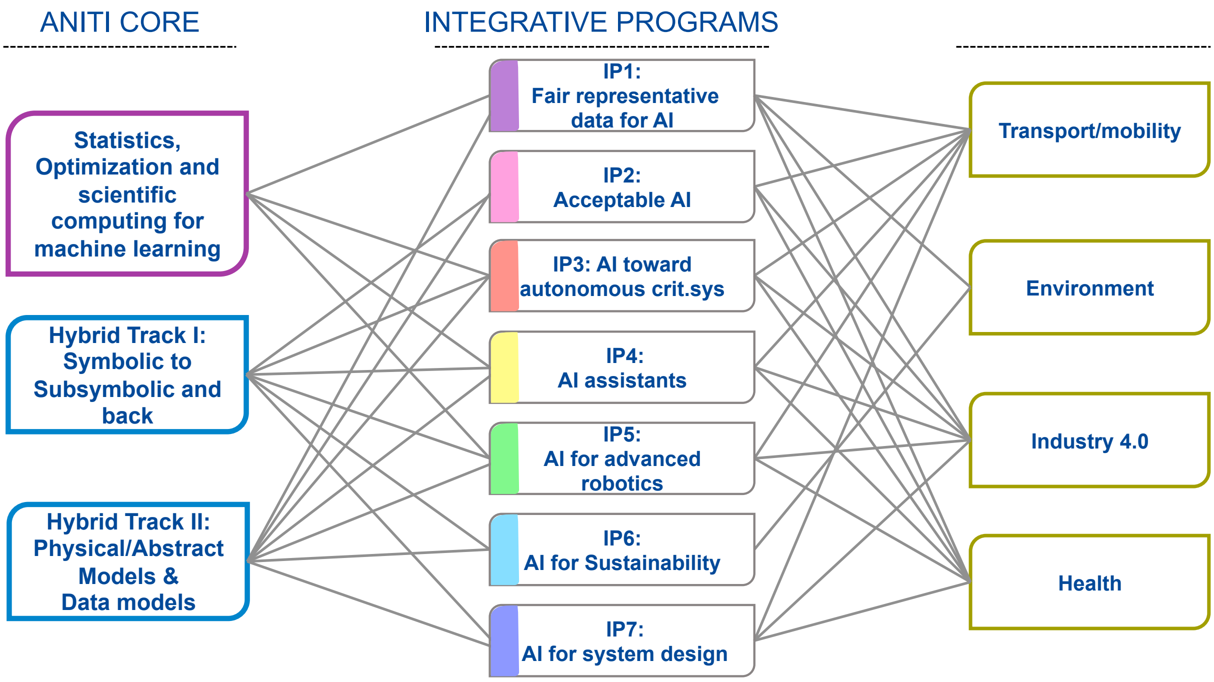
Institut 3iA - Artificial and Natural Intelligence Toulouse Institute

ANITI Integrated Programs and Chairs

1) ANITI Integrated Programs

As illustrated in the following figure, ANITI's scientific project is structured around seven integrative programs (IP), based on advances in three core areas of artificial intelligence and in relation to the application sectors targeted by the project.



The core subjects will explore solutions potentially allowing to obtain different properties that one seeks to satisfy, in particular related to the challenges derived from the application areas covered by the project: the robustness, the reliability, the explicability of the modeled phenomena or of the behavior of the system, the adaptability of the algorithms to changes of the environment, compliance with normative constraints, social or economic acceptability, or certifiability. Other criteria are also important and include the need to reduce the learning effort or optimize the performance of proposed solutions. In particular, two hybrid tracks are distinguished. Hybrid Track 1 addresses relations between subsymbolic representations, for example representations in a continuous, high dimensional space, and symbolic representations, for example a set of logical constraints. Hybrid Track 2 examines challenges related to how to complement and even replace analytical models of complex physical systems with data-driven ones exploiting machine learning.

In the following, we describe the seven proposed IP with the proposed Chairs, according to the following structure:

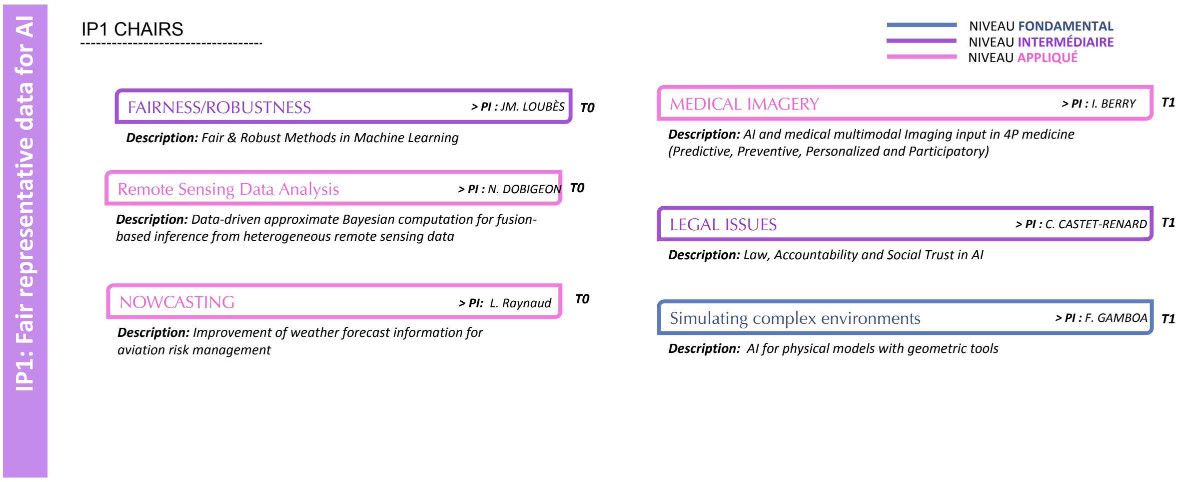
1) A figure illustrating the AI core topics addressed, the targeted properties and relevant applications areas
2) A short synopsys of the IP taken from the project proposal

3) The list of proposed chairs with the names of the Principal investigator (PI), the topic and proposed starting date. The appendix provides more details for each chair. While the Chairs are all part of an IP and thus are linked both to the pull of application problems and questions and to the push of theoretical research, we distinguish broadly three levels in how closely they are tied to applications or theory. The Chairs are grouped into three categories identified by three different colors:
    a. The Blue chairs are closely tied to theoretical concerns whether they have to do with the mathematical foundations of machine learning, to hybrid systems or to symbolic based representations and reasoning
    b. The Purple chairs are somewhere in the middle between theoretical concerns and applications: they are driven by a mixture of each.
    c. The Pink chaires are more oriented application of AI. Note that an application of AI need not be an industrial concern, however. It might be an application of AI to legal thinking, for instance.
4) A more detailed description of the IP outlining the objectives and the connection with the proposed chairs

Note that some chairs can contribute to two IPs.

IP1: Fair, representative data for AI

Synopsis: This program aims to develop techniques to tackle problems related to 1) the existence of bias in the selection and interpretation of data used by models of learning 2) the prevention of the risk of not taking into account rare events in the learning process 3) automatic annotation and semantic representation of heterogeneous, multi-source, multi-scale, and time-varying data masses. These locks are common to several areas of application including the environment, agriculture, health and transport.



Description:

This program has several parts. The first has to do with problems of bias and fairness in data, data selection and interpretation. Toulouse has expertise in this area and has proposed a local chair, J.M. Loubes (T0), to put 50% of his ANITI time on this topic. As this problem also has legal implications, we are proposing that 50% of C. Castet-Renard's ANITI time be dedicated here (T1).

A second theme that comes from several application domains has to do an unbiased selection of data on-line using a model to search. This model will rely on theoretical studies of bias, which is an expertise of the local chair (J.M. Loubes) as well as others on the Toulouse site. In addition, streaming algorithms will most likely be relevant to solving this problem; for this we will need outside help and plan to hire an external junior chair in this area in T2.

A third part has to do with the problem of how to prevent the erasing of improbable but extremely important events for the learning process, for which hybrid models may be useful. We are proposing Laure Raynaud as a junior chair in this area for T1.

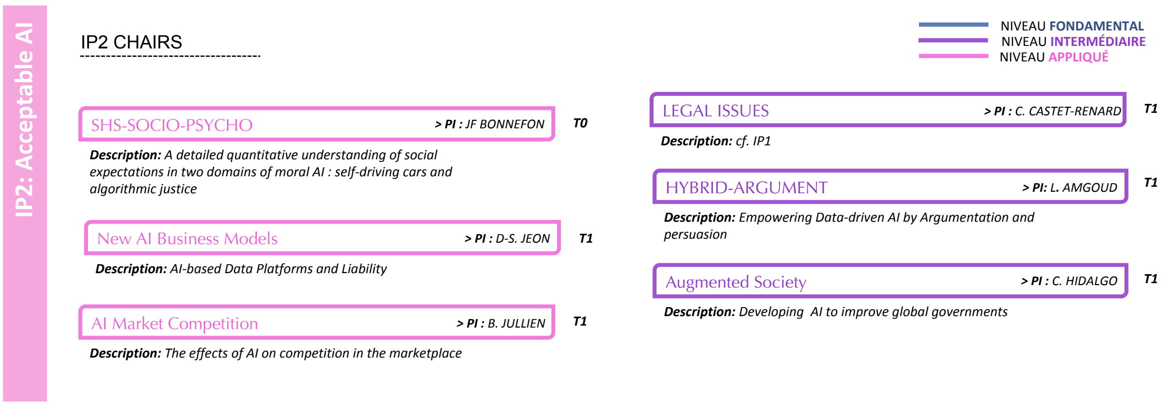
A fourth component of this research project has to with using Hybrid Track 1 for the semantic labeling of data. For this IRIT has strength in this area.

A fifth component has to do with multi source, multi-scale and temporally dynamic data. To get a comprehensive view of Earth's environment and that environment's evolution, for instance, we have to use space-based measurements (optical and radar imagery, altimetry, radiometry, gradiometry, atmospheric sounders…), as they provide global coverage of every component of Earth's environment (continental surfaces, oceans, atmosphere, solid earth), with regular revisits over a period of about three decades. A big challenge is to extract the right information from these highly data sets, which are heterogeneous in term of the nature of their measurements, their spatial or temporal resolutions to relative to a complex scheme of interactions, and in terms of the spatial and temporal variability (and non linearity) of the earth system. How can we harmonize such data in a coherent semantic representation? How can we learn from a temporally changing flux of data? How does that work for learning and for modification of theory? Another problem is considering multi-scale multi source data that evolves over time. Here we are proposing a local chair Nicolas Dobigeon (T0) to work on these topics. In general, hybrid AI algorithms will be easier to explain than pure machine learning algorithms. And to this end we are proposing Fabrice Gamboa as a senior chair in this area.

This program has applications to the Environment, Agriculture, Health and Transport sectors. For instance, in health, the proposed chair of Isabelle Berry will combine techniques in this IP for interpreting imaging with medical applications like cancer detection or the classification of skin lesions. Generally, the successful implementation of ANITI requires the availability of relevant datasets covering the various ANITI application domains. We have identified different types of data sets that are publicly accessible or that will be provided by the project partners covering in particular transport, mobility, environment or agriculture application areas. While the CHU and the university have worked together in Toulouse to build an HDS certified secure environment for accessing and sharing sensitive data in the health domain, challenges still exist on this issue.

IP2: Acceptable AI

Synopsis: This program deals with different facets of the problem of social, economic, legal and ethical acceptability of systems integrating artificial intelligence algorithms. Acceptability is intimately related to the ability to explain and interpret the results and behaviors of these algorithms and the confidence that can be placed in them. It also involves trade-offs in the performance of these algorithms and their economic impact.



Description:
This integrative program deals with several facets of AI acceptability and argues that the combination of outputs from ANITI core areas with research-based insights from social and human sciences can make AI systems more likely to be accepted. This has repercussions for all application areas.

AI acceptability depends to a large extent on its explainability, although all of the desirable properties for AI systems are in some sense relevant. We are proposing Leila Amgoud as a senior local chair to devote 50% of her time in ANITI to study how we can extract explanations and arguments from AI systems and how this relates to persuasion and bias, a theme of IP1. AI systems will typically be better accepted if they mimic human behavior/decisions. In particular we need to compare algorithmic decisions with human decisions in controlled environments, to which end we are requesting Bonnefon as a local senior chair (T0). Generally, elements of human cognition or "natural intelligence" like those discussed in Hybrid track 2 need to be integrated into AI systems to improve their acceptability. But explainability and "human-like" behavior of systems may involve trade-offs with other desirable properties (speed, quality). This IP will investigate such tradeoffs via an external chair (Conati T2).

Another factor that will affect AI's acceptability is its economic impact. Another aim of this IP is to study this impact and whether its potentially negative economic effects can be prevented (e.g. through regulation). In particular, the consequences of AI on the labor market are still not well understood and there are some potential dangers regarding the way AI affects competition: AI pricing algorithms can facilitate collusion among competitors, and the combination of powerful algorithms and large databases can create barriers to entry in data-intensive industries. Moreover, the use of AI-based data analytics by firms will generate "network effects" that will affect their strategies and the benefits that consumers reap from using their products. The Toulouse School of Economics has expertise in this area and we plan to hire two local chairs from TSE, Bruno Jullien and Doh-Shin Jeon (both at T1).

Another factor that could affect AI's acceptability are the risks for individuals and societies: explainability, fairness, non-discrimination, transparency, privacy, security, safety, and democracy concerns are the most frequently mentioned. AI needs to be human-centric, and respectful of fundamental rights. In a context of rapid technological change, it is essential that trust encourage the innovation and deployment of technologies. Trust in AI means to trust in a robust technology, as well as in the rules, laws, and norms that govern it. Most of them are outdated and we will develop a human-centric framework for trustworthy and competitive AI based on new legal rules, accountability governance of AI, and ethical purposes. Céline Castets-Renard (UT1) has expertise in this area, and we plan to hire her as a local chair (T1).
Another important question is, what are the roles of governments, senior management, and academic laboratories in promoting AI-enabled devices and applications among individuals, organizations and societies? Finally, AI acceptability depends on the way it affects, and is affected by, uncertainty. How should the absence of certainty affect the use of AI? We are proposing an external senior chair Cesar Hidalgo (T1), who investigates these questions.

This IP will benefit from ongoing international collaborations with several universities including MIT, Harvard, Yale, Boston University, University of British Columbia, and the University of Bologna.

IP3: AI towards autonomous critical systems

Synopsis: This program aims to develop new methods, models and tools based on hybrid AI to design and validate adaptive autonomous critical systems for which strong guarantees are required in particular from certification authorities (e.g. in Aeronautics), e.g., dependability, explicability, etc. Different levels will be considered, ranging from a component or embedded basic function, to the autonomous vehicle, to a fleet of vehicles or to the global transport system. In addition to the autonomy of the operations, the work will concern the autonomy of the maintenance activities including the automation of the monitoring activities of the systems and the associated recovery and reconfiguration actions.
These objectives concern the field of autonomous transport systems (aeronautics, automotive, space), but address similar issues in other areas of application such as health, industry or the environment.

Chairs: see Appendix for details for each chair

IP3: Certifiable AI toward autonomous criti. Sys.

IP3 CHAIRS

NIVEAU FONDAMENTAL
NIVEAU INTERMÉDIAIRE
NIVEAU APPLIQUÉ

- Data Assimilation and ML — > PI : GRATTON — T1
  Description: Efficient algorithms and Data Assimilation for Computationally Efficient Constrained Advanced Learning
- HYBRID ML and MODELING — > PI : ANGELOV — T1
  Description: Hybrid Learning and modeling
- HYBRID SUBSYMBOLIC → SYMB. — > PI : J.MARQUES SILVA — T1
  Description: The use of constraint satifaction methods in proving robustness for ML systems
- FAIRNESS/ROBUSTNESS — > PI: JM LOUBÈS — T0
  Description: cf. IP1
- GAMES and ADERSARIAL NETS — > PI : J RENAULT — T0
  Description: Game Theory and convergence for generalized Asdversarial nets and other ML architectures
- MATH INVARIANTS in ML — > PI: BARTHOLDI — T1
  Description: Geometric knowledge, invariants, and structural properties in Machine Learning
- LARGE SCALE OPTIMIZATION — > PI : BOLTE — T0
  Description: Large scale optim. for AI convergence properties/rates, global optim. & error bounds, design/optim. of the underlying geometrical structure, optim. of adversarial models
- POLYNOMIAL OPTIMISATION for ML — > PI : JB LASSERRE — T0
  Description: Polynomial optimization for ML using sum of squares/Lasserre hierarchies and functions for data analysis
- MIXED OPTIMISATION for ML — > PI: RONDEPIERRE — T1
  Description: Combining Discrete and Continuous Optimization for ML
- EMBRACING non Convexity — > PI: M.TEBOULLE — T1
  Description: Pushing the fronteer of non convex ootimization to more general setting and understanding why it works.
- CERTIFICATION — > PI: PAGETTI — T1
  Description: New certification approaches of critical AI based systems
- MOBILITY MANAGEMENT — > PI: DELAHAYE — T1
  Description: AI for Air Traffic Management and Large Scale Urban Mobility
- ADVANCED MACHINE LEARNING — > PI: To be Recruited — T1/T2
  Description: TBD

Description:

This integrative program focuses on certifiable AI for safety assured autonomous systems that will become a ubiquitous feature of future transport and mobility. We will develop methods, models and tools for hybrid AI solutions that define the functions required for adaptable autonomous systems, from sensors to systems of systems (e.g. fleets). We will also study tools to define and to verify the properties required for their proper functioning.

The Toulouse site is already home to research and development of many such systems in academia (ISAE-SUPAERO, ENAC, LAAS, ONERA, …) and industries: urban air mobility (Airbus, Thales, Delair, Eva, ...), autonomous terrestrial vehicles (Actia, Continental, Renault, Easymile, ...), and fleets of satellites, aircraft and heterogeneous entities. We have ongoing international collaborations on these topics: AI, Machine learning and Human-system interactions: Brown University Providence; Decision-making under uncertainty and safety constraints: Australian National University Canberra. Toulouse has a strong history of research on safety, dependability and system certification (LAAS, IRIT, ONERA, IRT Saint-Exupéry) in collaboration with industry (Airbus, Thales). As for international collaborations we have: AI and Systems Engineering: MIT Boston, Georgia Tech Atlanta, KTH Sweden.

Optimisation methods are crucial for all deep learning approaches from convolutional networks to the most sophisticated GANs. Their training boils down in the final analysis to some high dimensional optimisation problem with an often complex objective or loss function. While most of the currently fashionable optimisation methods have been around for a while, we still don't understand why simple methods like gradient descent or various first order methods work so well.

To determine exactly what are the limits of reliability and robustness for various learning systems, the local optimisation chairs with Bolte, Lasserre (T0) and associated researchers Pauwels and Filbet, which we will reinforce the external chair of Teboulle and local junior chair Rondepierre (T1), will examine problems of non-convexity, convergence rates of optimization methods, statistical risk bounds, adversarial regret bounds, and information-theoretic risk lower bounds. Using advanced mathematical ideas from geometry, game theory and topology the local chairs of Loubes/Renault (T0) and the Bartholdi external chair (T0) (with researchers Rachelson, Serrurier, and Gerchinovitz and Magouire) will also contribute to our understanding of learning architectures. To further strengthen research in this area, we also plan to hire one of our eminent visitors (Kwiatkowska, Anandkumar, Mausam) in machine learning to reinforce this area by T2.

However, providing absolute guarantees of reliability and robustness is particularly difficult if not impossible to achieve for many modern machine learning systems when considered in isolation. Using translation techniques from subsymbolic to symbolic representations, the external hybrid track 1 chair of Marques-Silva (T0) with local researcher Hebrard will verify or guarantee the robustness and explainability of learning models relevant to autonomous systems. This challenge can also be addressed when such systems are embedded in a larger context---for instance, when integrated in complementarity with other models as suggested in Hybrid track 2; this work will be carried out by chairs Angelov (T1) and Gratton (T0). Bringing this work into the domain of practical applications will be the subject of the chairs Pagetti/Delahaye (T1).

Autonomy concerns not only operations but also maintenance. As an example, we have in mind the automation of at least components of 100 hour inspections and their consequences. This will require techniques of similarity analysis that exploits both physical models and data-driven techniques, as well as symbolic reasoning and decision making. Another example is automated troubleshooting and reconfiguration of various systems like satellite constellations and aircraft.

Autonomous predictive care is also a concern for the medical industry (Oncopôle, Toulouse CHU, INSERM), when patients with critical issues are monitored by automatic systems (chair Andrieu). Autonomous monitoring systems are also a feature of the agricultural and environmental domains and are studied at for instance INRA, OMP, CNES.

IP4: AI Assistants

Synopsis: This program focuses on interactions between humans and AI systems and their complementarity in order to increase the performance of the activities implemented, thanks to hybrid AI. Two parts will be explored. In the first, the system integrating AI is a cognitive assistant that contributes to different human activities: a driver or a passenger in transport; a doctor, a multi-disciplinary medical team or a patient or user needing to be guided in his or her health care path, in an administration or a banking institution. These assistants will incorporate advanced dialogue and interaction capabilities, the design of which will be based on models characterizing human behavior from the cognitive sciences. The second part deals with the monitoring of complex systems in order to model their behavior and predict their evolution, to detect precursor symptoms that make it possible to anticipate incidents and to carry out corrective actions proactively. These issues are important for all ANITI application areas.

IP4: AI assistants

IP4 CHAIRS

NIVEAU **FONDAMENTAL**
NIVEAU **INTERMÉDIAIRE**
NIVEAU **APPLIQUÉ**

REVERSE-ENGINEERING the BRAIN — > PI: T.SERRE — T0
Description: *Reverse-engineering the brain to build machines that can see and interpret the visual world as well as humans do*

THEORY of MIND — > PI : A.HERZIG — T1
Description: *Reasoning and planning with other's beliefs and goals*

HYBRID-ARGUMENT — > PI : L. AMGOUD — T1
Description: *cf. IP2*

NEURO-ERGONOMICS — > PI: F. DEHAIS — T1
Description: *Neuro-adaptive Technology based Mixed-initiative to enhance Man-Machine Teams*

NEURO-INSPIRED DEEP LEARNING — > PI: R. VAN RULLEN — T0
Description: *Neuro-inspired Deep Learning : towards more human-like AI architectures*

DIAGNOSIS — > PI: L. TRAVÉ-MASSUYES — T1
Description: *Synergistic transformations in model based and data based diagnosis*

MEDICAL PREDICTIVE AI — > PI: S. ANDRIEU — T1
Description: *Prognostics and Predictive AI for Human Health*

AI for Transparent & Personalized Interaction — > PI: Conati/Carenini? — T2
Description: *TBD*

Description:

This IP will examine and harness the interaction between - and complementarity of - humans and AI systems where there is evidence from games (Atari, Go, Chess) that an integrated human/AI system performs better than each of them in isolation. A successful integration of human decisions and AI algorithms cannot rely on either machine learning models or symbolic inference rules alone. While learning basic interactions involving speech and movements seems feasible with current deep learning methods, the ability to persuade a human counterpart or to take decisions in complex systems will in all likelihood have to rely on higher level logical representations. In particular, the AI assistant will most likely have to have at least a rudimentary model of its human counterpart, in order to reason about his needs and beliefs effectively. Thus, we envision hybrid AI as a key enabler of future human/AI systems.

This IP naturally divides into two cases. The first is one where the AI system is a cognitive assistant that can support many human activities: a pilot, driver, passenger, operator, maintainer in transport; for doctor, multidisciplinary medical team, a person requiring orientation in the health care system, in a financial or administrative institution will all benefit from such assistants. To this end, we will investigate cognitive interactions with humans as well as cognitive modeling. This will require exploiting logic based but also cognitive science based models. To study the persuasive aspect in particular, we propose that Amgoud devote 50% of her chair to this issue. In order to have these models adapt to the peculiarities of particular human counterparts, our AI assistants will also have to incorporate elements of human like learning visual processing and language, thus naturally implicating some sort of hybrid architecture in which an abstract model is integrated with a data-driven one. We are proposing two senior chairs in this area--- one external for Thomas Serre from Brown and one local for Rufin van Rullen (T0).

Such AI assistants should also have advanced language and dialogue capabilities, which we will derive from studies of human behavior. Toulouse has strong academic expertise in language models and argumentation (IRIT), qualitative reasoning (IRIT) and mixed-initiative planning (ONERA, LAAS, ISAE-SUPAERO), and neuroscience and cognition (CRCA/ CERCO, TMBI). We plan to hire in this area in T2 (Carenini, Conati).

The second type of AI system involves monitoring of complex systems and diagnosis of faults. This will involve the modeling of the normal behaviour of the system in order to predict the system evolution, detect anomalies and anticipate incidents. This problem covers prognostics & health management of a vehicle (drone, aircraft, ground vehicle), a robot or a machine in manufacturing, anticipation of a patient's heart attack in an Intensive Care Unit, etc. For this we will once again mix physical models and data-based models (from sensors time series data). We are proposing Louise Travé as a senior chair (T0) in this area for systems. We will propose a local (Sandrine Andrieu, Inserm) or external senior chair in T1 to research prognostics and predictive AI for human health (Toulouse CHU) based on various optimization and algorithmic efficiency techniques developed in AI math core track 1 as well as mixed physical/symbolic models investigated in hybrid track 2.

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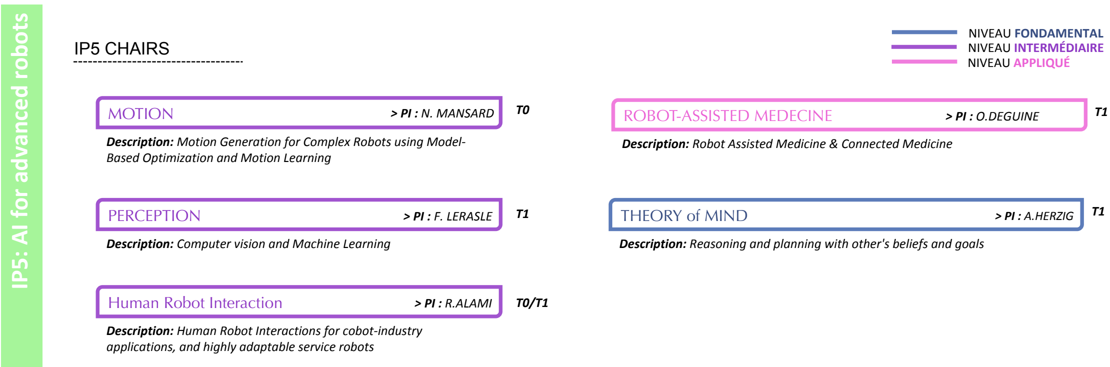
IP5: AI for advanced robot motion and interaction capabilities

Synopsis: This program focuses on the study and design of autonomous mobile robots with human, cognitive and physical interaction capabilities (manipulate / move objects, apply forces, ...), in order to perform complex tasks in collaborative way. This requires advances in several areas 1) the perception of the environment (location and detection of the presence of humans, fusion and integration of multi-modal and multi-sensory data, etc.) 2) the generation of motion for anthropomorphic robots with multiple degrees of freedom and which are subject to several constraints inherent in their mode of mobility and dynamics) the physical and cognitive interaction between humans and robots which involves the development of learning techniques by discussion and by observation and interpretation of actions performed by humans. These topics have applications in several areas including industry 4.0 and services, agriculture or health.



Description:

This integrative program will endow mobile robots with the capability to move and interact autonomously. Here “interacting” means acting physically on the environment (applying forces, carrying tools, manipulating objects,…) but also having cognitive interaction with humans. This requires advanced computational abilities to deal with the key problems of perception, interpretation, motion generation and cognitive reasoning [1].

For perception, we need to provide robots with the capability to perceive their environment, localize their position and the presence of humans in their vicinity and regulate their displacement by integrating motion plans and sensor-based control loops. We want to investigate the fusion of multimodal cues (image, video, audio, haptic, proprioception…)[6] to improve the system robustness to scene variability. Combining model-based and deep-learning approaches will improve multisensory and sensorimotor integration in the robotics framework. We also aim at optimizing the embeddability of the proposed solutions.

Motion generation is also a key integrative challenge for AI. Mobile robots are complex systems that include many degrees of freedom and are subject to numerous constraints inherent in their dynamics and their locomotion mode. Today, most proven motion generation approaches rely on model-based predictive control which explicitly optimize the future robot behavior based on the knowledge of its physics [7]. New approaches have emerged in the past decade that aim at using machine learning, notably reinforcement learning, to solve the motion generation problem by exploring large volumes of data [8, 9]. The two approaches are complementary. Though model-based trajectory planning methods guarantee awareness of the physics of systems, they become extremely tedious as soon accurate representations are required (actuator dynamics, flexibilities, contact representation, friction, ….). Furthermore, they do not allow robots to exploit knowledge from past motion experience. Reinforcement learning techniques are efficient in extracting representative features from data by capitalizing from knowledge without requiring a model. But the exploration strategies on which they depend can hardly cope with the high dimension of typical robot state spaces (up to 100 for a humanoid robot). We will rely on model-based trajectory planning to explore possible motion strategies [10] and reinforce the motion generator using what has already been learned in an incremental way [11], thus providing a particular kind of hybrid model based AI. Nicolas Mansard is our local candidate chair for this topic (T0). We will reinforce this chair with work on vision with local chair Frederic Lerasle in T1.

At a higher integrative level, we want to make robots able to interact with humans both in a physical and cognitive way. In the context of Industry 4.0, service robotics or health care, robots must be able to move in a robust, adaptive and safe way amidst humans, with a high level of autonomy [12]. This challenge will be led by local chair Rachid Alami (T0). To make robots that interact and act jointly with humans, we will in T2 endow them with sophisticated natural language capabilities. In particular robots should be able to learn from human tutors by discussion, which goes beyond current paradigms of learning by demonstration (in which the robot learns an action by observing it being performed by a human tutor). In learning by discussion, the robot not only observes an action but acquires knowledge about the action — in particular why the action needs to be performed in a certain way or how the action resembles actions the robot already has in its repertoire. We plan to hire Alex Lascarides as a senior chair in this area in T2.

These AI systems will have a wide range of possible interactive tasks with humans. We plan to focus on three of them: autonomous teammate robots (or cobots) that will work in collaboration with human workers, 2) cognitive and interactive mobile assistants for people in need of constant care, 3) highly adaptive service robots in public spaces, digital agriculture and other areas. Each of the areas mentioned above will leverage theoretical advances in robotics in similar but distinct ways. For instance, the industrial cobot or the care assistant robot will ideally have a model of the human's goals and beliefs [14] and preferences, in order to synthesize behaviors that are acceptable and legible by their human partners [15]. We are proposing a local senior chair A. Herzig for this area (T1). As an example of robotics applications in tasks of type 2, we are proposing a senior local chair Olivier Deguine. We are also proposing a senior chair F. Dehais for enhancing human interactions with artificial agents through neuro-ergonomics.

Toulouse is a unique place in France in academic research in robotics (LAAS, ONERA) gathering skills in robot motion and task planning, in robot decision making, and in Human System Interaction (IRIT). In particular LAAS has a recognized expertise with robotics pioneers and a new generation of talented researchers, and a robotic platform, unique in Europe. Several collaborations exist with industry (e.g., LAAS-Airbus joint lab ROB4FAM, partnerships with Continental, Siemens, Robotics Place, etc.), with academic partners in France such as LIRMM, and at the international level (e.g., H2020 projects Mummer, Euroc, Aeroarms, …), in particular with Germany (DLR, Univ. Heidelberg, KIT, …).

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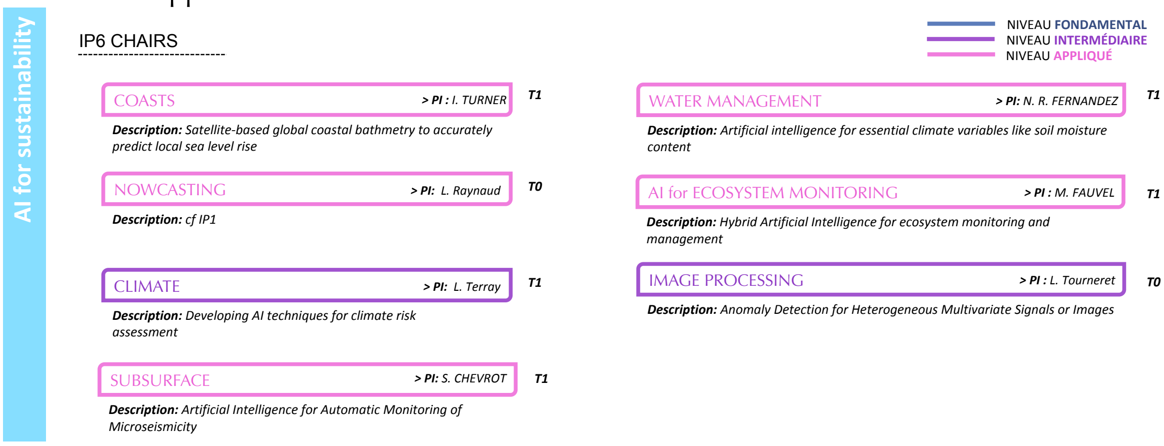
IP6: AI for a sustainable planet: From monitoring to management

Synopsis: This program aims to better understand and predict the impact of human activities on the evolution of the state of the planet. The ambition is to contribute to the development of a more sustainable society by relying on the expertise of the Toulouse site in the field of observation and prediction of the state of the environment (remote sensing, observation of the earth, atmosphere and oceans, biodiversity, etc.), and the availability of large, multi-source and multi-scale, very rich data masses. The aim is to take advantage of fundamental advances in the field of hybrid AI by integrating heterogeneous physical / chemical / biological / economic models for 1) a better prediction of extreme natural events (sudden floods, tornadoes, etc.).), the evolution of the state of the coast (erosion, flood,) and the oceans (sea level rise, dispersion of contaminants, ...) 2) integrated and sustainable management of continental water resources to find acceptable trade-offs in terms of biodiversity, productivity, and ecosystem supply; 3) optimization of geophysical exploration processes; and 4) contribution to the definition of public policies in the field of protection of the ecosystem integrating socio-economic and legal dimensions.

Chairs: see Appendix for details for each chair



Description:

This integrative program aims to understand, explain and predict the links and interactions between human activities and the continuously evolving and unstable "state of the planet". The situation is urgent and critical, as emphasized by high-level international organisations such as the UN and as recognised and supported at the national level (e.g. the presidential programme "Make Our Planet Great Again").

Placing AI at the heart of these efforts is a strategic key to better decisions and organization of relevant services. AI can help extract relevant information from ever more numerous and detailed monitoring programmes, while also providing essential inputs for the definition of new courses of legislative and societal action. Given the local academic and industrial strengths, the focus of this IP will be on the water cycle, with the following specific goals:

Better atmospheric, weather and climate models. This will require expertise in image analysis and for this we are proposing J. Y. Tourneret for a senior chair. This will enable us to predict extreme chaotic events at short time and length scales (e.g. tornadoes, flash floods), where hybrid AI will improve robustness and time of convergence of current models and can increase the reliability of the warning system using genuine AI decision-support tools (Laure Raynaud's T0 chair of IP1 will be relevant here). We will use techniques from the Statistics, Optimization and Scientific Computing for Machine Learning Track to provide algorithms that converge (as fast as possible) to stable results, and techniques of uncertainty quantification and sensitivity analysis to the question of data quality and propagation of uncertainties. Addressing very large high-dimensional problems (e.g. ensemble of numerical weather prediction models, very high-resolution simulations) will be crucial. We plan to propose L. Terray for long term climate forecasting in T1 or T2.

Better models for protecting the ocean and the coastline. We will integrate remote sensing, modelling of the ocean circulation (e.g. dispersion of contaminants) physical/chemical/ biological models of ocean and coastal dynamics and data driven models using techniques of Hybrid Track 2 (data-based vs model-based) to predict coastline changes, erosion, flooding, contamination and storm (marine) surges alerts, sea-level rise projection. We are proposing an external senior chair Ian Turner (Australia) (T1) to manage this topic.

Managing, in a sustainable way, water resources on land (soil moisture, rivers/lakes level changes, groundwater), for example, applying deep- and machine- learning techniques to 4D remote sensing and in-situ data sets for water management, including trade-offs between productivity, biodiversity and ecosystem services provision. We are proposing a junior local chair (T0) Nemesio Rodriguez Fernandez for this topic.

Techniques for finding and exploiting subsurface resources. We will embed data processing/classification probabilistic models in physical based models using techniques from Hybrid Track 2 to improve the interpretation of multi-scale and multi-source datasets used for geophysical exploration. We are proposing Sebastien Chevrot accompanied by Roland Martin, who has considerable ML expertise, as a local chair for this area in T1.

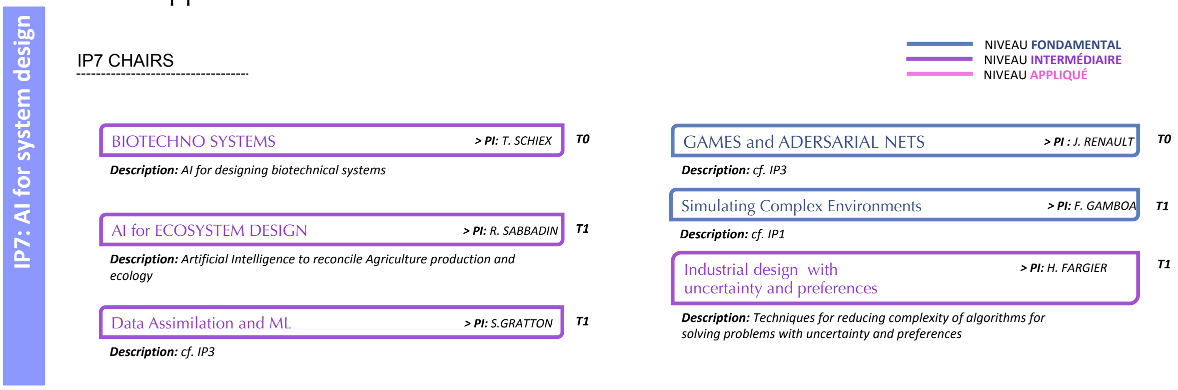
We will use hybrid AI approaches to graphically represent interactions between humans and the environment to describe and predict interactions between climate, environment, health, economy, ethics, law and politics. Mathieu Fauvel is a proposed junior chair for this topic (T1).

Toulouse and the Occitanie region have recognized world-class academic excellence in relevant fields (Remote sensing, Oceanography, Earth Science, Atmospheric Science, Water Resources, Ecology, Economics - all ranked in the world's top-50). In addition, the presence of strong communities working in the fields of the Social Sciences (UT2J), Health and Economics (TSE, ranked 17 by ARWU in 2018), make Toulouse ideally placed to make ground-breaking contributions in the emerging interdisciplinary field of "Sustainability Science". It is also home to major state-funded structures that provide remote sensing data of the Earth (CNES, SPOT image, Airbus Defence and Space, etc.) and meteorological surveillance and forecasting (MétéoFrance). Huge amounts of high-quality data relevant to this field are thus available. The Occitanie region is hosting over 10 of the 35 prestigious "Make Our Planet Great Again" international researchers, underlining the academic potential in this field. Finally, Toulouse has a rich ecosystem of private companies extending from large multinationals involved in making satellites to local start-ups involved in providing environmental services. All of this will contribute to a large spectrum of downstream activities (e.g. health, agriculture, defence) and build bridges to major complementary initiatives such as the Space Climate Observatory pioneered by France.

IP7: AI for design of innovative systems and products

Synopsis: This program aims to develop automated methods based on hybrid AI to optimize the engineering, design and evaluation of innovative systems and products. The fields of application are diverse, for example, aeronautics or automobile transport systems and infrastructures with the objective of implementing design approaches optimized by mission-driven design; bio and nanotechnologies including the design of new molecules, or agriculture for the optimized design of agro-food products, from the gene to the biological product (enzymes, yeasts, plants), with the aim of reducing the use of inputs, better resistance to pathogens and diseases and a better match between organic products and their environment. The work will require advances in the use of multi-source, multi-scale data, the coupling of heterogeneous and multidisciplinary models, as well as the development of multi-criteria optimization approaches based on heuristics combining learning techniques and models. Taking into account the economic dimension (forecasting markets, estimating competition, etc.) and its impact on the design process is also an important issue.

Chairs: see Appendix for details for each chair



Description:

This IP is about the use of AI methods for automatically exploring, evaluating and optimizing designs of innovative systems and products. This task is already underway in Toulouse in several areas: bio and nanotechnologies including drug design, agriculture, transport and aeronautics, manufacturing, etc.

To give some details, in biotechnology, the recent capacity of AI to perform automated reasoning will enable us to design the main molecules of life, proteins, and open the way to a more environment-friendly chemistry. In agriculture, AI will enable farmers to produce better and healthier products while reducing the environmental footprint with the creation of new genetic varieties of plants, new methods of crop production and optimized agro-ecosystems, improved biomass valorization and even new food products. In transport and industry, we see the following applications: new mission-driven vehicle design, city multi-modal transport infrastructure design, etc.

In each of these domains, we will rely on the output of IP1 to have good and fair data sets.In particular, for agriculture we will integrate multi-sensor data RGB, NIR, multi-spectral, LiDAR on different vectors: robots on the ground, drones, satellites. This will allow predict more accurately properties of interest for agricultural production (vigor, population, senescence, architecture) and finalized technical characteristics (content of molecules of interest: proteins, oil, carbohydrates). As to the automation of design itself, we will exploit techniques from Hybrid track 1 that will allow us to move from information graphs to causal graphs in (coexpressed) gene networks, for instance. In addition, the design problems require us to reason simultaneously on many different interacting components, defining complex optimisation problems (NP-hard for the discrete and non-convex ones). The efficiency of the associated algorithms is a constant issue that can be addressed by having algorithms that learn heuristics while solving a single problem or that learn how to solve specific families of problems. INRA has worked extensively on these issues, with industrial partners like Biogemma and Syngenta.

We will also make use of techniques from Hybrid track 2 for injecting physical constraints and knowledge into data driven models. Because of the extreme complexity of design problems, computational design often relies on semi-empirical models that accumulate simplification assumptions. More realistic models often exist but are not amenable to a form that is suitable to optimization. These sophisticated models can be used to produce in-silico data for ML/DL to build better empirical models that would be efficient and amenable to optimization. To study this issue, we are proposing that Gratton's (T0) and Gamboa's (T1) chairs have 50% time allotted to this issue in this IP.

This requires also methods to decide which data needs to be produced for efficient unbiased learning, and ML methods to produce empirical models in a mathematical form suitable for optimization/design. Once again INRA researchers have worked on this. ONERA, IRT Saint-Exupéry and Airbus have exploited multi-disciplinary optimization in integrating physical and data-driven models for mission-driven product design. We are proposing Thomas Schiex as a senior local chair for this topic (T0), with help on mixed optimisation from Rondepierre (IP3). We are also proposing Helene Fargier as a senior local chair to deal with design issues involving beliefs and preferences of consumers or users of the designed system (T0). We are proposing local chair Regis Sabbadin to examine AI design for environmental systems to preserve biodiversity (also relevant to IP6).

Finally, designing distributed systems with both cooperative and non-cooperative agents is an important topic for all kind of business, but especially the air transport industry in Toulouse (aircraft design based on market prediction and competitor assessment) and automotive industry (autonomous vehicles driving along with piloted vehicles). This will require collaborative research between economists, game-theorists and statisticians (TSE, IRIT, ENAC, LAAS) and industry partners (Airbus). And in particular, this will require marrying symbolic models like those in game theory with a complex high dimension data set describing the actual empirical decision. Senior local chair Jerome Renault will pilot this part of this IP.