Freie Universität Bozen
Libera Università di Bolzano
Università Liedia de Bulsan

Topic Descriptions – PhD in Computer Science

Research Topic A1: Computer Vision and Multimodal Learning

Supervisor: Prof. Oswald Lanz

Topic Description: We invite applications for a PhD position in Computer Vision and Multimodal Learning. Please visit the website of the Visual Computing Lab (VCL), vision.projects.unibz.it for information about the research group - you will join a dynamic team and vibrant environment. Topics are not sharply defined but might connect to relevant background and existing research of the group in

- Egocentric Perception (action recognition/anticipation/mistake detection, 3D reconstruction and scene graphs),
- Multimodal GenAI (retrieval-augmented generation, video search and retrieval),
- AutoML for Video Understanding (neural architecture search).

Furthermore, we also welcome expressions of interest in

- Foundational research on Neuro-Symbolic Integration in the context of multimodal procedural activity recognition and human-robot collaboration. Can be offered in co-supervision with other faculty, experts in process mining.

VCL is strongly connected to Covision Lab https://covisionlab.com/en and its spinoff company Covision Media https://covisionmedia.ai where specific topics of interest can be offered.

Required mandatory skills: PhD topics reside at the intersection of computer vision, computer graphics and machine learning. The candidate has undertaken computer vision and deep learning courses with proficiency. Ideally the MSc thesis is in the field of deep learning and computer vision. Solid programming skills and experience with deep learning frameworks such as pytorch are required.

Desirable (optional) skills: MSc thesis as valuable background experience to start PhD research. Ideally the MSc thesis has led or will lead to publication.

Research Topic A2: Innovative solutions for Computing Education

Supervisor: Prof. Ilenia Fronza

Topic Description: We invite applications for a PhD position focused on Computing Education. The activity aims to propose and develop customized, interactive, and immersive solutions that support computing education at all levels, from early education to professional contexts. For instance, these solutions may combine XR/VR technologies and serious games to enhance learning and teaching experiences, such as coding camps, possibly in online or hybrid settings. The ideal candidate should be prepared to empirically evaluate these solutions by directly engaging with diverse audiences, including school students and teachers of varying ages and backgrounds. Strong communication skills are essential, and the candidate should be interested in participating in communication and dissemination activities and events. The PhD candidate will conduct research with a dynamic and multidisciplinary team at the Hands-On LAboratory (HOLA), a cutting-edge space for Computing Education Research.

Required mandatory skills:

- Proven ability to create research prototypes
- Solid understanding of qualitative and quantitative research methods (e.g., experiments, interviews, surveys), with a focus on evaluating research prototypes
- Good communication skills
- Strong aptitude for collaborative teamwork

Desirable (optional) skills:

- Expertise in design thinking to drive creative solutions
- Experience in projects focused on the development of solutions for teaching/learning
- Expertise in applying qualitative and quantitative research methodologies to evaluate research prototypes
- Experience in organizing or facilitating software/IT events, including coding camps, workshops, and hackathons

Research Topic A3: Artificial Intelligence for Process Mining

Supervisor: Prof. Chiara Ghidini

Topic Description: We invite applications for a PhD position focused on Artificial Intelligence for Process Mining. We are looking for PhD students interested in exploring synergies between AI techniques (both logic-based and machine learning based) and a wide range of Process Mining tasks such as discovery, compliance checking, verification, prediction and recommendation. We are looking for students interested in topics such as:

- Machine Learning and Predictive methods applied to Predictive Process Monitoring
- Neuro-symbolic AI frameworks for temporal data and Process Mining data and knowledge
- Explainable AI techniques for Predictive Process Monitoring.

Required mandatory skills: PhD topics reside at the intersection of machine learning, knowledge representation and reasoning, and Process Mining. The candidate has undertaken machine learning courses with proficiency and has knowledge (or is willing to learn) about temporal logics. Ideally, the MSc thesis is in the field of Process Mining, Machine Learning, Explainable AI, neurosymbolic integration, or knowledge-informed machine learning. Computer programming skills. Analysis and problem solving. Critical thinking. Collaboration.

Desirable (optional) skills: Programming skills in Python.

Research Topic A4: Higher-order complex networks and dynamical systems on top of them

Supervisor: Prof. Maria Letizia Bertotti

Topic Description: The study of numerous systems composed of many interacting entities cannot disregard the network of links existing between individual entities. Whereas the study of complex networks, graphs composed of numerous nodes and arcs describing binary relationships, has been in recent decades the subject of a myriad of works, only recently has the need for a further paradigm shift been realized, aimed at dealing with networks in which higher-order relationships are considered alongside binary ones. A very interesting research perspective opens up here with obvious possible spin-offs in various fields. Aspects that require attention range from the need for an innovative formalization for the representation of networks to the analysis of statistical quantities that different network topologies may have, to the study of dynamical systems that may relate to the social sciences (spread of epidemics, formation of opinions, ...), ecology (networks with interacting species, ...), economics (networks of economic or financial transitions, ...), and engineering (electrical networks, ...). A fundamental question common to all these contexts concerns understanding how the presence of higher-order interactions affects the dynamics and contributes to the macroscopic emergence of a given outcome. In summary, possible research topics include the creation of codes for the generation of synthetic higher-order complex networks, the development of new mathematical schemes and methods for the study of specific systems on top of these networks, analytical and computational investigation of the dynamics.

Required mandatory skills: Calculus and linear algebra, Basic knowledge of ordinary differential equations and of complex networks. Experience with software like Mathematica, Python or similar, Computer programming skills, Critical thinking, Collaboration skills.

Desirable (optional) skills: Basic knowledge of stochastic differential equations. Some knowledge of statistical mechanics and agent-based models.

Research Topic A5: Enhancing Agile Software Development Practices with AI technologies

Supervisor: Prof. Xiaofeng Wang

Topic Description: This research project aims to investigate the integration of Artificial Intelligence (AI) into Agile software development processes to improve productivity, decision-making, teamwork and software quality. Agile methods have become the cornerstone of modern software engineering, emphasizing adaptability, iterative development, and close collaboration. However, they also present challenges such as uncertainty in task estimation, inconsistent documentation, and decision bottlenecks during sprint cycles.

This project will explore how AI, especially the recent GenAI technologies, can be leveraged to support Agile teams. Potential applications include automated analysis of user stories and sprint retrospectives, intelligent backlog prioritization, effort estimation from historical data, and teamwork enhanced with intelligent tools and techniques.

The research will combine qualitative and quantitative methodologies to develop, test, and evaluate AI-based tools in real or simulated Agile team settings. The outcome aims to contribute both theoretically and practically to the field of agile software development, offering insights into human-AI collaboration and tool-supported development.

Required mandatory skills:

- Solid knowledge of Agile software development methods and practices
- Strong programming skills in Python, Java, or a similar language
- Knowledge of large language models (LLMs) and prompt engineering
- Experience in software development project workflows
- Analytical and critical thinking skills

Desirable (optional) skills:

- Experience with natural language processing (NLP)
- Previous participation in Agile software projects (e.g., via internships or academic team projects)
- Familiarity with software engineering research methods

Research Topic A6: Knowledge-based Artificial Intelligence for Data Science

Supervisor: Prof. Enrico Franconi

Topic Description: Prof. Franconi from the KRDB research center for Knowledge-based Artificial Intelligence offers a PhD position in Knowledge-based AI for Data Science: the website krdb.eu/datascience has more information about the research focus. There are currently 10 professors, 10 postdocs, and 11 PhD students at KRDB, so you will join a dynamic team and vibrant environment; additional co-supervisors could be prof. D. Calvanese, prof. A. Artale. Knowledge-based AI for Data Science enables more advanced and interpretable data analytics and machine learning: by integrating knowledge and semantic layers into data analysis pipelines, data scientists can develop more robust models and interpret predictions more effectively. This ensures data quality, accessibility, integrity, meaning, and interoperability. The focus of a PhD research activity can be on any of the following topics (interested candidates are free to revise/adjust/extend the research, and to propose their own topic in the area):

- **Knowledge-based data management** enhances data quality, scalability, and interoperability in complex data-intensive environments, by embedding domain knowledge directly into data operations.
- **Ontologies and knowledge graphs** integrated with data sources support more expressive, semantic-rich querying, and semantic interoperability, with applications to unify and abstract over heterogeneous data, enabling users to interact with data in a more intuitive and meaningful way.
- **Data and knowledge modelling** involves creating high-level, abstract representations of domains to facilitate system design, analysis, and communication among stakeholders, by enabling richer and more precise representations of domain semantics, including temporal aspects.

Required mandatory skills: the PhD topic resides at the intersection of database research, semantic technologies, and knowledge representation. Critical thinking and curiosity are essential, together with a good ability to deal with rigorous and formal approaches. The PhD research could have a more theoretical or more applicative flavor, depending on the interests of the candidate. Contact prof. Enrico Franconi at franconi@inf.unibz.it before applying for the PhD scholarship.

Desirable (optional) skills: MSc thesis or working skills in the area as valuable background experience to start PhD research. Ideally the candidate has or is going to have some publication.

Research Topic A7: AI-based Design and Management of Knowledge Graphs

Supervisor: Prof. Diego Calvanese, Dr. Davide Lanti

Topic Description: Knowledge Graphs (KGs), which are rooted in Knowledge Representation in Artificial Intelligence (AI), have become a popular data representation format for data management, offering a schema-flexible, graph-based abstraction that enables contextualized, dynamic integration of heterogeneous data sources. Unlike relational and NoSQL models, KGs naturally capture relationships, support navigational queries, and incorporate ontologies and logical

rules for semantic reasoning. These features empower automated inference, improved interpretability, and seamless access to heterogeneous data. Thus, KGs play a key role in data preparation in AI.

We invite applications for a PhD position focused on AI-based technologies for the design and management of KGs. The following are some examples of specific PhD research topics that could be pursued, but interested candidates are free to revise/adjust/extend the research, and also to propose their own topics concerning KGs:

- Design and development of methods to semi-automatically construct KGs starting from relational data sources. The plan is to exploit a combination of different AI-based technologies and tools, including design patterns for mapping data to KGs, data profiling to improve the quality of the generated KGs, and Large Language Models to exploit various forms of textual information available in the data sources and in the target ontology.
Required mandatory skills: basic knowledge of Logic, Programming skills (preferably in Java)
Desiderable (optional) skills: logic-based formalisms for knowledge representation (e.g., Description Logics, OWL, RDF, SHACL), Data Profiling, Machine Learning, LLMs

- Extension of current KG mapping languages, which are restricted to relational data sources, to arbitrary heterogeneous data sources. The research will build on RML, an advanced language for constructing KGs from data in multiple formats, and will explore how to exploit its additional expressivity in the context of Virtual Knowledge Graphs (VKGs), where data is kept in the sources and only a virtual view over them is exposed to users. The study will be both foundational, as novel query-reformulation techniques will be required to handle advanced RML features, and applicative, as we aim at extending the state-of-the-art VKG System Ontop with support for RML.
Required mandatory skills: knowledge of Logic and of Semantic Web standards (RDF, OWL), Programming skills (preferably in Java)
Desiderable (optional) skills: logic-based formalisms for knowledge representation (e.g., Description Logics), Virtual Knowledge Graphs, Property Graphs

- Extension of the VKG paradigm to the setting of Property Graphs enriched with temporal semantics. The research will build upon existing formal frameworks for query rewriting over Property Graphs, with the objective of addressing the problem of query answering over temporally annotated ontologies. The investigation will have a dual focus: (i) foundational, involving the identification of expressive yet computationally tractable fragments of temporal description logics, query languages, and ontology languages; and (ii) experimental, to design and implement a proof-of-concept system to empirically evaluate the feasibility and performance of the proposed methods in realistic use cases.
Required mandatory skills: knowledge of logics for knowledge representation (e.g., Description Logics)
Desiderable (optional) skills: Programming skills, Temporal Logics, Property Graphs

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Research Topic A8: Efficient and accurate algorithms for time series analysis

Supervisor: Prof. Johann Gamper

Topic Description: Time series data are being generated at an unprecedented rate and in vast quantities across nearly all application domains—such as scientific experiments, Industry 4.0, the Internet of Things (IoT), traffic monitoring, healthcare, and precision agriculture, to name a few. This rapid growth necessitates advanced solutions for the storage, processing, and analysis of such data to fully leverage its potential for informed decision-making.

Processing time series data involves many challenges, including the cleaning of raw data to make it suitable for downstream analysis algorithms, addressing data quality issues, and performing fundamental operations such as missing value imputation, anomaly detection, and similarity search. It also includes more advanced tasks like clustering, motif discovery, and prediction. For all these applications, it is essential to develop solutions that are scalable, efficient, and accurate in order to handle the enormous volume of available data.

In this PhD project, we will focus on one of the aforementioned aspects and develop efficient solutions that push the boundaries of the current state of the art. The project will be supported by real-world case studies from industry and other domains. The candidate will design and implement novel solutions and evaluate them experimentally using both synthetic and real-world datasets.

Required mandatory skills:

- motivation for scientific work
- basic knowledge in databases
- interest in algorithmic thinking and problem solving
- good programming skills

- proficiency in English

Research Topic B1: Predicting the evolution of scientific knowledge: exploiting knowledge graphs and ontology embeddings

Supervisor: Prof. Oliver Kutz, Prof. Diego Calvanese; in cooperation with Sony CSL, Barcelona (50% co-funded by Sony CSL)

Topic Description: In partnership with Sony CSL, we invite applications for a PhD position in graph-based machine learning and semantic modeling. The PhD project is set up in collaboration with Sony's "AI for Scientific Discovery" team and will address AI/ML topics relating to the literature-based prediction of novel scientific insights, spanning from theoretical questions related to the use of knowledge graphs and ontology embeddings in ML models to the application of the resulting methods in high-impact real-world applications from the life sciences.

Topics can connect to one or several of the following themes:

- Extracting and representing multi-modal information (concepts and their relationships, experimental quantitative data, figures/graphs...) from scientific publications
- Modeling scientific knowledge and its evolution over time in expressive knowledge graphs
- Integrating semantic information (e.g., through ontologies) in ML models
- Developing high-accuracy link prediction and edge classification models over temporal sequences of expressive knowledge graphs

Required mandatory skills: PhD topics reside at the intersection of machine learning, knowledge representation and reasoning, and semantic technologies. The candidate has undertaken machine learning and knowledge representation courses with proficiency. Ideally, the MSc thesis is in the field of graph neural networks, neurosymbolic integration, or knowledge-informed machine learning. Solid programming skills in Python and experience with PyTorch are required.

Desirable (optional) skills: Previous experience with knowledge graphs and ontologies is a strong plus. Familiarity with the field of biomedical science as prospective application domain is a strong plus. Previous experience with software engineering is a plus. Ideally, the MSc thesis has led or will lead to publication.
