

PhD Program in Computer Science and Engineering

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Research areas

The PhD in Computer Science and Engineering of the Department of Bioengineering, Robotics, Informatics and System Engineering of the University of Genova covers the following research areas:

- machine learning,
- databases and information systems,
- image processing,
- graphics and geometric modeling,
- artificial intelligence,
- software engineering,
- human-machine interaction,
- programming languages,
- parallel and distributed systems,
- security and safety of critical systems,
- computer vision.

A list of specific research themes are given in Appendix A.

They are also available at the URL: <http://www.dibris.unige.it/dottorati>.

Research projects that do not refer to the above mentioned themes are still evaluated as long as they fall within the above mentioned research areas.

The PhD program requires a solid background in Computer Science, Engineering and Mathematics. International applicants are strongly encouraged.

Instructions for Applicants

Detailed instructions for applicants are available at the URL:
<http://www.disi.unige.it/dottorato>

Applications must include between one and three names of supporting researchers from Academia, Research Institutes or Industry.
It is the responsibility of the referees to send recommendation letters to the Coordinator of the PhD program at: [phd.compsci @ dibris.unige.it](mailto:phd.compsci@dibris.unige.it).

Name, title and affiliation of the referees must be indicated in the application.

A template of recommendation letters is available at the URL:
<http://www.disi.unige.it/dottorato>

Appendix A

Research themes

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1. Regularization Methods for Learning Effective Data Representation

Tutor

Alessandro Verri



Description

Regularization methods provide a theoretically sound framework for addressing learning problems. In the case of classification and regression smoothness plays the role of the regularization principle leading to effective algorithms starting from a given representation. As for feature selection sparsity is the key to find parsimonious representations starting from a fixed dictionary of (possibly infinite) features. The project aims at investigating regularization methods able to develop adaptive dictionary of features starting from large amounts of data in a loosely supervised setting. The methods to be developed will incorporate domain knowledge derived from the specific application scenario and benefit from optimization schemes capable of dealing with nonstandard penalties and huge datasets.

Within the proposed project several directions of research can be explored ranging from contributions in learning theory and algorithms to application-driven contribution in computer vision and computational biology.

The ideal candidate would have a background in computer science and engineering, and mathematics.

International applications are encouraged.

Reference

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2. Intelligent systems for sustainable development

Tutor

Armando Tacchella



Description

Sustainable development, hereby intended as a model of human development in which resource use aims to meet human needs while ensuring the sustainability of natural systems, is an important topic in the upcoming EU research agenda. Indeed, it is expected that “... *at least 60% of the total Horizon 2020 budget will be related to sustainable development ...*” [see http://ec.europa.eu/research/horizon2020/index_en.cfm?pg=h2020-documents]. A key enabler towards reconciling environmental needs with those of European societies is represented by intelligent systems, hereby intended as computer-based system which can display human-like capabilities in terms of learning, reasoning and adapting to unforeseen circumstances. The goal is thus to explore engineering applications of intelligent systems to monitoring, verification and diagnosis of complex implements that aim to reduce our ecological footprint including, but not limited to, distributed power generation and distribution networks, energy-efficient transportation vehicles and fleets, smart homes. It is expected that research will leverage the current state-of-the-art in the AI field in order to improve the dependability (reliability, availability, maintainability and safety) of energy-savvy systems and enable their large scale deployment. Current results (see reference) are the automated generation of ISO 13374-compliant monitoring and diagnostic systems, starting from high-level domain and processing descriptions.

Reference

Giuseppe Cicala, Marco De Luca, Marco Oreggia, Armando Tacchella.

Generation of Diagnostic Support Systems from Domain Ontologies and State Machines.

First Workshop on ICT for Sustainable Places. Nice, September 9-11, 2013.

<http://www.resilient-project.eu/documents/35984/36802/ICT+for+sustainable+places.pdf>

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3. Wearable Queries - Adapting Common Retrieval Needs to Data

Tutor Barbara Catania



Description

The wealth of information generated by users interacting with the network and its applications is often under-utilized due to complications in accessing heterogeneous and dynamic data and retrieving relevant information from sources having possibly unknown formats and structures. Processing complex requests on such information sources can, thus, be costly, though not guaranteeing user satisfaction. Furthermore, dynamic contexts prevent substantial user involvement in the interpretation of the request.

The aim of this research theme is to investigate an innovative solution to process the above mentioned requests, limiting user involvement by exploiting information on: (a) user context (geo-location, interests, needs); (b) data and processing quality; (c) similar requests repeated over time. While (a) and (b) are aspects which are well known in the literature but not yet explored in the considered setting, (c) is an innovative aspect, relevant in situations implying the sharing of complex information needs.

The notion of Wearable Query (WQ), i.e., a query that captures the user and request specificities, will be the basis for capturing requests. Methodological and technological solutions for WQs, in the presence of repeated information needs in distributed and heterogeneous environments will be investigated.

Reference

B. Catania, G. Guerrini, A. Belussi, F. Mandreoli, R. Martoglia, W. Penzo
Wearable Queries: Adapting Common Retrieval Needs to Data
In DBRank 2013

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4. Static type analysis of dynamic object-oriented languages

Tutor

Davide Ancona



Description

Retrofitting type systems in dynamically typed languages is becoming a prevalent line of research in the area of object-oriented (oo) programming, because languages like JavaScript and Python are widely used in many application domains. For these languages static type analysis can be effective for program verification and software refactoring. Abstract compilation aims to reconcile types and symbolic execution for software testing, and is particularly suited for the analysis of dynamic oo languages. It offers several benefits in comparison with more traditional approaches to static type analysis: source code can be analyzed without insertion of type annotations; it can be implemented in a modular way, to support different kinds of type analysis; it allows direct exploitation of the state-of-the-art compiler technology for static analysis. We will improve abstract compilation by focusing on subtyping, type narrowing, and other technical aspects whose study may improve the precision of the analysis. Subtyping allows termination of the analysis by type widening. We will study practical sound and complete algorithms for subtyping in the presence of union and record types interpreted coinductively, to allow a precise representation of cyclic structures. Intermediate representations like SSA and SSI allow type narrowing for stack variables; we will devise more advanced forms of abstract compilation to extend type narrowing to heap variables.

Reference

D. Ancona and G. Lagorio.

Idealized coinductive type systems for imperative object-oriented programs.

RAIRO - Theoretical Informatics and Applications, 45(1):3-33, 2011.

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5 Flexible composition of software fragments

Tutor

Elena Zucca



Description

We plan to investigate mechanisms for safe composition, manipulation, and exchange of fragments of open code which can be dynamically rebound. The motivation is the development of distributed, highly dynamic applications, where the meaning of identifiers can only be determined at runtime, or additional primitives allow explicit modification of environments, as, e.g., in dynamic updating of resources and exchange of mobile code. Moreover, our code manipulation operators should support meta-programming capabilities, and we plan to develop incremental typechecking techniques for guaranteeing safety, allowing a good compromise between expressive power and a purely static approach.

Reference

Davide Ancona, Paola Giannini, Elena Zucca.

Reconciling positional and nominal binding.

Intersection Types and Related Systems . To appear in EPTCS 2013.

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6. Dynamic Verification of Interaction Protocols in Multiagent Systems with Global Types

Tutor

Viviana Mascardi



Description

Multiagent systems (MASs) are an industrial-strength technology for integrating and coordinating autonomous and heterogeneous systems. Since MASs are open, dynamic and unpredictable, ensuring conformance of the agents' actual behavior to a given interaction protocol is of paramount importance to guarantee the participants' interoperability and security. Global types are a behavioral type and process algebra approach to the problem of specifying and verifying multiparty interactions between distributed components.

Global types are a promising approach to effective run-time verification of the conformance of a MAS implementation to a specified protocol; there are several lines of research that may be explored.

- Global types can be made more expressive to support parametric specifications.
- Global types can be extended with quantitative features, to allow specification and analysis of non-functional properties, such as response time, of MASs.
- Global types can be exploited for the specification and implementation of fault tolerance and error recovery, which are essential in distributed systems.
- Study of the complexity analysis and optimization techniques validated with a systematic empirical evaluation, to stress-testing the scalability of the verification process.

Reference

V. Mascardi and D. Ancona.

Attribute Global Types for Dynamic Checking of Protocols in Logic-based Multiagent Systems (technical communications).

Theory and Practice of Logic Programming Journal, On-line Supplement, 2013.

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7. Continuous scale-space methods for 3D geometric data

Tutor

Enrico Puppo



Description

Scale-space methods have a long-standing successful story in the analysis of digital images and 2D signals in general, while their application to higher-dimensional data has been little explored. Generally speaking, scale-space methods permit to extract relevant features from data at different scales, track such features through the scales and measure their relative importance. This provides basic support to multi-scale data analysis for a variety of applications.

The objective of the PhD program is to investigate several extensions of scale-space techniques, targeting primarily 3D data such as surfaces of geometric objects in space and hyper-surfaces described by volume data. The candidates will have the opportunity to develop inter-related activities such as: study and development of a virtually continuous scale-space model; study and development of a scale-space based on topological persistence, and its integration with more traditional diffusive scale-spaces; applications to face recognition from 3D scan data; applications to digital terrain analysis; applications in geometry processing of surfaces; applications to volume data analysis. Interaction with other national and international research teams collaborating on such themes will also be possible. Applicants are expected to have strong background and experience in at least one of the following topics: computer graphics, geometry processing, computational geometry, computational topology, numerical analysis. The candidates must have excellent programming skills and be motivated to work in a research team and in a collaborative project.

Reference

Rocca, L., Puppo, E.

A Virtually Continuous Representation of the Deep Structure of Scale-Space, Proc. Int. Conf. on Image Analysis and Processing, to appear 2013

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8. Computational methods for the design of 3D electronic sensors

Tutor

Giorgio Cannata



Description

Sensorized objects have a growing relevance in various application domains (e.g. robotics, rehabilitation, sport training, consumer electronics, domestic appliances, etc.). The development of these systems relies on the concurrent design of distributed and networked sensing and computational elements to be fitted over a 3D (and possibly complex) geometry. The objective of the PhD program is to investigate and develop computational methods for the 3D layout of distributed and networked sensor systems to be integrated on 3D objects. The problem is related to the optimal placement of distributed sensors over 3D surfaces constrained to technological and (sensor) data processing constraints specific to different application domains. The candidates will be involved in the activities of different research teams focusing on one hand on computational geometry methodologies and on the other hand on the design of large area tactile sensors.

Applicants are expected to have strong background and experience in at least one of the following topics: applied mathematics, computational geometry. The candidates must have excellent programming skills and be capable to interact with teams with engineering background, and finally be motivated to work in a research team and in a collaborative project.

Reference

Anghinolfi, D.; Cannata G.; Mastrogiovanni, F.; Nattero, C.; Paolucci, M.
On the Problem of the Automated Design of Large-Scale Robot Skin,
IEEE Transactions on Automation Science and Engineering, 99 (1--14)

Requirements

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9. Web Application Testing

Tutor

Filippo Ricca



Description

The economic relevance of Web applications increases the importance of controlling and improving their quality. Moreover, the new available technologies for their development (e.g., Ajax, Flash) allow the insertion of sophisticated functions, but often leave the developers responsible for their organization and evolution. As a consequence, a high demand is emerging for Web testing techniques and tools. Over the last 10 years, researchers have proposed several techniques and tools dealing with the unique characteristics of web based systems. However, nowadays, there are still several open issues in Web application testing. Among the most challenging issues, we have:

Augmenting Test Case Automation. To reduce significantly the manual effort needed to test each release of an application

Reducing Test Case Fragility. To obtain robust test cases that can be executed easily on different subsequent releases of an application (e.g., for regression testing)

Testing Multi-browser and Multi-platform Compatibility. To assess that a web application appears and behaves correctly employing different browsers (e.g., Firefox or IE), platforms (e.g., Windows or Android) or devices (PC or Smart-phone)

Generating Test Case Input. To automatically generate inputs with the aim of maximizing the exploration of the various parts of the Web application

The goal of this research theme is facing one or more of these (often interrelated) problems from a practical point of view, applying various testing techniques/tools to complex real web applications and evaluating their effectiveness by means of empirical investigations. The opportunity to work on a real case study will help us to better validate the techniques and tools that will be used and proposed.

Reference

Filippo Ricca, Paolo Tonella. Analysis and testing of Web applications.
Proc. of the 23rd International Conference on Software Engineering.
Toronto, Ontario, Canada, Pag 25-34, 2001, IEEE Computer Society

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10. Model driven development methods

Tutor

Gianna Reggio



Description

The key idea of the Model Driven (MD) approach to software development is that a software system should be built by transforming models (of the system itself) starting from model at a high-level of abstraction till to reach a detailed model that can be automatically transformed into code, instead of the classical approach that requires to directly produce the code.

The technological advances in the field of software based system development, e.g., Cloud, Internet of services, Internet of things, pose new challenges to the adoption of development following the MD. For example, now a running system has to adapt either to a changing context or to changing requirements without stopping the execution, or even the resources available for its execution may change, that requires that the models should be also available at run-time and that a running system may use them to adapt itself. The classical persistent data organization (relational database) and the related well-established modeling techniques are not any more viable in the Cloud.

The topic of the thesis is to design new MD development methods for software systems built using the current technologies (as the Cloud), starting from the results of two ph.d. thesis which are now reaching the conclusion (one about MD methods for developing service based systems, and the other proposing software engineering methods to build model transformations).

Reference

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11. Improving tracking and logistic operations in floriculture environment as an Internet of Things App

Tutor

Gianni Vercelli



Description

Floriculture industry is nowadays a big market with great growing potentials in the next future. Actually, there are several problems that have not been solved such as the lack of a unifying technological framework to improve tracking and logistic operations in vases management from production to plants' sale. Every year a huge number of vases are lost or not given back to the producers due to a very limited and not sufficient use of basic ICT technology such as bar codes. The research in objective has as result the dramatic change in the management of the vases themselves. We will improve the logistic system by introducing RFID tags and transducers to keep track of the movements inside a warehouse but also having an historical database of the life of each vase. Inspired by the "Internet of Things" paradigm, a series of algorithms and software components will be implemented to increase the level of reliability of actual RFID networks. Therefore, the target industry will be able through a web-based framework to know with high precision where and to whom each vase has been sold or rent. The research will involve different players such as floriculture organizations, floriculture industries and companies focused in sensors manufacturing.

Reference

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12. Concurrent and distributed systems

Tutor

Giorgio Delzanno



Description

Modern software applications (e.g. software for mobile devices) highly depend on concurrent and distributed components implemented at different level of abstractions (from threaded programs to communication libraries). Despite of the advances of hardware and software technology, developing reliable concurrent programs is still considered as a very difficult task. Bugs in concurrent programs are indeed very difficult to detect and reproduce.

Multicore architectures make the problem of debugging concurrent programs even more difficult. There are well known examples of concurrent programs that are not secure under relaxed memory models as those adopted in multicore computers.

Validation techniques like model checking, run time verification and testing are getting more and more important in this context in order to increase the quality of critical software.

The proposed program is focused on improving the state of the art validation methods for concurrent and distributed systems with particular attention on multithreaded programs that use concurrent data structures -- under strong and weak memory models -- and distributed algorithms.

A possible starting point for the proposed research program is the verification methodology based on the combination of graph-based and automata-based techniques proposed in [1,2]. The research will be conducted in collaboration with researchers working at Uppsala University, Linkoping University, and Liafa@Paris 7.

References

[1] G.Delzanno and R.Traverso.

Specification and Validation of Link Reversal Routing via Graph Transformations.

In Proc. SPIN 2013.

[2] G.Delzanno and R.Traverso.

Decidability and Complexity Results for Verification of Asynchronous Broadcast Networks.

In Proc. LATA 2013.

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13. MOOC - Massive Online Open Courseware: hardware and software architecture and framework

Tutor

Giovanni Adorni



Description

The aim of this research project is the study of novel methodologies and technologies to improve online education according to a model of open and shared knowledge in a framework of collaboration among institutions for higher education courses. The proposed activity will be carried on in collaboration with other Italian Universities, specifically “Trento”, “Modena e Reggio Emilia” and “Politecnico di Milano”, which have common interests and are working on the same research theme. Such universities are investigating the educational and sociological aspects and implications, not technological ones, herein proposed. In more details, the research will investigate the model of Massive Online Open Courseware (MOOC), which is supposed to be the most important innovation in the field of distance education in the next years. In this scenario, the aim of this project is to experiment and to analyze the state of art of such systems and related technologies, which will lead to the design of an experimental framework (both hardware and software) to enable the development new solutions and to evaluate educational methodologies. The final objective should be demonstrating that openness of higher education institutional models is a feasible solution, suitable for the Italian situation too. The scientific relevance of this project lies not only in the study and analysis of the described topic, but also in the implementation of a pilot system to be shared between the involved universities. Research challenges are not only in the development on an effective storage and delivery system for multimedia content to multiple users, yet semantic web technologies will be adopted for indexing and retrieval as well the possible integration with the Internet of things in social networking environments will be considered. The final result will be the development of a networked environment for the Massive Online Open Courseware, which will characterize and represent the Italian state of play and practice in the topic.

Reference

Adorni, G., Coccoli, M., Torre, I. (2012).

Semantic Web and Internet of Things supporting enhanced learning.

JOURNAL OF E-LEARNING AND KNOWLEDGE SOCIETY, vol. 8, p. 23-32

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1 14. Description-based segmentation of shapes in 3D and higher dimensions

Tutor

Leila De Floriani



Description

Digital representations of shapes are a mainstay of graphics and visualization, resulting as a product of both user modeling and acquisition processes such as range and volumetric scanning. The most common structural shape representation is a partition of the shape into parts referred to as shape segmentation. At the fundamental level, a shape is composed of atomic geometric elements. In order to progress from this basic level to the computational understanding of shape on which automated tasks are based, these atomic elements must be grouped, structured and labeled in cognitively meaningful ways. Segmentation research has long been focused on 2D and 3D images and, more recently, on 3D shapes discretized as triangle meshes. Beyond 3D meshes, many applications rely on volumetric and other higher-dimensional representations, including a temporal component.

The objective of this research is two-fold. On one hand, the project requires investigating and developing segmentation algorithms for 4D shapes (i.e., 3D shapes varying over time), such as those generated by animation sequences, or isosurfaces of time-varying scalar fields, by using tools rooted in computational topology. On the other hand, it will be necessary to investigate tools for facilitating user communication of semantic information and the optimization of segmentations that conform such information. The PhD work is part of an international collaboration involving research groups at Catholic University, at the University of Maryland and at Lawrence Livermore Research Labs. (USA).

Reference

Requirements

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15. Multi-scale biological knowledge formalization: definition, properties, and applications

Tutors

Michela Spagnuolo



Funding: EU (Marie Curie program)

Description: The research programme focuses on semantic 3D media, coupling knowledge technologies and computer graphics, for the development of services for searching, retrieving and visualizing data and information to support computer-aided diagnosis.

Human body representations have been used for centuries to help understanding the shape and function of its compounding parts. The large amount of data (eg, MRI, PET) made available by existing technologies, makes it possible to think of digital patient representations, as a complex system which includes not only anatomy but also the mechanics of human motion, the pathological and healing processes, growing and ageing.

In this context, the PhD programme will be conducted within the scope of the MultiScaleHuman Marie Curie project, an Initial Training Network funded under the FP7 PEOPLE programme (see <http://multiscalehuman.miralab.ch>), at the Institute of Applied Mathematics and Information Technologies of the National Research Council, Genova (IMATI-CNR).

Development of original solutions for the integration of existing ontologies into a unified framework supporting multi-scale descriptions of entities and concepts, modularization and integration of medical ontologies will be studied. Semantic annotation techniques applied to 3D models of anatomy will be studied as a support next generation Computer-Aided Diagnosis systems and services including advanced searching and inference.

Reference

Requirements

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16. Relational learning methods and their applications

Tutor

Stefano Rovetta



Description

Learning machines are currently applied in a variety of problems and settings, including big-size problems (high cardinality and/or dimensionality), concepts that drift in time, and data for which computing an explicit similarity measure is not possible or practical. Data clustering has been used in machine learning for a long time, and was notably used to model concept formation, a phenomenon that is at the core of the mechanisms used by living beings to understand their environment. During the last decade the development of powerful, novel methods for data clustering and related tasks has opened new perspectives. This research aims at studying and improving state-of-the-art data clustering methods to cope with the issues summarized above: approximated methods to deal with high-cardinality data, effective data representations to tackle high-dimensional problems; online methods for time-varying concept learning; secondary similarity measures to be used when primary measures are not given, or given only by examples, or bring about computational issues (e.g., curse of dimensionality, irrelevant features). The research will:

- propose and implement new methods according to the stated goals;
- apply these methods in interesting applicative scenarios, such as high-level concept learning, robotics, natural language processing, bioinformatics;
- explore their connection with current developments of neural networks, for instance in deep learning and mixed symbolic-subsymbolic learning.

Reference

Filippone, M., Camastra, F., Masulli, F., Rovetta, S.
A survey of kernel and spectral methods for clustering.
Pattern recognition, 41(1), 176-190, 2008.

Requirements

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