Summaries of the presentations during the environment and digital day

Tuesday, octobre 19th 2021

Processing and analysis of genomic data

- **Genomic data indexing, from generic search engine to bacterial strain identification**

  Pierre Peterlongo (GENSCALE)

  Suppose you happily suspect “ACGGCAT…CGGATAG” to be a piece of a gene acting as a major component in a critical research domain, e.g. plant resistance to drought or plankton adaptation to climate change. The next step would be to check whether this gene or a very similar version has already be seen somewhere or not. And if this is the case the following steps are to check the potential differences, to check the context where this gene was seen, and, at best, to check if it was already associated with specific species or strain, and to a particular phenotype. Surprising as this may seem, these searches are not feasible on a world-large scale today.
  In this talk, I will explain this context, and I will show the work in progress made in the team to offer research engines able to answer such queries.

- **Detection of genomic variants in natural populations to study the evolution and adaptation of various insect species**

  Claire Lemaitre (GENSCALE)

  Analyzing sequence differences between the genomes of individuals sampled from natural populations provides a better understanding of how species evolve and adapt to their environment. Current sequencing technologies allow the acquisition of sequence data for many individuals at low cost. However, the data produced are massive, fragmented and noisy and require specific computational processing to reconstruct genomic information and detect variation efficiently. In the Genscale team, we are involved in several projects on the ecology and genomics of insect species, such as the pea aphid and Amazonian mimetic butterflies. We will present several methods we have developed in this context to better detect and interpret genomic variations in these data.

- **Integration and analysis of heterogeneous biological data modelled with multilayer graphs and applied for a better understanding of variations in feed efficiency of growing pigs**

  Camille Juigné (DYLISS)

  The pork industry is facing several issues related to competition, competitiveness and the environment. Improving feed efficiency is a good solution to address these issues. Feed efficiency (FE) is the efficiency with which the bodies of growing pigs convert animal feed into quality meat by maintaining all the physiological functions of the animals, by reducing effluents and by optimizing the use of ressources. Thus, the objective of this thesis is to develop methods and analyses for the integration of multi-omics data to identify the mechanisms responsible for differences in FE and the biological bases of this inter-individual or inter-lineage variability.

Environmentally friendly cyber-physical systems

- **SeDuCe (Sustainable Data Centers), a Grid'5000 site partially powered by renewable energies.**

  Jean-Marc Menaud (STACK)

SeDuCe is a scientific datacenters testbed, supply by renewable energy sources, to enable experiment-driven research on both thermal and power management aspects of parallel and distributed computing system (Cloud, HPC etc.). The testbed is physically hosted at the IMT Atlantique, Nantes campus, and one of the Grid'5000 sites.

Any Grid'5000 user can reserve servers of the ecotype cluster and conduct experiments on them by using the usual Grid'5000 tools. The testbed is designed for research related to power and thermal management in datacenters: during an experiment, a user can access in real time to information regarding the temperature of the servers involved in its experiment, and get the power consumption of any parts of the testbed (servers, switches, cooling systems, etc.), or control some parameters of the testbed, such as setting temperature targets for the cooling systems of the cluster.

SeDuCe is partially powered by renewable energies. During the day, photovoltaic panels, produce enough energy for our cluster. Different photovoltaic panels orientations and technologies are installed, thus making it possible to compare the approaches.

This talk introduces this infrastructure.

- **Energy-efficient computing architectures through hardware acceleration**

  Olivier Sentieys (TARAN)

  Energy efficiency has now become one of the main requirements for virtually all computing platforms. Computer architects are however facing new challenges for the next couple of decades, with the most prominent one being the end of CMOS scaling (Moore's law). Our belief is that the key to sustaining improvements in performance (both speed and energy) is domain-specific computing where all layers of computing, from languages and compilers to runtime and circuit design, must be carefully tailored to specific contexts. In this new age, the processor will be augmented by a bunch of hardware accelerators meant to perform specific tasks in a more efficient way. Our research team focuses on designing accelerators that can prove energy-efficient and fault-tolerant. Another key ingredient to these frugal architectures is accurate computing. It consists in minimizing the number of binary digits used for a given calculation. Converting for instance the code from floating-point to computing with few bits translates into huge gains. In this talk we elaborate the challenges

of domain-specific computing and illustrate them by some concrete examples of energy-efficient or ultra-low-power computing platforms that can be used in applications related to environment and ecology.

- **Towards Smart cyberphysical systems**

  Benoît Combemale (DIVERSE)

  Cyber-Physical Systems involve numerous interconnected components that sense or enact on the physical world to support customized software services for human beings. From a software and systems engineering point of view, such systems are essentially complex sociotechnical systems that lead to the development of dynamically adaptable systems. The adaptability with regards to the physical environment comes from a feedback (control) loop (e.g., MAPE-K loop) assimilating data from the sensors, building a model of the surrounding environment, planning or possibly predicting new scenarios, and soliciting the actuators accordingly, in the form of a sequence of actions.
  As any sociotechnical systems, the planning process is usually semi-automatic, highly interacting with final users to provide the best experience. Various software services have been developed in the past decade, e.g., leveraging important frameworks developed by the Internet of Things community (e.g., protocols and gateways), and leading to a wide range of smart systems in energy, production systems, robotics, transportation, healthcare, agriculture among others. The smartness of the system comes from the ability to bring intelligence into the feedback loop. This intelligence primarily leverages the assimilation and curation of the acquired data. This need is currently supported by the concept of digital twin. However, as a sociotechnical system, it is of outermost importance of also considering broader physical, economic, social and environmental concerns in which the systems and final users involved. Since such information is difficult to get from sensors, or to hard-code into the software itself, additional information must be combined with the available data to provide an holistic and systemic view of the system and its environment, support for taking informed decisions.
  When comes the time of designing such a feedback loop, modeling appears to be key. Modeling is key to capture any sort of knowledge in the form of descriptive models built from acquired observations or data, and modeling is also key to drive the development and evolution of complex systems in the form of

prescriptive models reducing the accidental engineering complexity. The gap between the descriptive models and the prescriptive models can be made manually, or automatically through predictive models.
In this talk, I review the various types of models required for intelligently designing cyber-physical systems, and I discuss the different roles such models are playing in the overall lifecycle. I present the opportunities for the modeling community, as well as the open challenges to be tackled to achieve such a vision. In particular, I explore the required common modeling foundations for seamlessly combining the different types of models, and the associated modeling environments to support a broader engagement and take informed decisions.

Wednesday, octobre 20th 2021

Optimization and Energy

- **Shape optimisation: a technical solution for the future of the aircraft industry?**

  Enora Denimal (I4S)

  Despite the climate crisis, the number of air travellers continues to rise every year. According to some scenarios, this number could triple by 2035. However, the aviation industry predicts that by 2050, C02 emissions will be half of what they were in 2005, leaving room for technical and scientific innovation. One of these solutions consists of lightening various components while increasing their efficiency, now made possible by the arrival of additive manufacturing (3D printing). The presentation focuses on work carried out in this context to optimise the shape and/or topology of turbine components in order to improve their non-linear vibratory performance, with a particular focus on frictional dampers.

- **Towards an intelligent management of infrastructures and buildings for energy optimization.**

Jean Dumoulin (I4S)

As part of the energy transition (i.e. saving energy and reducing consumption of fossil fuels), many studies and developments have been carried out on the use of renewable energies (water, wind, solar, waves). In addition, apart from actions to rehabilitate built heritage (large energy consumer), energy optimization avenues combining models and measurements for the dynamic management of such systems are also explored. These avenues may also include adding new features to existing infrastructures in an attempt to reduce the impact of climate change (e.g. urban heat islands) or even moderate surface temperatures in winter. In the context of this presentation, after having briefly introduced the case of buildings, we will focus on adding functionalities to transport infrastructures subjected to a variable natural environment. Some examples of work on such structures ranging from energy recovery to surface temperature control will be presented and discussed.

- **Modeling energy networks with Modelica : the scalability challenge**

  Benoît Caillaud (HYCOMES)

  Modelica language is perfectly suitable for modeling energy networks. The paradigm underlying the Modelica language, the multimode Differential Algebraic Equations (mDAE), enables the use of a physical component-based modeling methodology. Multimode models are often improperly handled by state-of-the-art Modelica tools. The cause of this difficulty lies in the approximate structural analysis method implemented in Modelica compilers: Models are considered as if they had only one mode, and the code generated by these compilers is most often incorrect. The Hycomes team has designed an mDAE structural analysis algorithm, that can be used to perform, at compile-time, an exact strcutural analysis, for all modes at once. This algorithm is based on symbolic techniques, using Binary Decision Diagrams (BDD). A compositional structural analysis technique will be detailed, that enables the compilation of large mDAE systems, such as those used to model energy networks.

- **Modeling and optimization of Smart Grids.**

  Anne-Cécile Orgerie (MYRIADS)

Smart Grids rely on ICT infrastructures to jointly optimize electricity production, distribution and consumption. Understanding this tight coupling between the electrical grid and its ICT control infrastructure is crucial to ensure performance and to move towards the ultimate goals of reducing overall consumption and integrating a greater share of electricity from renewable energy sources. This talk will present our work on the co-simulation of Smart Grids and our study on the impact of network latency on on-line shedding strategies.

Frugal computing

- **Frugal distributed systems: from measuring their energy consumption to quantifying and reducing their environmental impact**

  Anne-Cécile Orgerie (MYRIADS)

  Cloud computing and distributed systems are increasingly spanning worldwide, with digital services hosted all around the globe and often belonging to complex systems, utilizing many other services and hardware resources themselves. Along with this increase comes an alarming growth of Cloud devices and their related energy consumption. Despite the distributed systems' complexity, understanding how they consume energy is important in order to hunt wasted Joules. This talk will present our work on measuring and understanding the energy consumption of distributed systems, as well as quantifying their environmental impact. This step is essential to propose effective strategies for frugal distributed systems.

Stochastic ocean modeling

- **Stochastic modelling of large-scale geophysical fluid flows**

  Etienne Mémin, (FLUMINANCE)

  In this talk, I will describe a formalism, called modelling under location uncertainty (LU), to derive in a systematic way large-scale stochastic representations of fluid flows dynamics. This modelling enables to take into account in the evolution laws the neglected small-scale effects through the introduction of a random field.

The resulting dynamics is built from a stochastic representation of the Reynolds transport theorem. This formalism enables, in the very same way as in the deterministic case, a physically relevant derivation (i.e. from the usual conservation laws) of the sought evolution laws. We will in particular show how to derive systematically stochastic representation of flow dynamics. We will give several examples of simulations obtained by such system and how an ensemble of such realizations can be used in data assimilation or for uncertainty quantification.

- **Next-generation satellite altimeter SWOT for tackling the internal wave challenge in the ocean**

  Noé Lahaye (FLUMINANCE)

  SWOT satellite, who will have a novel generation altimeter onboard, is expected to be a major innovatios of the next decade in spatial oceanography. Expectations and challenges will be discussed, particularly in relation to internal waves – ubiquitous current and density perturbations propagating through the ocean. These waves, which play a key role in the global ocean circulation and climate, have a signature at the sea surface. In the context of observation-based estimates, this constitutes one the one hand a challenge for the estimation of near-surface currents, but on the other hand an opportunity for a better estimation of their dynamics. These challenges call for innovative model/observation coupling methods. »

Digital Agriculture

- **Haptic shared control of heterogeneous human-robot team for environmental monitoring**

  Claudio Pacchierotti (RAINBOW)

  Teams of coordinated robots have been proven useful in several high-impact applications, including urban search and rescue (USAR), disaster response, and environmental monitoring. While most approaches consider the sole presence of robotic teams, we have recently focused on the control of heterogeneous teams

composed of an arbitrary number of mobile robots (drones and ground robots) as well as humans, for collaboratively achieving more complex tasks in a distributed way. Differently from other works, here the human users physically become part of the team, moving in the same environment of the robots and receiving information about the team connectivity through wearable haptics or audio feedback. While the human explores the environment, the robots move so as to keep the team connected and fulfil a specific task, e.g., visit a part of the map to register an environmental parameter of interest.

- **AgriSense: a platform for precision agriculture**

  Frédéric Weis (EASE)

  Very small and connected objects (microcontrollers) are now capable of executing software codes, driving different types of sensors, exchanging data with other devices in their physical neighborhood, and pre-processing the data for cleaning/aggregation. The AgriSense platform aims to investigate the use of these objects for crop monitoring. In this talk, we will highlight the main technological barriers that limit their use for digital agriculture: having an open node at the software level, managing the energy consumption of the node while exploiting different types of sensors. We will show the first experimental results obtained with this platform in collaboration with the DEMECOLOGY team of INRAE.

- **Analysis of sensor data from precision breeding**

  Véronique Masson (LACODAM)

  More and more farms are equipping their animals and buildings with sensors in order to have a finer monitoring of key parameters of each animal in the herd. Within the framework of the Convergence Institute #DigitAg, the Lacodam team collaborates with the UMR Pegase of Inrae Rennes to analyze the data from this type of sensors. This work focuses on the analysis of uni or multi-varied time series, in the context of dairy or pig farms. The issues addressed range from animal reproduction (ovulation detection) to animal welfare assessment. The presentation will show what data science can bring in each of these cases.

Digital sciences and technologies and ecology

- **The LivingFog platform, from water consumption measurement to environmental monitoring**

  Guillaume Pierre (MYRIADS)

  The LivingFog platform was developed by seven talented PhD students taking part of the FogGuru European project. It enables its users to process IoT data transmitted using the LoRa wireless networking technology immediately next to the LoRa gateways which receive the information. This, in turn, brings low response times, reduced usage of long-distance networks and better resilience to networking outages. The platform was initially developed to process data coming from smart water meters, then extended to support an IoT hackathon in the Marina in València (Spain), and is now one of the main building blocks for a new PIA3 project on natural environment monitoring.

- **SmartSense: a sensor network platform for energy and usage management in buildings and beyond**

  Olivier Sentieys (TARAN) introduced by Guillaume Pierre (MYRIADS)

  With 150 nodes deployed in the buildings of INRIA/IRISA (Lannion and Rennes), SmartSense can collect a large amount of data on energy consumption and usage in buildings. This data allows a large number of applications, notably in data mining, disaggregation of electrical loads or AI-based sensor data processing. Each node includes about 20 sensors: image, infrared, audio, radio spectrum, inertial unit, humidity, pressure, temperature, light (red, green, blue, white, UVA, UVB), distance radar with centimeter accuracy, CO2+VOC. A version developed for deployment in an outdoor environment is currently being tested in collaboration with OSUR/Géosciences Rennes (SmartObs and Terra Forma projects).

- **AI Interpretability/Explainability for Meta-Modeling. Application to the field of Agro-Ecology**

  Tassadit Bouadi (LACODAM)

In the context of modeling and simulation of complex systems, the model is seen as an abstraction of the related system, and the simulation as an experimental design that allows the exploration of a multitude of scenarios. These models are often very complex and are seen by the user as black boxes.

The TNT2 agro-hydrological model, developed by the UMR SAS of Inrae Rennes, is an example of this type of models.
In the framework of this work, the Lacodam team collaborates with the UMR SAS to develop a meta-model based on the TNT2 simulations.
The objective of this work is to exploit a set of simulations in order to deduce sets of operating rules, which thus constitute a simplified model of the initial model (i.e. a meta-model). In other words, we wish to open the black box in order to understand how it works, and to propose a simplified representation.

More exactly, we propose to transpose our meta-modeling problem to the IA interpretability/explainability problem.

- **Microbial ecology : elucidate and take advantage of the diversity of bacterial functions**

  Anne Siegel (DYLISS)

  Microbial and systems ecology aims at understanding interactions between a consortium of microbes and a host organism, where a “host” can be a plant, an algae, or a human. This issue is more and more crucial at the environmental scale since it has been proved that microbes interact with their environment in order to provide some specific nutrients and facilitate the adaptation of the host to external perturbations. In this talk, we will detail the issues raised by the interpretation of microbial diversity (metagenomics) into functional large-scale models of host-microbes consortia and the solutions needed to analyse these systems.