particularly welcomed. Mike Hinchey, co-editor of the 2012 Springer book on "Conquering Complexity" will give an invited keynote.

Participation is subject to registration to the ECCS conference. Attendance is open to non-presenters. Presenters will be selected by an international PC on the basis of a paper submission. The workshop's proceedings will be published for free as a volume of the open online CEUR Workshop Proceedings (ISSN 1613-0073).

Call for Papers

Prospective presenters should submit either a position paper (5 pages) or a full research paper (10 pages). Submissions should describe innovative research, research challenges in the field, or speculative ideas with a potential to generate interesting discussions during the workshop. The deadline for submissions is 7 May (tbc).

Topics

Topics of interest include, but are not limited to:

- cross-disciplinary research on complexity-related aspects from other disciplines that may play a role in software development
- advances and insights in factors and mechanisms that affect, deteriorate or reduce software complexity
- techniques and tools to compute, visualise, analyse, measure, estimate, predict, control software complexity
- empirical and statistical studies on software complexity and its evolution over time
- studies on the relation between software complexity and software quality

All kinds of software complexity can be considered, including:

- data complexity
- complexity of software processes, projects, communities, or ecosystems
- algorithmic, computational and logical complexity
- complexity of the software product at various levels of abstraction
- complexity of the social networks involved in creating and using software
- complexity of the environment surrounding the software system

More information:
http://informatique.umons.ac.be/genlog/rcsc2012

Call for Papers

ERCIM/EWICS/DECOS Cyberphysical Systems Workshop at SAFECOMP 2012

Dependable Embedded Systems, Robotics, Systems-of-Systems: Challenges in Design, Development, Validation & Verification and Certification

Magdeburg, Germany, 25 September 2012

Computers are everywhere – may they be visible or integrated into every day equipment, devices, and environment, outside and inside us, mobile or fixed, smart, interconnected and communicating. Comfort, health, services, safety and security of people depend more and more on these "cyber-physical systems". They combine software, sensors and physics, acting independently, co-operative or as "systems-of-systems" composed of interconnected autonomous systems originally independently developed to fulfil dedicated tasks. The impact on society as a whole is tremendous - thus dependability in a holistic manner becomes an important issue, covering safety, reliability, availability, security, maintainability, robustness and resilience, despite emergent behaviours and interdependencies.

Technology is developing very fast. Demanding challenges have to be met by research, engineering and education. Smart (embedded) systems are regarded as the most important business driver for European industry. They are a targeted research area for European Research Programmes in Framework 7, in the ARTEMIS Joint Undertaking, and in several other dedicated Programmes and European Technology Platforms (ARTEMIS, EPoSS). Their application is not only in the traditional areas of aerospace, railways, automotive, or process industry and manufacturing, but also in robotics and services of all kind, in home appliances (smart environments, smart homes, ambient assisted living) and health care.

This workshop at SAFECOMP follows already its own tradition since 2006. Sessions will be held on:

- Dependable and resilient embedded systems
- Autonomous Systems and Robotics
- Systems-of-Systems.

They cover aspects from design, development, verification and validation, certification, maintenance, standardization and education & training. This is a workshop, and to be distinct from the SAFECOMP conference mainstream, it allows reports on "work in progress" aiming at hopefully fruitful discussions and experience exchange. Reports on European or national research projects (as part of the required dissemination) as well as industrial experience reports are welcome.

You want to present your ideas and results? What do you have to provide? For this workshop, workshop pre-conference proceedings by Springer LNCS (in addition to the SAFECOMP proceedings) are planned. Papers (6-8 pages, same format as for the SAFECOMP proceedings) will be reviewed by at least three reviewers. Deadlines are:

- 25 May 2012: Full papers, send to chairpersons
- 15 June 2012: Notification of authors
- 29 June 2012: Final camera-ready papers

The International Programme Committee is composed of selected EWICS and ERCIM members.

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More information:
SafeComp 2012:
http://www-e.uni-magdeburg.de/safecomp/

IFIP Theoretical Computer Science 2012

Amsterdam, The Netherlands, 26-28 September 2012

The conference Theoretical Computer Science, which is held every two years, either in conjunction with or in the framework of the IFIP World Computing Congress (http://www.wcc-2012.org/), is the meeting place of the TC1 community where new results of computation theory are presented and more broadly experts in theoretical computer science meet to share insights and ask questions about the future directions of the field.

TCS 2012 is associated with The Alan Turing Year 2012 (http://www.math-comp.leeds.ac.uk/turing2012/) and will be located at CWI.

More information:
http://tcs.project.cwi.nl

Call for Papers

ERCIM Dependable Embedded Systems Working Group Session at IDIMT 2012

12-14 September, Jindrichuv Hradec, Czech Republic

IDIMT - Interdisciplinary Information and Management Talks, organized by the University of Economics, Prague, and J. Kepler University, Linz, are a truly interdisciplinary and international forum for the exchange of concepts and visions in the area of complex and/or software intensive systems, management and engineering of information and knowledge, systemic thinking, business engineering, and related topics.

This year, Erwin Schoitsch, chair of the ERCIM Dependabe Embedded Systems Working Group organises a session related to the topics of the Working Group entitled "Reliance on Cyber-Physical Systems: 'Systems-of-Systems'-Challenges". ERCIM members are invited to submit a draft paper (about 4 pages) for review by 21 April. The full paper is due (after notification by 19 May 19) by 9 June 2012.

Session: Reliance on Cyber-Physical Systems: "Systems-of-Systems"-Challenges

The ubiquitous deployment of software-intensive embedded (cyber-physical) systems requires to take into account the complex interplay of software, hardware, networks, environment and humans actors in different roles, including unexpected and unpredictable, emergent system behaviour (especially in case of interlinked "systems of systems", composed of (legacy) systems originally designed as autonomous systems).

The design, operation, and protection, but also risk assessment, validation, verification and certification, maintenance and modification through the life cycle of these systems have to take into account unexpected behavior or threats experienced from the real-world environment and the other interconnected systems. The interplay between humans, environment and systems must be considered in a holistic, interdisciplinary view for the distribution of tasks, including mutual overriding mechanisms for automated and human decisions, for performing interventions at system failures, etc. Systems must be robust to cope with these problems in an adaptive manner ("resilient systems), which is an ever increasing challenge for system design, verification, validation and deployment.

The session is chaired by Erwin Schoitsch, AIT Austrian Institute of Technology (chair) and Gerhard Chroust, JKU Linz (co-chair).

Papers covering holistic aspects as well as papers covering partial aspects of cyber-physical systems are encouraged, including academic as well as practical industrial contributions.

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More information about IDMT:
http://www.idimt.org

Computing in the Cloud at EIT ICT Labs

Seif Haridi, SICS, leads the 'Computing in the Cloud' action line at EIT ICT Labs.

Seif Haridi, Chief Scientific Advisor at SICS, leads the 'Computing in the Cloud' action line at the European Institute of Innovation & Technology's ICT Labs. SICS is also one of the main partners in the Europa project, one of four activities within the 'Computing in Cloud' action line.

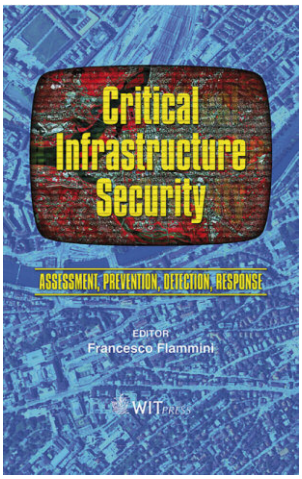
Europa, which started in mid-2011, is developing a new cloud-based data-intensive computing platform. The platform includes a programming model called PACT that extends the MapReduce model to include 2nd order functional programming operations, and highly-available elastic data storage that extends the HDFS platform. The project is led by Volker Markl at Technical University Berlin and includes besides SICS also Inria, University of Paris XI, Technical University-DELFT, AALTO University, and the University of Trento.

More information: http://eit.ictlabs.eu/research/research-action-lines/computing-in-the-cloud/

Book Announcement

Francesco Flammini (Editor)

Critical Infrastructure Security: Assessment, Prevention, Detection, Response



This book provides a comprehensive survey of state-of-the-art techniques for the security of critical infrastructures (CI). It addresses both logical and physical aspects of security from an engineering point of view, and considers both theoretical aspects and practical applications for each topic. Recently developed methodologies and tools for CI analysis are investigated as well as strategies and technologies for CI protection in the following strongly interrelated and multidisciplinary main fields: vulnerability analysis and risk assessment; threat prevention, detection and response; emergency planning and management.

WIT Press, United Kingdom; ISBN: 978-1-84564-562-5, 326 pages, 2012, Hardback

Euro-India SPIRIT Project: Final Recommendations Published

The Euro-India SPIRIT project published its final recommendations booklet "The New Digital Paradigm - Harnessing EU-India ICT Cooperation". The project's aim was, in brief, to examine the state of the art in Indian ICT and develop a set of recommendations for a mutually beneficial research agenda between the EU and India. In order to do so, the project collated the discussions of 18 (nine Indian and nine European) renowned ICT experts specially selected for the project as well as taking input from the wider ICT community in India through events such as eWorld and eIndia. The project also promoted the opportunities available to Indian organisations, from an SME level upwards, through participation in EC-funded ICT projects. ERCIM was the administrative coordinator of this project.

More information:
final recommendations booklet download page:
http://www.euroindia-ict.org/Pages/SelectedDocument.aspx?id_documento=8db63f3c-a86b-4c9a-8f37-e7c2775ca385

Opening of Fraunhofer Project Center in Brazil

The first Fraunhofer Project Center (FPC) in Brazil had its opening ceremony on 9 March 2012 in Salvador, Bahia. The center is located in the Technological Park of Bahia, which hosts companies such as IBM, Portugal Telecom Innovation, and several big Brazilian companies. The new Fraunhofer Project Center will be active in the area of Software and Systems Engineering and will address topics such as innovative solutions for critical and/or large systems, mobile business applications, e-Government, and ambient assisted living. The center is a joint initiative of the Federal University of Bahia (UFBA) and the Fraunhofer-Gesellschaft in Germany. Brazil is the world's eighth-largest economy and one of the fastest-growing major economies. The country has a sophisticated technological sector, developing projects that range from submarines to aircraft, and is also a pioneer in many fields, including ethanol production and deep-water oil research. In terms of software technologies, Brazil was the first country in the world to have fully automated electronic elections. The establishment of the Fraunhofer Project Center at UFBA will bring the Fraunhofer-Gesellschaft into the Brazilian market for software and systems technologies.

ERCIM
European Research Consortium for Informatics and Mathematics

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 member institutions aim to foster collaborative work within the European research community and to increase co-operation with European industry.

ERCIM is the European Host of the World Wide Web Consortium.

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