LIST OF RESEARCH PROJECTS – CALL 38th CYCLE
PHD PROGRAM IN COMPUTER SCIENCE

F4-Multi model and multi sensor data fusion for integration of spatial temporal information in the context of earth observation and climate data analysis (prof. Liotta)

F5- How to bring the Metaverse into the vehicles for a novel video conferencing experience (prof. Haller and prof. De Angeli)

F6- Entertainment in the car by using a cognitive seat with tactile feedback (prof. Haller e prof. De Angeli)

F7- I_C&C: Interfacing Creativity and Computation (prof. De Angeli e prof. Montali)

F8- Predictive maintenance for industrial equipment (prof. Gamper)

A1 - The Mathematics of Large Scale Scientific Computation

Advisor: **prof. Bruno Carpentieri.**
Co-advisor: **to be defined**

Project Description:
The scientific investigation of physical processes through modelling and simulation on computers may be considered the third pillar of science, complementing theory and experimenting. Recent advances in computer technology and the introduction of innovative algorithms with reduced computational and memory requirements are opening up unprecedented opportunities for research in computational science and engineering, making a rigorous numerical solution affordable for many practical applications. However, modern massively parallel computers put us at a fundamental turning point in algorithmic and software development. To benefit from the continued performance growth, our application needs to exploit a high degree of concurrency, running efficiently on hundreds or thousands of simultaneous processes. As we will be solving much bigger problems, novel classes of highly parallel numerical methods need to be found. Only algorithms with linear or almost linear complexity can be of interest, as their computational cost for the solution increases linearly with respect to the number of unknowns, which is expected to grow very large in the future.
Aim of this doctoral project is to develop innovative computational tools and software for fast numerical solution of multiphysics and multiscale models in areas like fast fusion research simulation, high-frequency electromagnetic scattering, computational fluid dynamics, and new applied machine/deep learning solutions. Our goal is to develop numerical tools that can enable very fast simulation with the potential to be used by industry, filling a gap in current software to solve such problems.

Required skills:
Knowledge of numerical linear algebra methods. Computer skills. Knowledge of at least one high-level programming language. Analysis and problem solving. Critical thinking. Collaboration.

A2 - Smart Knitted SpaceSuit

Advisor: **prof. Antonella De Angeli**
Co-advisor: **prof. Michael Haller**

Project Description:
At the Media Interaction Lab, we are working on smart textile interfaces [1][2]. More recently, we designed and implemented a resistive force-sensor based on a spacer fabric knit – mostly focusing on use cases for the automotive domain. For our multi-component knit, we added a resistive yarn to the filler material, in order to achieve a highly sensitive and responsive pressure sensing textile. Due to its softness and elasticity, our sensor provides an appealing haptic experience and can be optimally integrated into wearables. It enables continuous input with high precision due to its innate haptic feedback and can be manufactured ready-made on a regular two-bed weft knitting machine, without requiring further postprocessing steps. In this PhD thesis, we would like to explore the possibilities of a spacer knit textile interface in combination with wearables, with a special focus on a spacesuit, cf. [3]. The overall goal will be the design and implementation of a lightweight solution with a high flexibility due to the stretchy garment. The spacesuit should also provide different input modalities and provide novel interaction possibilities that are beyond simple on-surface gestures (e.g. by introducing full-body gesture input). As the garment will be based on a novel thread that has been implemented within the Media Interaction Lab, the suit should also be enhanced with additional threads to provide a multi-functional garment (e.g. for sensing internal pressure, temperature etc.).

Required skills:
The candidate should have a background in one of the following fields Computer Science, Human Computer Interaction, or Electronic Engineering and have a passion for designing and implementing smart prototypes together with a team, that will support us with the implementation of the garment. Deep understanding of

sensors and actuators and the knowledge in microelectronic circuits and experience with design tools are a plus.

References

[1] R. Aigner, A. Pointner, T. Preindl, R. Danner, and M. Haller, “TexYZ: Embroidering Enameled Wires for Three Degree-of-Freedom Mutual Capacitive Sensing,” in Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems, New York, NY, USA, 2021, doi:10.1145/3411764.3445479

[2] T. Preindl, C. Honnet, A. Pointner, R. Aigner, J. A. Paradiso, and M. Haller, “Sonoflex: Embroidered Speakers Without Permanent Magnets,” in UIST’20: 33rdth ACM User Interface Software and Technology Symposium, Minneapolis, Minnesota, USA, 2020, doi: 10.1145/3379337.3415888

[3] J. Stroming and D. Newman, "Design of an External Compensatory Breathing Bladder for the BioSuit," 2020 IEEE Aerospace Conference, 2020, pp. 1-9, doi: 10.1109/AERO47225.2020.9172486.

A3 - Explaining Artificial Cognition with Experimental Psychology

Advisors: **prof. Antonella De Angeli**
Co-advisor: **to be defined**

Project Description:

As new legislation and foundational ethical concerns are fueling the field of eXplainable AI, a growing corpus of research has addressed the issue of clarifying why the machine took a certain decision. This problem encompasses two foundational steps: 1) understanding computational reasoning; 2) explaining it to the user. Many difficulties emerge at this point because both the machine and the user are black boxes. In a black box, the decision-making process can only be inferred by systematically manipulating the input and observing the output. This is the epistemic challenge faced by experimental psychologists in the last 150 years. It is elegantly illustrated by Taylor and Taylor 2021 while explaining the difference between correlation (the core of machine learning) and causation (the core of experimental psychology). In this project, we aim to study cognition in the most advanced techniques for machine learning following experimental psychology. Foundational experiments will be replicated to systematically study artificial cognition, and expose similarities or differences between machine and human learning thus providing invaluable feedback to design trustworthy explanations. The outcomes of the projects will be a solid methodological framework to explain how machines make decisions and evaluate human trust in their judgement.

Taylor JET, Taylor GW. Artificial cognition: How experimental psychology can help generate explainable artificial intelligence. Psychon Bull Rev. 2021 Apr;28(2):454-475.

Required skills:

The ideal candidate has strong knowledge of experimental psychology (experimental design and data analysis) and a willingness to work in a dynamic multidisciplinary environment with colleagues who build the technology.

A4 - Multi-task Learning in Deep Neural Networks

Advisor: **prof. Giuseppe Di Fatta**
Co-advisor **prof. Giuseppe Nicosia (University of Catania)**

Project Description:

In most Machine Learning (ML) approaches, the trained model is specialised on a single task and cannot be adopted to solve any other problem. In contrast, Multi-task Learning (MTL) is an ML approach in which a model is trained to solve multiple tasks simultaneously. This is similar to the learning process in humans, who learn general skills useful to multiple tasks: e.g., hand dexterity is useful to solve many tasks and is improved by learning many tasks at the same time. In recent years, MTL has been shown to be particularly effective in generating better generalised models that take advantage of the similarities and differences across tasks. In this PhD project MTL methods will be investigated to identify and apply novel approaches for Deep Neural Networks. The overarching aim of this project is to contribute to the theory as well as applications with an effective use of MTL in combination with other methods such as Deep Learning, Deep

Neuroevolution, non-linear optimization, sensitivity analysis for explainable AI. Multi-task Deep Learning will be applied to some classic and to more recent testbeds for Deep Learning (e.g., CIFAR-100, Atari games, XTREME, StarCraftII) as well as real-world problems, such as the prediction of neurodegenerative diseases (dementia) from brain images or synthetic motor control for modelling rich and diverse motor behaviour across multiple tasks at humanoid scale.

Required skills:
This project requires a strong motivation to study fundamental theory of Machine Learning and, in particular, of Deep Learning. A good understanding of the basic Mathematics for engineering and computer science, including Linear Algebra, Probability and Calculus, is required. General programming skills in any language are essential, including the fundamental paradigms of procedural, object-oriented and functional programming. A specific preference for some knowledge and practical skills in Python, as the language of choice of this project. Good communication kills and good knowledge of the English language for technical report writing and verbal communication are also required.

A5 - Decentralised Consensus for Extreme-scale Blockchain

Advisor: **prof. Giuseppe Di Fatta**
Co-advisor: **to be defined**

Project Description:
Blockchain technologies have shown a great potential for a wide range of applications with an impact in several domains, such as finance, logistics, healthcare, advertising, insurance, copyright protection, energy, smart contracts, and more. Many of the current blockchain systems have shown limitations in performance and security, which still need to be addressed for a wide-scale adoption. Although distributed consensus has long been studied in distributed systems, it is now receiving an increasing attention due to its core role in Blockchain. Distributed consensus is a fundamental network operation that underlies distributed communication and computation in a Blockchain system and determines its overall performance and security. Blockchain systems critically rely on a specific distributed consensus algorithm to ensure the agreement among the participating nodes on the current system state and on its transitions. This project intends to investigate and develop a novel approach to distributed consensus for large and extreme-scale Blockchain systems. The project will investigate fully-decentralised protocols that can provide intrinsic robustness, scalability and fault-tolerance for dynamic distributed systems even in the presence of unpredictable node behaviour. Combining these types of protocols with a Blockchain architecture is expected to enable a new range of large-scale applications with a significant potential impact in many domains.

Required skills:
This project requires a strong motivation to study and advance fundamental aspects of Distributed Systems and, in particular, of Blockchain. A good understanding of the basic Mathematics for engineering and computer science, including Linear Algebra, Probability and Calculus, is required. General programming skills in any language are essential, including the fundamental paradigms of procedural, object-oriented and functional programming. Good communication kills and good knowledge of the English language for technical report writing and verbal communication are also required.

A6 - CHRISpredict: privacy preserving AI platform for personalized risk prediction

Advisor: **prof. Johann Gamper**
Co-advisor: **dr. Christian Fuchsberger (Eurac Research), Dr. Anton Dignös**

Project Description (Max 250 words):
Artificial Intelligence (AI) is widely considered to be a key enabler for the next breakthrough in personalized risk assessment and prevention in health care. To provide maximum value, AI tools need to be trained on high-quality patient data, such as collected by the South Tyrolean CHRIS study. CHRIS is the largest population-based resource in Italy to investigate the genetic and molecular basis of age-related common chronic conditions, such as diabetes and cardiovascular disease. Unfortunately, the GDPR and national or organizational data policies restrict access to such data: authorized users can

typically only access data located in their organization or in a national health data hub of their country. To enable medical doctors to assess the risks of individual citizens and perform timely detection, prevention and prognosis, it is needed to deploy AI algorithms in a highly privacy-preserving federated learning setting, training AI models near the data without moving the data across organizational or national boundaries.
The goal of this PhD-project is to design, model, and implement an framework to learn privacy-preserving federated AI models and to validate the approach on a rich multicenter dataset available through the network of the Eurac Institute for Biomedicine.

Required skills:
The required skills for this PhD position are:

- motivation in scientific work
- basic knowledge in bioinformatics and AI/ML
- algorithmic thinking
- good programming skills
- proficiency in English
- Bonus: proficiency in German

A7 - IoT Design and Development with End Users for a Sustainable Future

Advisor: **dr. Rosella Gennari**
Co-advisor: **dr. Luisa Petti**

Project Description:
The PhD student will work with members of the Human Computer Interaction (HCI) research group at the Free University of Bozen-Bolzano (unibz), and she/he will have access to the Sensing Technology Lab of unibz. Both have a reputation for international research in Europe. The focus of the studentship is HCI for IoT.
According to the classical HCI paradigm, human beings interact with computers through specific devices (mainly, keyboard, mouse and screen). Thus, traditionally, user interfaces are taken as starting points for designing user interactions with computers. In the Internet of Things (IoT) era, the interaction paradigm is different: it is humans' physical actions which are taken as starting points for designing their interactions with different sorts of smart things, part of the IoT. Working in HCI for IoT requires expertise in HCI, physical computing and sensing technology. The studentship offers students the possibility of working with experts in HCI, physical computing and sensing technology. Starting from existing expertise and toolkits (e.g., SNaP, IoTgo), the student will investigate how to engage end users (e.g., teens, children) in the design and development of their own smart things for a sustainable future. The design and development activities are expected to be conducted by the PhD student in a distributed setting, with end users living in different areas.
The project will be developed differently according to the skills and expectations of the PhD students.

Required skills:
The student needs to have

- working knowledge of programmable microelectronics, e.g., Raspberry Pi, Arduino boards,
- programming skills, especially in C, C++ and/or Python.

Ideally the student can

- work in inter-disciplinary fields and teams,
- relate well with end users, especially teens and children,
- work in distributed settings
- plan her/his own work independently and comply with team and project-related deadlines.

A8 - Deep Learning for Image and Video Understanding

Advisor: **prof. Oswald Lanz**
Co-advisor: **prof. Sergio Escalera, University of Barcelona (ES)**

Project Description:

The project will explore novel techniques for semi-automated design and effective training of deep architectures for image and video understanding. Of particular interest are scenarios where lots of raw data is available but either annotation is scarse and/or distribution of data is highly unbalanced. Such situation is often encountered in anomaly detection, recognition and forecasting, preventing supervised learning at scale. Transfer learning, data augmentation and a task-specific architecture design can alleviate but this typically requires the inventive contribution of an expert. Investigations in this project will contribute towards automating the design and training process by leveraging self-supervised pre-training, neural architecture search, multi-modal learning. Furthermore, domain knowledge is often available but it is non-trivial to represent and integrate with deep learning. Relevant research contributions might include knowledge injection and distillation, and neuro-symbolic integration for vision. The application context for this project is not sharply defined, but can build upon previous research of the group (see http://srl4v.github.io) and the student can consider use-cases from industry (see https://covisionlab.com).

Required skills:
The eligible candidate has undertaken computer vision and deep learning studies at university courses with proficiency. The MSc thesis is in the field of deep learning and computer vision, ideally already providing the background on one aspect related to the project and the research proposal by the applicant. Solid programming skills and experience with deep learning frameworks such as pytorch are requested.

A9 - Sparse Artificial Neural Networks for Intelligent Internet of Things

Advisor: **prof. Antonio Liotta**
Co-advisor: **to be defined**

Project Description:
Artificial Neural Networks (ANN) are enabling new applications in artificial intelligence, data science and, generally, intelligent systems. ANNs are at the heart of machine learning (ML), which essentially involves training complex prediction models starting form big data. ML is typically relegated to high performance computers that have the compute power to both build and execute the models. In this project, we aim to streamline ML so that it can be performed in commodity hardware. This is particularly relevant in the context of intelligent Internet of Things (IoT), whereby we want to interconnect intelligent objects (at the network edge), thus embedding ML processes into the edge nodes (i.e., beyond the Cloud). In this way, these digital objects will be able to use a range of ML techniques to make sense of their context, make inference on their input data, or act upon their environment. To this end, we study ´sparse´ (rather than ´dense´) ANNs and use ingenuous network science techniques to train lightweight models. The project aims to demonstrate this new concept of edge intelligence in the context of practical case studies such as smart sensing, smart city and intelligent IoT.

Required skills:
This project requires a strong motivation to study fundamental theory of Machine Learning and is best suited to someone who has already started building a portfolio of data science projects. A good math background is required, including linear algebra and calculus. General programming skills in any language are essential, including the fundamental paradigms of procedural, object-oriented and functional programming. There is a preference for Python, which is the language of choice for this project. Knowledge of graph theory and network science would be an advantage.

A10 - Explanations for a Human-centric AI

Advisor: **prof. Markus Zanker**
Co-advisor: **dr. Roberto Confalonieri**

Project Description:
In recent years, we have witnessed the advent of increasingly accurate and powerful algorithms and techniques to personalize the content presented to users. This capability to effectively assess users' tastes and interests in information is primarily based on the collaborative recommendation paradigm (often exploiting machine learning techniques) without taking enormous amounts of knowledge, both structured and unstructured, describing the domain of interest into account. This project will therefore focus on the study of the aspects related to the exploitation of external and explicit knowledge sources to feed a

recommendation engine and how they can aim at beyond the accuracy objectives in contrast to traditional recommendation algorithms. It will be investigated how knowledge encoded in ontological and logical knowledge bases, knowledge graphs, and/or the semantics arising from the analysis of semi-structured textual sources can lead to more novel and diverse recommendations, as well as enhance them with explanations of the recommended elements. Finally, understanding the impact of explanations on the human users is another important aspect of this PhD project as this is partially overlooked in the literature.

Required skills:
Skills in data analytics, recommender systems, machine learning, knowledge graphs

B1 - SQL-Based Declarative Process Mining

Advisor: **prof. Fabrizio Maria Maggi**
Co-advisor: **to be defined**

Project Description:
Process mining is driven by the ambition to understand how a process is truly executed in practice, why certain activities are executed and under which circumstances. It aims at analyzing business processes from an event log consisting of traces, such that each trace corresponds to one execution of the process. Each event in a trace consists as a minimum of an event class (i.e., the activity to which the event corresponds) and generally a timestamp. In some cases, other information may be available such as the originator of the event (i.e., the performer of the activity) as well as data produced by the event in the form of attribute-value pairs. Declarative process mining has been proven to be suitable to analyze knowledge-intensive processes working in environments that are unstable and unpredictable. It is also well known that behavior is typically intertwined with dependencies upon value ranges of data parameters and resource characteristics. Therefore, Declare has been extended towards Multi-Perspective Declare (MP-Declare) in which conditions on data parameters, resource and timestamps can be specified. However, state-of-the-art mining tools do not scale well when analyzing processes using MP-Declare rules and, therefore, are difficult to be used in real scenarios. In this project, we will investigate the possibility of using SQL as an instrument to store event logs so that advanced developments in database theory can be used to efficiently implement different multi-perspective process mining use cases like conformance checking, query checking, and process discovery.

Required skills:
The candidate needs good programming skills especially in Java, interest in business process data analysis and database technologies. The candidate should also be interested in understanding temporal logic specifications and their meaning especially for what concerns their practical implications in the context of business process analysis. Good language skills in English both in writing and speaking are welcome. Social skills, availability to collaborate with colleagues and ability to work in team are fundamental.

B2 - Strategy and Explainability for Knowledge Bases

Advisor: **dr. Oliver Kutz**
Co-advisor: **dr. Nicolas Troquard**

Project Description:
This research project is about advancing the reasoning with conflicting knowledge, both in the strong sense of inconsistency, and in weaker varieties that involve conceptual clashes, empty concepts, or over-commitments. It focuses on bringing together three recent strands of research, namely 1) methods to weight information, 2) methods to weaken axioms, and 3) methods to negotiate or play games with information.
The general application area is knowledge engineering, in particular providing solutions to the problem of resolving inconsistent information when an agent adds new knowledge to a knowledge base. But additionally, this entails the problem of explaining why a certain combination of knowledge is inconsistent, and it requires to explain or justify the proposed changes.
Weighted logic focuses on the idea that different pieces of information have different value, or weight, reflecting a very natural idea from common sense reasoning. Axiom weakening allows for a fine-grained

repair of inconsistent knowledge bases. Its main advantage is that it repairs them by making axioms less restrictive rather than by deleting them.
Typical research questions are:

- **Strategic reasoning:** How can the techniques from multiagent systems and game theory be applied to problems of collaborative ontology engineering and to concept combination? E.g., how can different agents agree on the weight of a particular piece of information?
- **Explainability:** How can we best combine the ideas of weighted logic, where different pieces of information have different weight, and refinement, where we specialize or generalize our information? How can we explain and justify the weakening of information?

Required skills:
In general, applicants for this project are expected to have some good acquaintance with classical logic and its syntax and semantics. More advanced knowledge of proof methods, meta-theory, and non-classical logic will be a plus. The ideal candidate will already have some background in agents or game theory as well as KR languages such as description logics.
Programming skills: experience with programming would be valuable, particularly for the purpose of carrying out evaluation studies and improving research prototypes.

B3 - Graph Data Management with Linear Algebra

Advisor: **prof. Werner Nutt**
Co-advisor: **dr. Julien Corman**

Project Description:
Graphs arise naturally when modelling social or traffic networks, molecules, or general world knowledge. While linear algebra operations over real or complex numbers are central in processing large data sets, specifically in data science and artificial intelligence, it is less known that many data analysis techniques over graphs can be expressed using linear algebra over a wide class of algebraic structures that are known as semirings.
In mathematics and computer science researchers have come up with techniques to efficiently execute linear algebra operations over these structures. It is not clear, however, to which extent and how linear algebra over semirings can be integrated into existing data management techniques.
The goal of this PhD project is to contribute to this goal. The following are examples of research questions that arise in this context:

- What is the scope of questions about graphs that can be formulated in this way?
- How can linear algebra over semirings be embedded in larger declarative languages to satisfy the needs of applications? What is the expressivity of such languages?
- How do properties of the language depend on the properties of the semiring employed?
- What algorithms allow one to execute such queries efficiently? How can query execution be supported by auxiliary structures such as indexes?

Required skills:
In general, applicants for this project are expected to have some acquaintance with logic and algebra. They should feel at ease with abstract mathematical thinking and mathematical proofs. Furthermore, good knowledge of data structures and algorithms is expected.

C1 - Assessment Methods for Decision-making in Service-based Architectures

Advisor: **prof. Xiaofeng Wang**
Co-advisor: **dr. Eduardo Martins Guerra, dr. Andrea Janes**

Project Description:
Microservices and other service-based architectures are becoming popular in the software development industry due to the benefits that their strong modularization can bring to maintainability and scalability. However, this distributed nature makes it hard to have an overall view of the system, which, consequently, can also be a problem for making informed design decisions. In fact, from a software engineering point of view, microservices are disruptive since they invalidate many design principles and techniques from the past and require the establishment of new practices and architectural patterns that take their particular

properties, such as slow communication, into account. So, to propose solutions that can aid in decisions about its design and evolution, research projects can make advances in these four areas: (1) approaches and tools that extract metrics and other data relevant for decision-making considering the heterogeneous nature of the services; (2) methods and tools that can process the data obtained from these systems to search for recognizable structures that can reveal information about the patterns implemented, design disharmonies, and potential targets for refactoring; (3) visualize the collected information about the system to aid in reasoning about its structure; (4) identify new architectural patterns and study the trade-offs from the existing ones to overcome the identified problems. The research method used to evaluate techniques in this context should consider its usage in the architecture of real systems and their usefulness for the professionals that work with them.

Required skills:
Strong programming skills in at least one programming language; knowledge about software architecture patterns; knowledge in the development of microservice-based systems; passion about software architectures; curiosity about the identification of root causes; empathy about how programmers use software development frameworks and apply software patterns; good mathematical skills to apply machine learning in software engineering contexts; interest in solving a general problem well (opposed to solving a small problem perfectly).

C2 - Agile training for scaling agile and agile transformation

Advisor: **prof. Xiaofeng Wang**
Co-advisor: **dr. Ilenia Fronza**

Project Description:
Since the publication of agile manifesto in 2001, agile software development methodologies (e.g., eXtreme programming, Scrum) have been adopted by an increasing number of companies worldwide, and have become the mainstream software development approaches employed in the software industry. Organizations are realizing the benefits of adopting agile, mainly at the project level.
In terms of organizational level agile adoption, however, much fewer companies have a high level of competency with agile practices across the organization. Although there are widely used approaches to scaling agile, e.g., SAFe (Scaled Agile Framework), companies are confronted by various challenges of scaling agile, among them are organizational culture at odds with agile values, resistance to change, lack of skills/experience with agile methods, insufficient training and education on agile methods, minimal collaboration and knowledge sharing. Meantime, internal agile coaches and executive sponsorship are among the success factors reported by the industry for scaling agile to the whole organization.
The goal of this project is to research innovative and educational techniques and tools to train companies on agile, focusing on agile scaling and transformation. To this end, participants will be provided with a common knowledge foundation that could be applied across different contexts regardless of their roles and responsibilities. To deliver such agile training, an agile way of teaching will be preferred, which is characterized by problem and challenge-based iterative processes, visible feedback and reflection, and collaborative and shared learning styles.

Required skills:
Technical skills: Analysis and problem-solving, agile project management, research and information management, written and oral communication, programming skills,
Soft skills: Interpersonal and leadership skills, self-management and work habits, concentration, and patience

D1 - Virtual Digital Assistants for Healthcare

Advisor: **dr. Chiara Ghidini**
Co-advisor: **dr. Mauro Dragoni**

Project Description:
One of the pillars of healthcare digital transformation focuses on the integration of AI-based solutions within the clinician-patient relationships with the aim of monitoring and/or supporting them towards the achievement of healthy functional status.

Examples of these systems are: (I) virtual coaches to support remote monitoring and recommendations for patients affected by nutritional chronic diseases or to support the prevention of the onset of such diseases; (ii) telehealth solutions to enhance care capabilities of health organizations; and, (iii) tools to orchestrate care pathways involving, beside patients, multiple clinical actors.
This Ph.D. works within this context with the aim of designing novel AI-based approaches to trigger the implementation of the next-generation virtual digital assistants.
The area of intervention is very broad since the research areas involved are, for example, knowledge management, human-computer interaction, pervasive computing, machine learning, probabilistic graphical model, natural language processing, and planning.
For this reason the Ph.D. candidate will have the opportunity to explore the virtual digital assistants domain in order to analyse current open challenges, to decide which ones to address and which AI-based approaches she/he will use to tackle such challenges.

Required skills:

- Knowledge of the Artificial Intelligence domain.
- Basic knowledge of at least one of the following research area: knowledge management, human-computer interaction, pervasive computing, machine learning, probabilistic graphical model, natural language processing, or planning
- Good developing capability, in particular good knowledge of Java.
- Basic knowledge of the Digital Health domain.
- Good knowledge of the English language.
- Team working.

D2 - Emotions in Multilingual Texts

Advisor: **dr. Carlo Strapparava**
Co-advisor: **dr. Chiara Ghidini**

Project Description:
The affective dimension of word meaning often forms part of our reservoir of common-sense knowledge, and it is reflected in the way we use words. This project aims at producing and evaluating new technologies for recognition of emotional language and possibly other subtle pragmatic aspects of communication. Because there are diverse subtilties in emotional expressions in different languages, the project will devote particular attention in approaching the problem from a multilingual point of view.

Required skills:
Good familiarity and expertise with Computational Linguistics techniques. Experience in machine learning. Good programming skills.

D3 - Neural models of collaborative behaviours in conversational agents

Advisor: **dr. Bernardo Magnini**
Co-advisor: **dr. Chiara Ghidini**

Project Description:
Human-human dialogues are characterized by collaborative behaviours, through which interlocutors achieve their communicative goals. As an example, proactivity (i.e., anticipating user needs during dialogue) and grounding (e.g., posing clarification questions) are two relevant cases that have been investigated from a linguistics perspective. However, such collaborative behaviours are still largely absent in current neural dialogue models. There are several open research challenges in this direction, including investigating how dialogue systems can learn when and how to be collaborative, depending on the dialogue context, and how do we evaluate whether collaborative behaviours have improved the efficacy of dialogue. This PhD project addresses collaborative behaviours in conversational agents from a computational perspective, exploiting the integration of machine learning approaches based on neural models, reinforcement learning, and knowledge-based techniques.

Required skills:

Good familiarity and expertise with Computational Linguistics techniques. Experience in machine learning. Good programming skills.

E1 - Human Creativity and Machine Learning for public awareness of AI

Academic Advisor: **prof. Antonella De Angeli**
Co-advisors: **dr. Maria Menendez Blanco, Federico Bomba (Sineglossa)**

Project Description:
This project proposes interdisciplinary research at the frontiers between human creativity and machine learning. The objective is twofold. On the one hand, we want to explore new possibilities for artistic expressions driven by the artist imagination and machine learning synergically. On the other hand, we want to design critical artefacts to increase public awareness of AI. Awareness refers to the knowledge of possibilities and limitations of machine learning capabilities. This knowledge is a fundamental predecessor of informed trust and a key component of public digital literacy on AI development and deployment.
AI is identified as a key enabler across different missions and the horizontal reformation of the Public Administration in the National Plan for Recovery and Resilience . Current research, however, has demonstrated the complexity of explaining how AI works and foundational concerns have been raised with respect to low public acceptance, and a generalized mistrust on machines that make decisions on the human's behalf, often relying on biased data. Source credibility alongside advice personalization and predictability are fundamental determinants of trust on machines. The key research question, therefore, is "how can we enhance AI awareness and credibility?" for all citizens, independent of their digital skills, cultural background, and idiosyncratic interests.
The project addresses this question by combining the scientific method of experimental research in human-computer interaction, the reflexive approach of science and technology studies, and creative practices of critical design. Main project outcomes will be ML-based critical design artefacts, academic research, and public exhibition that contribute to public awareness of AI. The cultural organization Sineglossa will host the student during their placement, the City Council of Bozen-Bolzano will facilitate the contact with the local public.

Required skills:
Ideal candidates have a keen interest on shaping the future of AI with a focus on societal well-being and public empowerment. The project is open to many curriculum and expertise. They can be designers and developers with expertise in ML and an interest in critical design approaches to digital literacy: social scientists willing to investigate future societies or people; and educators aiming to understand and explain how AI work to the general public. The project require strong communication abilities, empathy and a willingness to work in a multidisciplinary team.

E2-Ethical Artificial Intelligence for Public Administration Data and Social Policies

Academic Advisor: **prof. Antonio Liotta**
Co-advisors: **prof. Antonella De Angeli, prof. Stefania Baroncelli**

Project Description:
The digitalization of cities and the integration of data from all sorts of sources has made it possible for the public administration (PA) to fuse heterogeneous data about both the city and the citizen. The different departments of the PA are bound to make these data publicly available, either in full or in an anonymized fashion. This data provides information about citizens, policies, interventions, or investments, but also about the city, environmental parameters, the traffic, etc. There are vast volumes of data, which are difficult to curate in such a way as to meet legal standards (e.g. transparency vs privacy). At the same time, their elaboration requires advanced data processing, data integration, data fusion, and artificial intelligence (AI). Finally, the user shall trust their outcome, so as to ensure adoption and compliance.
An application of AI in the PA which takes into account the protection of constitutional principles requires thoughtful analysis of this data, which has intrinsic limitations, such as biases and implicit assumptions often reflecting social inequalities at the basis of discrimination. For example, the ways in which data is extracted, aggregated, and manipulated in smart cities creates new urban orders where cars and people compete for a common space, which is regulated by algorithms. In this project, we focus specifically on

the ethical use of the heterogeneous PA data through AI, aiming to enable their safe, legal and ethical use. This project explores techniques to anonymize sensitive data and make them accessible to anyone.

Required skills:
This project requires a strong motivation to study fundamental theory of Machine Learning and is best suited to someone who has already started building a portfolio of data science projects. A good math background is required, including linear algebra and calculus. General programming skills in any language are essential, with a preference for Python, which is the language of choice for this project. Knowledge of ethical use of data would be an advantage.

E3- Teaching Physical Design and Computing

Academic Advisor: **dr. Rosella Gennari**
Co-advisor: **dr. Syed Mehdi Rizvi, Politecnico Milano**

Project Description:
The PhD student will work with members of the Human Computer Interaction (HCI) research group at the Free University of Bozen-Bolzano (unibz), she/he will have access to the technology labs of unibz, and to the Public Administration (PA) entity engaged in the PhD. The focus of the studentship is on methodologies and tools for teaching physical computing and design.
Physical computing combines software and hardware to build smart cyber-physical things that sense and respond to the real world, and interact one with another, supported by the IoT architecture (https://en.wikipedia.org/wiki/Physical_computing).
Physical computing leads naturally to collaborative, reflective, hands-on activities, which require design thinking (DT) besides Computational Thinking (CT).
Such activities can help in reducing the gender gap in information technology and, in general, in engaging different learners, e.g., from cultural minorities, in shaping technology and critically reflecting on it (Shaw et al., 2021, https://ieeexplore.ieee.org/abstract/document/9620625).
This PhD project aims at investigating methodologies and toolkits for bringing CT and DT into different contexts and studying their effectiveness. It starts from existing work led by R. Gennari et al. at the Free University of Bozen-Bolzano, related to different CT and DT initiatives for learners or educators, such as SNaP and IoTgo.
The project will be developed differently according to the skills and expectations of the PhD student, in agreement with the PhD advisor and under her supervision.

Required skills:
The ideal PhD candidate has

- a Master's degree in Applied Linguistics, Human Computer Interaction, Computer Engineering and Automation, Electronics Engineering, Applied Computer Science, or an equivalent degree,
- programming skills, especially in Python, and possibly, working knowledge of web design,
- possibly, working knowledge of programmable microelectronics, e.g., Raspberry Pi, Arduino boards.

Moreover, the ideal PhD candidate

- can work in inter-disciplinary fields and teams,
- can relate well with end users, especially teachers, teens, and children,
- can plan her/his own work independently and comply with team and project-related deadlines,
- is willing to live and work in Bolzano and the local area.

F1 - CHRIS2People: a framework to increase population health based on the analysis of large data collections

Advisor: **prof. Johann Gamper**
Industry Advisor: **dr. Christian Fuchsberger (Eurac Research)**
Co-advisor: **dr. Anton Dignös**

Project Description:
Why do we get sick? And what role do genes, lifestyle, and a person's environment play in the onset, progression, and treatment of disease? To investigate these questions the Eurac Institute for Biomedicine

uses data from the Cooperative Health Research In South Tyrol (CHRIS) study. CHRIS is the largest population-based resource in Italy to investigate the genetic and molecular basis of age-related common chronic conditions, such as diabetes and cardiovascular disease. Until now, >13,000 adults have participated, and more than one million biological samples and epidemiological, molecular and genetic data were collected.
Thus far a strong focus has been on the collection of the data and the generation of novel scientific insights. To date, the main benefit for the participants have been a free blood and urine test, ECG, blood pressure and anthropometric measurement. However, these data are not shared directly with their general practitioner (GP), nor has their GP access to additional data available in CHRIS (such as genotype data which e.g. could help to predict adverse drug reactions).
The goal of this PhD-project is to design, model, and implement techniques and algorithms to dynamically identify the most relevant data for each CHRIS participant during his/her visit at the GPs office, to exchange this information between CHRIS and GPs in a GDPR compliant and privacy conserving manner, and to visualize the shared information to the GP and CHRIS participant taking into account the scientific nature (=uncertainty) of the collected results.

Required skills:
The required skills for this PhD position are:
- motivation in scientific work
- basic knowledge in bioinformatics
- algorithmic thinking
- good programming skills
- proficiency in English
- Bonus: proficiency in German

F2 - Dynamic association graph inference for applications in biomedicine

Advisor: **prof. Johann Gamper**
Industry Advisor: **dr. Christian Fuchsberger (Eurac Research)**
Co-advisor: **dr. Anton Dignös**

Project Description:
Association graphs are graph structures in which the edges indicate interesting associations among its vertices. For instance, in health research, such a graph can be used to indicate associations between genetic variants and phenotypes, such as diabetes and blood pressure. These graphs tend to be very large, e.g., the number of genetic variants measured in the Cooperative Health Research in South Tyrol (CHRIS) study is about 20 million. A graph for a specific study is generally created using a filter on the input, i.e., over subsets of the input, for which the associations are computed, and they need to be recomputed from scratch if the subset of the input changes.

This PhD project focuses on the efficient and dynamic computation of association graphs based on different subsets (filters) of the input and will be applied to GWAS results from the local CHRIS study, one of the largest population cohorts in Italy.

Required skills:
The required skills for this PhD position are:
- motivation in scientific work
- basic knowledge in bioinformatics
- algorithmic thinking
- good programming skills
- proficiency in English

F3 - Data quality assessment and control in complex processing chains for earth observation and climate data analysis

Academic Advisor: **prof. Antonio Liotta**
Industry advisor: **dr. Alexander Jacob (Eurac Research)**

Project Description:
In the context of creating a more accurate understanding of our earth, digital twins are developed in order to model and experiment with different environmental conditions and show how changing conditions might affect the situation in a given region. Models are both augmented and verified using observational data from many different sources including earth observation data from space and the ground, as well as meteorological and hydrological data.
Complex workflows including a multitude of different datasets and tools are used in order to conduct impactful and insightful analysis to inform on important questions in research and governance of climate change. It is key to understand the quality and reliability of results produced. The core topic of this research should focus on how to track and trace quality and reliability of results produced in such complex workflows, and how to make the information on quality travel through the processing chain.

Required skills:
This project requires a strong motivation to study fundamental theory of Machine Learning and is best suited to someone who has already started building a portfolio of data science projects. A good math background is required, including linear algebra and calculus. General programming skills in any language are essential, including the fundamental paradigms of procedural, object-oriented and functional programming. There is a preference for Python, which is the language of choice for this project. Knowledge of graph theory and network science would be an advantage. Experience with spatial and temporal data and how they are organized would be highly beneficial, including both vector and raster data.

F4 - Multi model and multi sensor data fusion for integration of spatial temporal information in the context of earth observation and climate data analysis

Academic Advisor: **prof. Antonio Liotta**
Industry advisor: **dr. Alexander Jacob (Eurac Research)**

Project Description:
In the context of creating a more accurate understanding of our earth, digital twins are developed in order to model and experiment with different environmental conditions and show how changing conditions might affect the situation in a given region. Models are both augmented and verified using observational data from many different sources including earth observation data from space and the ground as well as meteorological and hydrological data.
Data needs to be harmonized and gap filled and potentially adapted both in temporal and spatial resolution. All data processing should be describable in an abstract way, following workflow descriptions and information of data quality based on the applied processing steps. Machine learning techniques should be employed where they are useful and linked with the general workflow design as well. In the context of the data fusion, both domain adaptation as well as dealing with noisy or incomplete data should be considered here.

Required skills:
This project requires a strong motivation to study fundamental theory of Machine Learning and is best suited to someone who has already started building a portfolio of data science projects. A good math background is required, including linear algebra and calculus. General programming skills in any language are essential, including the fundamental paradigms of procedural, object-oriented and functional programming. There is a preference for Python, which is the language of choice for this project. Knowledge of graph theory and network science would be an advantage. Experience with spatial and temporal data and how they are organized would be highly beneficial, including both vector and raster data.

F5-How to bring the Metaverse into the vehicles for a novel video conferencing experience

Academic Advisor: **prof. Michael Haller**
Industry advisor: **to be defined (BMW Group)**
Co-advisor: **prof. Antonella De Angeli**

Project Description:

With all the interest recently in eXtended Reality (XR) and the metaverse, also the automotive industry is looking to bring Augmented Reality, Virtual Reality, and Mixed Reality elements into vehicles. A huge number of in-car infotainment systems, for example, now have AR integrated as part of their augmented navigation systems, displaying arrows through a holographic windscreen in front of the car.
Within this proposal, together with BMW, we want to take this adoption of XR a step further by bringing the metaverse into vehicles. Of course, there are a huge number of entertainment opportunities. In this thesis, however, we want to bring video conferences and meetings to the next level. The seats, but also the interior of the car itself will become a central part of the interaction. Combined with mid-air gestures and speech, we would like to explore the new possibilities of interaction. This scenario offers several possibilities to the driver experience but also many challenges to their safety.
More specifically the objectives are:

1. the design and implementation of a novel Metaverse paradigm in the vehicle for a novel video conferencing experience;
2. the design, implementation and critical evaluation of case studies and prove of concept with a strong focus on safety.
3. The study of how attention can be divided between the virtual and physical space.

Required skills:
The prospective PhD student will work together with a team in the field of next-generation interfaces.
The candidate must fulfill the following conditions to be eligible for employment:

- a Master's (MSc) degree in Computer Science or a closely related area,
- Human-computer interaction and/or computer graphics background with interest in XR fluency in written/spoken English

F6-Entertainment in the car by using a cognitive seat with tactile feedback

Academic Advisor: **prof. Michael Haller**
Industry advisor: **to be defined (BMW Group)**
Co-advisor: **prof. Antonella De Angeli**

Project Description:
When the vehicle takes over the driving function, users can devote themselves to other activities that are currently not possible in this form. This goes far beyond a simple phone call or video conference opening the door to the satisfaction of hedonic goals. At present, the entire vehicle interior is geared only to driving, when the person is comfortably sitting in front of the steering wheel. If we imagine, instead, a driver who is sleeping or entertaining themselves inside the car with the seat in an almost bed-like position, we will quickly notice that the current position and interaction modalities for seat adjustment are useless. There is a need to (a) identify new creative use-cases (in the context, for example, of tourism) and (b) rethink how the controls should be changed to transform the vehicle into a unique experiential space.

The goal of this thesis is the design and development of an experiential (cognitive) car seat acting as an input sensitive, fully interactive device which interfaces the driver with digital content. Equipped with pressure-sensitive textile patches, the seat with will recognize full-body interactions allowing the driver to interact with the car.
The seat sensing ability can be improved by adding input devices, such as cameras, speech etc.). More specifically, the objectives are the

4. design and implementation of different multi-modal interfaces for novel user experiences;
5. design, implementation and critical evaluation of prove of concepts.

Required skills:
The prospective PhD student will work together with a team in the field of next-generation interfaces. The candidate must fulfill the following conditions to be eligible for employment:

- a Master's (MSc) degree in Computer Science or a closely related area,
- Human-computer interaction and/or computer graphics background with interest in game development (e.g. Unity, Unreal),
- fluency in written/spoken English.

F7-I_C&C: Interfacing Creativity and Computation

Academic Advisor: **prof. Antonella De Angeli**
Industry advisor: **Federico Bomba (Sineglossa)**
Co-advisor: **prof. Marco Montali**

Project Description:
Research on end-user development (EUD) has consolidated in the last two decades across different application domains. Initially, it emerged at the boundaries between software engineering and human-computer interaction to guide domain experts (e.g., business analysts or healthcare professionals) who are not formally trained in software development but need to adapt computing programs to their contextual working needs. Later applications emerged in the domain of smart homes to allow consumers to program appliances' behaviour in their intimate space. This context expanded the reach of EUD from the satisfaction of pragmatic goals (e.g., setting the room temperature) to fulfilling hedonic goals (e.g., changing the lighting colour when certain music is on). More recently, the game industry has resorted to EUD approaches to improve the player's agency in the definition of gameplay dynamics.
The ambitious goal of I_C&C is to expand research on EUD to the application of AI in artistic practices. We will design an educational platform that presents algorithms as creative material using a language that can be easily understood by artists and designers to mediate the complexity of AI. Besides, we will create novel interfaces that can allow the manipulation of such algorithms to satisfy the aesthetic goals of the artist. For example, she could generate artworks by modifying a training dataset or the parameters of a machine learning model. Else, she could use AI to explore novel synergies between humans and algorithms as co-authors of artworks. In these scenarios, EUD requires the definition of original metaphors that can create bridges between creativity and computation, allowing artists and designers to understand how AI artefacts work and exploit them in creative practices.

The project follows a user-centred approach, which iteratively moves through three steps.

1) Benchmarking – identification of the design space in terms of user requirements and technological possibilities.
2) Prototyping – incremental design of metaphors and interfaces for allowing the use of AI in creative practices.
3) Evaluation – operational definition of new metrics also addressing creativity of the artworks from the author and the spectator perspective.

Required skills:
The ideal candidate has working knowledge of ML algorithm and interface design skills. Artistic skills (or a passion for the Arts) are desirable as the successful candidates will work in collaboration with artists, social scientists and designers.

F8-Predictive maintenance for industrial equipment

Academic Advisor: **dr. Anton Dignös**
Industry advisor: **Michael Deflorian (Durst)**
Co-advisor: **prof. Johann Gamper**

Project Description:
The maintenance of industrial equipment is typically preventive, scheduled based on calendar time, asset runtime, or some other period of time, or reactive when errors occur. Today's availability of huge amounts of sensor data allows predictive maintenance, which is scheduled as needed based on real-time conditions of industrial assets. Predictive maintenance tracks the performance of equipment during normal operation and detects possible defects before a failure occurs. Such a maintenance strategy brings significant cost savings due to a reduction of downtime, as maintenance steps can be better scheduled, and a reduction of resources, as parts are only changed if their performance degrades.

This PhD project aims at developing new algorithms or adopting/adjusting existing algorithms for predicting with high accuracy the next maintenance steps for or a degradation of industrial devices. This includes at least the following challenges: identifying signals with a high prognostic value and choosing prediction strategies that are appropriate for the specificities of the data. The project is done in collaboration with the

company Durst Phototechnik AG. The methodology used in the project includes basic research, implementation and extensive experimental evaluations using real-world data.

Required skills:

- The required skills for this PhD position are:
- motivation in scientific work
- basic knowledge in databases
- algorithmic thinking
- good programming skills
- proficiency in English