UMR IRISA

Activity Report 2025

Team VIRTUS

The VIrtual Us

Joint team with Centre Inria de l'Université de Rennes

D5 – Virtual Reality, Virtual Humans, Interactions and Robotics

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Project-Team VIRTUS

Creation of the Project-Team: 2022 July 01

Each year, Inria research teams publish an Activity Report presenting their work and results over the reporting period. These reports follow a common structure, with some optional sections depending on the specific team. They typically begin by outlining the overall objectives and research programme, including the main research themes, goals, and methodological approaches. They also describe the application domains targeted by the team, highlighting the scientific or societal contexts in which their work is situated. The reports then present the highlights of the year, covering major scientific achievements, software developments, or teaching contributions. When relevant, they include sections on software, platforms, and open data, detailing the tools developed and how they are shared. A substantial part is dedicated to new results, where scientific contributions are described in detail, often with subsections specifying participants and associated keywords. Finally, the Activity Report addresses funding, contracts, partnerships, and collaborations at various levels, from industrial agreements to international cooperations. It also covers dissemination and teaching activities, such as participation in scientific events, outreach, and supervision. The document concludes with a presentation of scientific production, including major publications and those produced during the year.

Keywords

Computer sciences and digital sciences

A5.5.4. – Animation

A5.6.1. – Virtual reality

A5.6.3. – Avatar simulation and embodiment

A5.11.1. – Human activity analysis and recognition

A9.3. – Signal processing

Other research topics and application domains

B1.2. – Neuroscience and cognitive science

B2.8. – Sports, performance, motor skills

B7.1.1. – Pedestrian traffic and crowds

B9.3. – Medias

B9.5.6. – Data science

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1 Team members, visitors, external collaborators

Research Scientists

- Julien Pettre [Team leader, INRIA, Senior Researcher, HDR]
- Samuel Boivin [INRIA, Researcher]
- Stéphane Donikian [INRIA, Senior Researcher, from Apr 2025, HDR]
- Ludovic Hoyet [INRIA, Researcher, HDR]
- Katja Zibrek [INRIA, ISFP]

Faculty Members

- Kadi Bouatouch [UNIV RENNES, HDR]
- Mathieu Chambe [UNIV RENNES, from Sep 2025]
- Marc Christie [UNIV RENNES, Associate Professor]
- Anne Helene Olivier [UNIV RENNES II, Associate Professor, HDR]

Post-Doctoral Fellows

- Agathe Bilhaut [UNIV RENNES II, Post-Doctoral Fellow, from Apr 2025 until Aug 2025]
- Ahmed Syed [INRIA, Post-Doctoral Fellow]
- Pierre Vauclin [UNIV RENNES II, Post-Doctoral Fellow, from Sep 2025]
- Lezhong Wang [UNIV RENNES, Post-Doctoral Fellow, from Dec 2025]

PhD Students

- Kelian Baert [TECHNICOLOR, CIFRE]
- Thomas Bouyer [CEA, CIFRE]
- Philippe De Clermont Gallerande [INTERDIGITAL, CIFRE]
- Celine Finet [INRIA]
- Théo Gerard [UNIV RENNES]
- Bhaswar Gupta [UNIV RENNES, from Dec 2025]
- Alexis Holzbacher-Jensen [INRIA, from Nov 2025]
- Alexis Holzbacher-Jensen [UNIV RENNES, until Oct 2025]
- Kilian Marcelin [INRIA, from Nov 2025]
- Jordan Martin [LCPP]
- Xiaoyuan Wang [ENS RENNES]
- Tony Wolff [UNIV RENNES]
- Kebing Xue [INRIA, from Oct 2025]

Technical Staff

- François Bourel [UNIV RENNES]
- Bhaswar Gupta [INRIA, Engineer, until Oct 2025]
- Anthony Mirabile [UNIV RENNES , from Sep 2025]
- Alice Phung-Ngoc [UNIV RENNES, Engineer, from May 2025]

Interns and Apprentices

- Iwan Derouet [INRIA, Intern, from Jun 2025 until Aug 2025]
- Theo Hourmand [ENS RENNES, Intern, from Oct 2025]
- Raphaël Manus [Ecole Polytechnique]
- Raphael Manus [Université de Rennes]
- Clara Moy [ENS RENNES, Intern, until May 2025]
- Alexis Pechard [UNIV RENNES II, Intern, from Dec 2025]
- Mehmet Akif Sahin [INRIA, Intern, from Jun 2025 until Aug 2025]
- Alexandre Watrin [INRIA, Intern, from Mar 2025 until Aug 2025]

Administrative Assistant

- Gwenaelle Lannec [UNIV RENNES]

Visiting Scientists

- Krista Best [Université Laval, CIRRIS, from Sep 2025 until Oct 2025]
- Arnau Colom Pasqual De Riquelme [UNIV POMPEU FABRA, from Apr 2025 until Jun 2025]
- Jean-Bernard Hayet [CIMAT, Mexico, from Dec 2025]
- Vinu Kamalasanan [TU Clausthal, Allemagne, from Sep 2025 until Sep 2025]
- Francisco Ortega [Colorado State University, from Jul 2025 until Jul 2025]
- Angelo Silvino [Université de Campania Luigi Vanvitelli, from Sep 2025]

External Collaborator

- Aline Hufschmitt [UNIV RENNES]

2 Overall objectives

The VirtUs research team focuses on developing tools for building and studying the usage of immersive simulations of populated spaces.

2.1 Context

Virtual reality has made significant breakthroughs in several specific domains that are central to our research interests. First, in the professional sphere, particularly within the creative industry, virtual reality has joined the palette of tools used in the production of works, especially complex productions such as films. In other domains, virtual reality serves as a communication tool. While this also extends to the industrial sector, these applications are highly developed in the private sphere, where virtual reality has been recognized as a potential medium for distant social relations that are enhanced compared to existing communication means. Finally, virtual reality is being exploited in our own field, scientific research, where it has proven to be a powerful research tool that complements the experimental apparatus used by researchers to explore human behavior when exposed to certain situations, here recreated through the medium of virtual reality.

2.2 Research Vision

VirtUs was born from the observation that, across all these applications, a salient research challenge concerns populated immersive universes. This represents a particularly difficult aspect in the development of tools, a difficulty that arises specifically from the need to represent and animate humans in the scene. This challenge stems from the complexity and variety of human behaviors, as well as from users' sensitivity to the quality of these representations. VirtUs emerged from the desire to provide technical solutions to these needs, but also to test them against specific use cases, including the domains mentioned above.

The necessary qualities of immersive content and the technical means to create them are intimately linked to the domains in which they are applied. The required level of visual realism, the flexibility needed for content creation, and the expressiveness of content for communicating certain information differ radically from one type of application to another. A strategic positioning of VirtUs is to be scientifically engaged on both these facets: the creation of tools for immersive simulation and the exploration of applications of our simulators, with a central focus on the human agents that populate our scenes.

This dual commitment allows us to advance both the technical foundations and the practical understanding of populated virtual environments. On one hand, we develop novel computational approaches for representing and animating virtual humans with varying degrees of fidelity and behavioral sophistication, addressing challenges in real-time rendering, crowd simulation, and procedural animation. On the other hand, we engage with concrete application domains to understand how different requirements—whether it be the photorealistic rendering needed for creative industries, the communicative clarity required for social VR platforms, or the experimental control necessary for scientific research—shape the design and implementation of our simulation tools.

The VirtUs team's approach is fundamentally interdisciplinary, bringing together expertise in computer graphics, artificial intelligence, human-computer interaction, and cognitive science, complemented by collaborations with domain experts from creative industries, social sciences, and applied research fields. By maintaining this bidirectional engagement between technical innovation and application-driven research, we aim to create immersive simulation tools that are both scientifically rigorous and practically relevant, advancing our understanding of how populated virtual environments can serve diverse professional, creative, and scientific purposes.

3 Research program

In concrete terms, our overall objective translates into scientific objectives for the VirtUs team across the following themes:

Modeling and Animation of Virtual Humans. This theme encompasses the performance of animation techniques for virtual reality applications, the physical and perceptual realism of animations, real-time interaction capabilities, and the controllability of behaviors to develop scenarios. Our research addresses the fundamental challenge of creating virtual humans that are not only visually convincing but also behaviorally responsive and adaptable to diverse interactive contexts.

Massive Scene Population Techniques. This work focuses on scaling to large environments, crowd modeling and simulation, and the authoring of populated scenes. We investigate methods that enable the creation of densely populated virtual spaces while maintaining computational efficiency and behavioral plausibility, from procedural generation techniques to intelligent distribution algorithms that respect spatial and social constraints.

Augmented Scene Capture and Composition Techniques. This theme includes scene capture, performance capture, tracking, and scene representation and rendering. Our research explores how to bridge the gap between real-world observations and virtual reconstructions, developing pipelines that can efficiently capture, process, and integrate real human performances and environments into immersive simulations, enabling hybrid approaches that combine captured and synthetic content.

4 Application domains

Application Domains VirtUs targets three major application domains:

4.1 Design and Management of Public Spaces

Context: Working with railway stations (SNCF) and mass events (Paleo, Hellfest)
Applications:

- Evaluation of public space design before construction
- Flow prediction and venue layout optimization
- Crowd safety and comfort assessment
- Emergency evacuation planning
- Dense crowd behavior analysis
- Festival and event management

Objective: Enable managers to immerse themselves in virtual replicas of spaces to assess design quality and collect behavioral data from immersed participants.

4.2 Social Virtual Reality and Wellbeing

Context: Communication and interaction in populated virtual worlds
Applications:

- Avatar-mediated communication
- Interactive virtual agents for psychotherapy
- Study of embodiment and presence
- Ethical considerations in the Metaverse
- Detection and prevention of inappropriate behavior
- Mental health and wellbeing in VR

Objective: Create realistic expressive virtual agents capable of natural interaction while addressing ethical issues and promoting user wellbeing.

4.3 Creative Industries (Cinema and Visual Effects)

Context: Film production, animation, and visual content creation

Applications:

- Virtual reality as a design tool for filmmakers
- Pre-visualization of complex scenes
- Character animation workflows
- Seamless integration of virtual objects into real footage
- Cinematographic style transfer
- Volumetric content authoring
- Camera control and virtual cinematography

Objective: Support the creative process by providing immersive tools for scene design, shot composition, and content manipulation, leveraging VR to enhance filming and post-production workflows.

Unifying Paradigm: Across all domains, VirtUs leverages Extended Reality (XR) both as a **support for technological innovation** (enabling designers to experiment with creations) and as a **scientific research tool** (exposing users to controlled, repeatable situations for behavioral observation).

5 Social and environmental responsibility

The VirtUs team is tackling the environmental issue by reshaping its ecosystem, in particular by redeveloping its national network, and is putting its scientific objectives and methodological approach at the service of applications linked to low-carbon energy mobility.

5.1 Footprint of research activities

VirtUs is seeking to reduce its footprint by 'relocating' its research activities and redeploying its local network within France. In particular, the team has submitted several collaborative research projects at national level with joint partners, including the SNCF (the national rail transport company), the "Museum National d'Histoire Naturelle", as well as the Gustave Eiffel University.

Some members of the VirtUs team, and in particular Ludovic Hoyet, CRCN Inria, are actively taking part in discussion groups on reducing the carbon footprint generated by research activities. For example, he is one of the two "Environmental Impact Reduction and Awareness Chairs" for the IEEE VR 2025 conference.

5.2 Impact of research results

VirtUs is also revisiting the applications of its research, seeking to address issues related to mobility and low-carbon modes of travel. Working with the SNCF, the VirtUs team is looking to tackle issues of crowd management in transport infrastructures. With teams from the University of Gustave Eiffel, VirtUs is exploring issues relating to the development of multi-modal traffic zones, and in particular pedestrian-bicycle interactions. Finally, with the "Muséum National d'Histoire Naturelle", VirtUs is exploring applications to Marine Biology, to better understand the impact of human activities on marine wildlife.

6 Highlights of the year

6.1 Strong involvement of the team in organizing the IEEE VR 2025 conference

Participants: Julien Pettré *(contact)*, Anne-Hélène Olivier, Ludovic Hoyet, Katja Zibrek.

Several members of the VirtUs team were heavily involved in organizing the IEEE VR conference. In particular, Anne-Hélène Olivier served as co-general chair for the conference. Katja Zibrek was XR Gallery co-chair (a new chapter for this conference introduced in 2025). Ludovic Hoyet was Environmental Impact Reduction and Awareness co-chair. Gwenaelle Lannec was Local Arrangement co-chair. Julien Pettré was Social Events chair. Several students or engineers in the team also took part to the organisation team, including Céline Finet and Rémi Cambuzat.

6.2 Team evaluation

In its fourth year of existence, the team was evaluated during the September 2025 wave. The evaluation is still being finalized, but the experts' reports highlighted the very high quality of VirtUs' scientific contributions during its first period (July 1, 2022 - August 31, 2025).

7 Latest software developments, platforms, open data

7.1 Latest software developments

7.1.1 AvatarReady

Name: A unified platform for the next generation of our virtual selves in digital worlds

Keywords: Avatars, Virtual reality, Augmented reality, Motion capture, 3D animation, Embodiment

Scientific Description: AvatarReady is an open-source tool (AGPL) written in C#, providing a plugin for the Unity 3D software to facilitate the use of humanoid avatars for mixed reality applications. Due to the current complexity of semi-automatically configuring avatars coming from different origins, and using different interaction techniques and devices, AvatarReady aggregates several industrial solutions and results from the academic state of the art to propose a simple and fast way to use humanoid avatars in mixed reality in a seamless way. For example, it is possible to automatically configure avatars from different libraries (e.g., rocketbox, character creator, mixamo), as well as to easily use different avatar control methods (e.g., motion capture, inverse kinematics). AvatarReady is also organized in a modular way so that scientific advances can be progressively integrated into the framework. AvatarReady is furthermore accompanied by a utility to generate ready-to-use avatar packages that can be used on the fly, as well as a website to display them and offer them for download to users.

Functional Description: AvatarReady is a Unity tool to facilitate the configuration and use of humanoid avatars for mixed reality applications. It comes with a utility to generate ready-to-use avatar packages and a website to display them and offer them for download.

URL: https://gitlab.inria.fr/avatar/avatarready

Contact: Ludovic Hoyet

7.1.2 PyNimation

Keywords: Moving bodies, 3D animation, Synthetic human

Scientific Description: PyNimation is a python-based open-source (AGPL) software for editing motion capture data which was initiated because of a lack of open-source software enabling to process different types of motion capture data in a unified way, which typically forces animation pipelines to rely on several commercial software. For instance, motions are captured with a software, retargeted using another one, then edited using a third one, etc. The goal of Pynimation is therefore to bridge the gap in the animation pipeline between motion capture software and final game engines, by handling in



Figure 1: Picture of the Infinadeck platform

a unified way different types of motion capture data, providing standard and novel motion editing solutions, and exporting motion capture data to be compatible with common 3D game engines (e.g., Unity, Unreal). Its goal is also simultaneously to provide support to our research efforts in this area, and it is therefore used, maintained, and extended to progressively include novel motion editing features, as well as to integrate the results of our research projects. At a short term, our goal is to further extend its capabilities and to share it more largely with the animation/research community.

Functional Description: PyNimation is a framework for editing, visualizing and studying skeletal 3D animations, it was more particularly designed to process motion capture data. It stems from the wish to utilize Python's data science capabilities and ease of use for human motion research.

In its version 1.0, Pynimation offers the following functionalities, which aim to evolve with the development of the tool : - Import / Export of FBX, BVH, and MVNX animation file formats - Access and modification of skeletal joint transformations, as well as a certain number of functionalities to manipulate these transformations - Basic features for human motion animation (under development, but including e.g. different methods of inverse kinematics, editing filters, etc.). - Interactive visualisation in OpenGL for animations and objects, including the possibility to animate skinned meshes

URL: https://gitlab.inria.fr/lhoyet/pynimation

Contact: Ludovic Hoyet

7.2 New platforms

7.2.1 Infinadeck omnidirectionnal treadmill

Participants: Anne-Hélène Olivier *(contact)*, Julien Pettré.

The VIRTUS team has recently acquired an omnidirectional treadmill, the Infinadeck, significantly strengthening its experimental infrastructure for immersive virtual environment research. The Infinadeck is an active-surface locomotion platform based on an array of independently actuated conveyor modules arranged along two orthogonal axes. This design enables real-time compensation of the user's movements, keeping the user centered on the platform while allowing natural walking in all directions, including forward,

backward, lateral motions, and rotations. The system relies on high-frequency position and velocity sensing combined with a low-latency real-time control loop, ensuring precise, stable, and responsive behavior. Fully compatible with standard virtual reality systems (HMDs and optical or inertial tracking solutions), the Infinadeck supports realistic walking speeds and substantial user loads, making it a state-of-the-art device for research in VR locomotion, human-environment interaction, and movement behavior analysis.

7.3 Open data

UnderPressure
Web site: https://doi.org/10.57745/FYXKXY
Self-assessment:

- Dataset Family: Dataset as a Vehicle for Research.
- Audience: dataset made openly available to people inside and outside the field
- Free Description: UnderPressure is a unique dataset of human motion sequences captured together with pressure insoles data, which was captured originally for our work on detecting human foot contacts and estimating ground reaction force for footskate cleanup of motion capture data.

4DHumanPercept
Web site: https://doi.org/10.57745/NZHDFY
Self-assessment:

- Dataset Family: Dataset as a Vehicle for Research.
- Audience: dataset made openly available to people inside and outside the field
- Free Description: his dataset was created for and used in the work ”Quality assessment of 3D human animation: Subjective and objective evaluation”. It contains virtual human animations acquired using a 4D acquisition system and distorted along controlled factors with corresponding per- ceptual similarity labels [11].

Pushing
Web site: https://doi.org/10.5281/zenodo.10512651
Self-assessment:

- Dataset Family: Dataset as a Vehicle for Research.
- Audience: dataset made openly available to people inside and outside the field
- Free Description: This dataset is composed of C3D files corresponding to full body motion of participants undergoing external perturbation at shoulder height with different sensory conditions. The temporal force profiles of the perturbations are also available.

8 New results

8.1 Classification of first recovery steps after quiet standing following external perturbation from different directions

Participants: Julien Pettré *(contact)*, Anne-Hélène Olivier, Ludovic Hoyet.

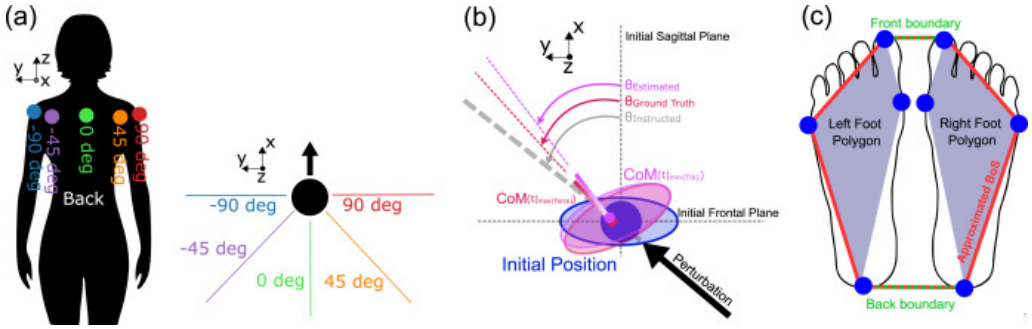


Figure 2: Overview of the different variables of the methods: (a) Instructed angles and the location of the perturbation application. For clarity, the referential of the instructed angles has been redefined in this study compared to Chatagnon et al. (2023). (b) Representation of the perturbation angles. The Instructed angle (gray) is defined as the angle between the initial sagittal plane and the perturbation direction given to the experimenter. The Ground Truth angle (red) is the angle between the sagittal plane and the direction of the participant's CoM velocity at peak perturbation intensity. The Estimated angle (purple) corresponds to the angle between the sagittal plane and the CoM velocity direction at the moment of minimal Ttb before step initiation. (c) Representation of the BoS, depicted as the polygon formed by linking all external foot markers (red). Blue dots indicate the positions of the motion-capture markers. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

The paper [8] and the poster [22] are related to our studies on physical interactions in dense crowds. It focuses on the recovery of equilibrium after disturbances that can occur during these interactions. Recovery from external perturbations typically involves stepping, with the perturbation direction playing a key role in determining the recovery strategy. To date, classifications of these stepping strategies have relied on prior knowledge of perturbation direction, which is not always available when considering experimental paradigms close to real-world scenario. Here, we introduce a novel Unified classification method that enables the labeling of first recovery steps based solely on body kinematics. We have also developed and validated a logistic regression model that effectively differentiates between different recovery strategies. The key ideas of the classification method is illustrated in Figure 2.

8.2 Herds From Video: Learning a Microscopic Herd Model From Macroscopic Motion Data

Participants: Julien Pettré *(contact)*.



Figure 3: Our method can simulate individual agents to replicate herd behaviour learnt from a video containing many animals. [Left and middle] The original video (lower-right) and our simulation (upper-left), optimized to fit the macroscopic density and velocity fields over a coarse grid. [Right] An authored simulation in which a herd transitions between the two illustrated behaviours, featuring narrow and broad formations.

We present a method for animating animal herds that automatically tunes a microscopic herd model from a short video clip of real animals, building on recent work on learning collective motion from dense visual observations [9]. The method targets dense herd scenarios, where individual motions cannot be reliably

extracted due to occlusion and limited observability. Our main contribution is a novel framework that infers macroscopic herd behavior from such videos and subsequently derives the microscopic agent parameters that best reproduce this behavior. Some results of the method are illustrated in Figure 3.

To enable this learning process, we extend standard agent-based models by introducing an explicit separation between leaders and followers, incorporating realistic occlusion and field-of-view constraints inspired by animal perception, supporting differentiable parameter optimization, and improving authoring control. We validate our approach by demonstrating that, once optimized, the learned social-force and perception parameters are sufficiently accurate to predict subsequent frames of the video, including macroscopic properties not explicitly used during optimization, in line with and beyond the predictive capabilities reported by Gong et al.

Furthermore, the extracted herding characteristics can be transferred to new terrains using a palette- and region-painting approach that generalizes across different herd sizes and leader trajectories. This enables the authoring of herd animations in novel environments while preserving the learned collective behavior.

8.3 Eliminating bias in pedestrian density estimation: A Voronoi cell perspective

Participants: Julien Pettré *(contact)*.

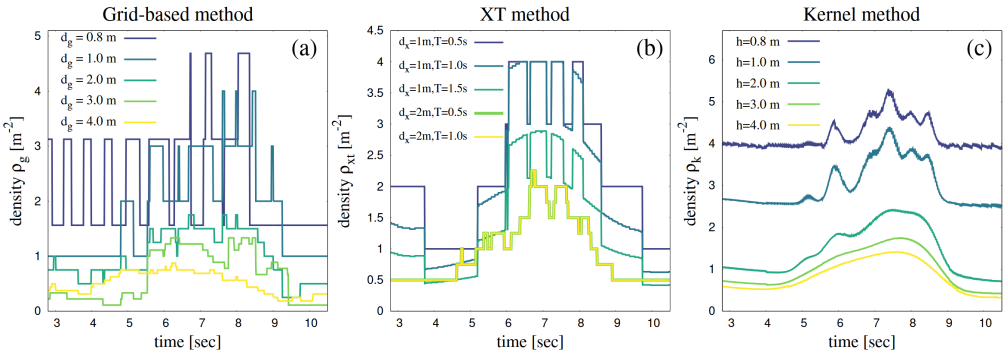


Figure 4: Temporal variations of density as a function of time, along the trajectory of a given pedestrian. Density is determined by (a) the classical grid-based method, (b) the XT-method, (c) the Gaussian kernel method. Time sequences are shown for several values of the spatial scale dg , dx, or h and in (b), of the time window T.

For pedestrians moving without spatial constraints, extensive research has been devoted to density estimation methods. In the paper [10], we introduce a new approach based on Voronoi cells that enables density estimation for individuals within small, unbounded pedestrian groups. A comprehensive evaluation of existing methods—including both Lagrangian and Eulerian approaches commonly used in similar contexts—reveals significant limitations. In particular, these methods are often ill-defined for realistic density estimation along an individual pedestrian's trajectory, exhibiting systematic biases and fluctuations that depend on parameter choices.

This motivates the need for a parameter-independent method capable of eliminating such biases. We therefore propose a modification of the widely used Voronoi-based density estimator that is applicable to pedestrian groups regardless of their size. The proposed method is instantaneous, requiring only the pedestrians' positions at a given time, and does not rely on tunable parameters. It provides a realistic estimate of local density in an individual's neighborhood and retains a clear physical interpretation for both small groups and large crowds across a wide range of situations. We conclude the paper with general remarks on the interpretation and meaning of density measurements in small pedestrian groups, as illustrated in 4.

8.4 Daily and seasonal spatial behaviour of waved whelk Buccinum undatum: implications for fishery management and restoration

Participants: Julien Pettré *(contact)*, Anne-Hélène Olivier.

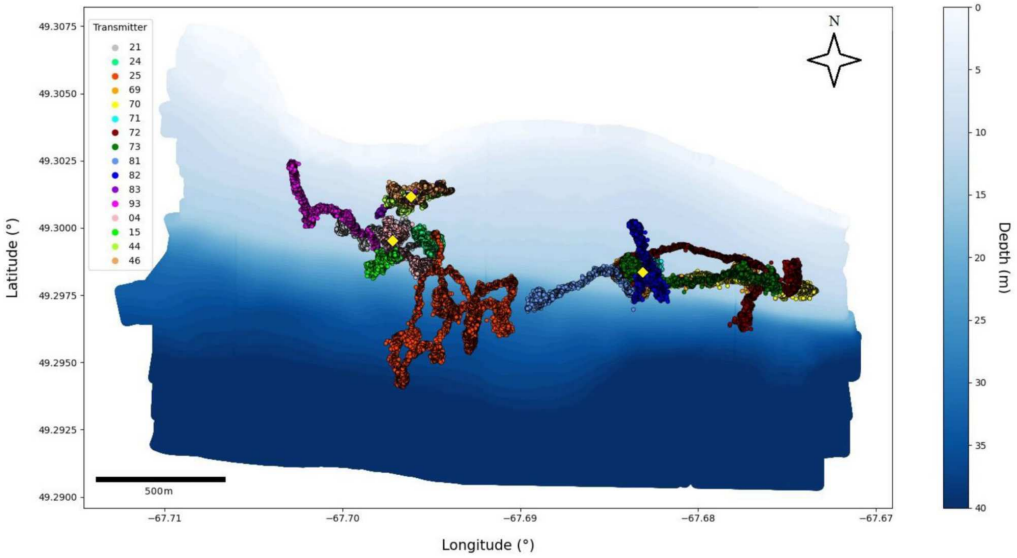


Figure 5: Recorded location of all 2020 tagged individuals from October 2020 to October 2021 with respect to bathymetry of the Petite baie de Saint-Nicolas. Tags (No. 21/24/25) show displacements from August 2019 to October 2021. The yellow diamonds represent the east and west main release points of the tracked individuals of waved whelks Buccinum undatum during the study period.

In the paper [12], we applied our methods to study spatial behaviours to marine species in collaboration with tehe Museum National d'Histoires Naturelles. Many marine invertebrate fisheries are vulnerable to overexploitation and therefore require effective conservation measures to ensure long-term sustainability. In recent years, landings of the waved whelk Buccinum undatum (Linnaeus, 1758) have declined markedly along the coasts of the St. Lawrence (Canada), with decreases of up to 76% reported in some fishing areas. Local overfishing may be partly explained by the species' oviparous reproductive strategy, which limits larval dispersal and restricts connectivity among populations.

Using a two-year acoustic telemetry study, we tracked 20 individuals to characterize their movement behavior and assess their potential for spatial dispersal (illustrated in Figure 5). Tagged whelks exhibited substantial daily movements, with mean speeds ranging from 2 to 16 $m.h^{-1}$, and showed no significant differences between day and night activity. Both movement speed and habitat usage potential (HUP) varied seasonally, likely reflecting the reproductive cycle: HUP was significantly greater during the breeding season in May (4570 m^2) and June (2779 m^2) than during the preceding winter months (1046 m^2).

Although some individuals traversed a broad depth range, no seasonal pattern was observed along the bathymetric gradient. Overall, the species' limited habitat usage potential constrains individual dispersal, resulting in weak connectivity between neighboring populations and increasing the vulnerability of Buccinum undatum to local overfishing.

8.5 Learning extremely high density crowds as active matters

Participants: Julien Pettré *(contact)*.

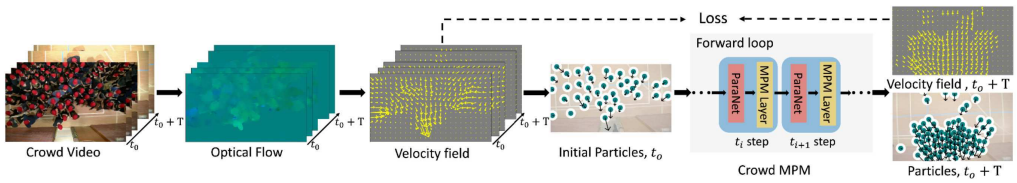


Figure 6: Overview. From left to right: optical flow estimation, velocity field generation, initial particle sampling, crowd simulation and loss calculation.

Video-based analysis and prediction of high-density crowds has long been a challenging problem in computer vision. Progress has been hindered by the scarcity of high-quality data and the intrinsic complexity of dense crowd dynamics, where severe occlusions and visual ambiguity make individual tracking or head counting unreliable. As a result, this regime remains relatively under-explored.

In the paper we published in CVPR 2025 [15], we introduce a novel approach designed to learn directly from in-the-wild videos, including low-quality footage where standard individual-based methods fail. Our key contribution is the introduction of a physics-based prior for crowd dynamics. We model high-density crowds as active matter: a continuum of active particles subject to stochastic forces, which we term crowd material. This formulation captures collective dynamics beyond individual-level representations.

We combine this physics model with neural networks, resulting in a neural stochastic differential equation framework capable of reproducing complex crowd behaviors. We illustrate our method in Figure 6 Owing to the lack of closely related work, we adapt several existing methods for comparison. Extensive evaluations demonstrate that our approach consistently outperforms state-of-the-art methods in both analysis and forecasting of extremely high-density crowds.

Importantly, our model operates in continuous time and is grounded in physical principles, enabling both simulation and interpretability. This stands in contrast to most existing deep learning approaches, which rely on discrete-time formulations and largely function as black boxes.

8.6 Evaluation of Body Parts Representations in Motion Reconstruction

Participants: Philippe De Clermont Gallerande, Ludovic Hoyet *(contact)*.

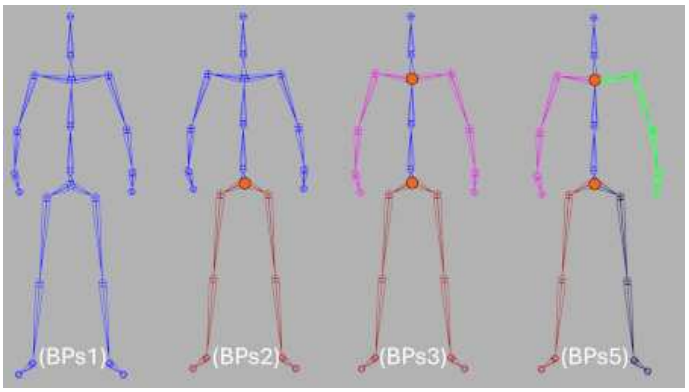


Figure 7: The different body decompositions evaluated in our work [14]. A Body Parts (BPs) model is a wrapper of one, or several, neural networks reconstructing a body part motion. They are linked together by overlapping joints: the BPs Connectors (orange circles). From left to right: BPs1 (whole-body), BPs2 (upper/lower body), BPs3 (spine, arms and legs) and BPs5 (spine, right/left arm, right/left leg).

Acquiring, encoding, transmitting, decoding, and displaying motion signals is an essential challenge in our new world of interconnected immersive applications (XR, online games etc.). In addition to being

potentially disturbed by multiple factors (e.g., signal noise, latency, packet loss), this motion data should be modifiable and customizable to fit the needs of specific applications. Simultaneously, several approaches have successfully proposed to explicitly integrate the semantics of the human body in a deep learning framework by separating it into smaller parts. In this work [14], we propose to use such an approach to obtain a robust streamed animation data. Specifically, we create and train several neural networks on the motion of different body parts independently from each other (Figure 7). We further compare the performances of several body decompositions using multiple objective reconstruction metrics. Eventually, we show that this Body Parts approach brings new opportunities compared to a compact one, such as a perfectly partitioned and more interpretable motion data, while obtaining comparable reconstruction results.

8.7 How do people perceive changes in physical bounce model for virtual racket interactions?

Participants: Ludovic Hoyet *(contact)*.



Figure 8: The experimental VR Setup used in [17]. Left: picture of a participant performing the "Perception-Action" block. Right: generic virtual room displayed in the head mounted display.

Nowadays, Virtual Reality is widely used in sports, to enhance physical fitness, or improve specific subskills, such as anticipation skills. However, many factors in VR can alter the experience and make it difficult to transfer the skills trained in VR to real practice. One of these factors is the physical simulation of the virtual environment, that may produce unexpected behaviours. Hence, if users are athletes in ball-based sports, the VR training simulator should compute ball trajectories that look plausible for them. In this work [17], our aim is to evaluate how human perception can be influenced by variations in a ball physics' model. We explore properties of human perception, the acceptance threshold beyond which a deviation from the reference ball trajectory is perceived more than 50% of time, and the Just-Noticeable Difference (JND) as an indicator of perceptual sensitivity. To this end, we conducted psychophysical experiments where participants were asked to either only observe, or observe and hit virtual bouncing balls simulated with varying coefficients of restitution (COR). We report the acceptance threshold and JND in different conditions. We found that participants detected variations in COR more easily when having the motor task. Additionally, their sensitivity to variations was globally higher when they first performed the perceptual task alone, before the motor task was introduced. These results contribute to the design of credible VR environments involving bouncing objects, such as for virtual sports.

8.8 Quality assessment of 3D human animation: Subjective and objective evaluation

Participants: Ludovic Hoyet, Anne-Hélène Olivier *(contact)*, Katja Zibrek.

Virtual human animations have a wide range of applications in virtual and augmented reality. While automatic generation methods of animated virtual humans have been developed, assessing their quality

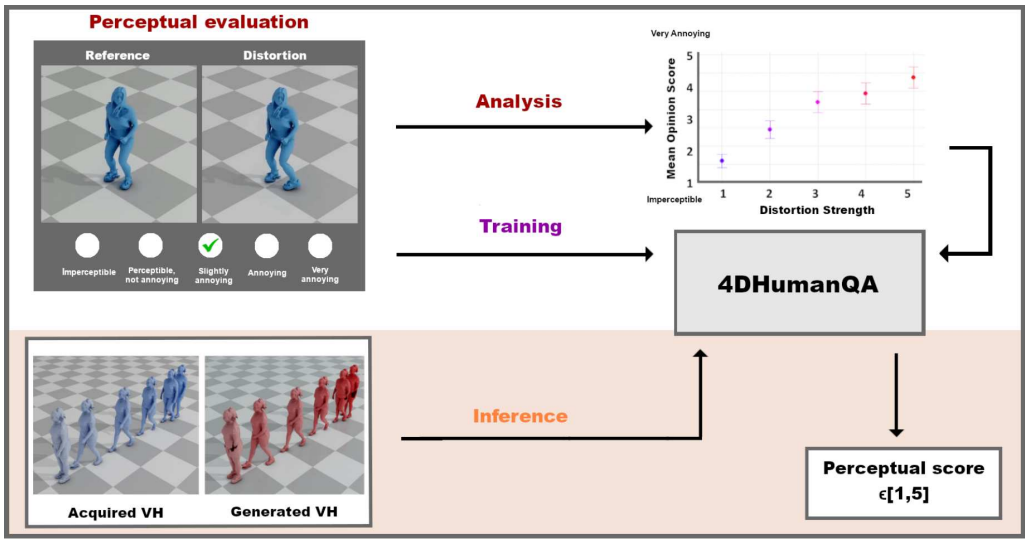


Figure 9: We conducted a perceptual evaluation to collect subjective scores for visual distortions of generated 3D human animations with respect to corresponding references, which are the acquired 3D reconstructions of real actors. We used the resulting *"4DHumanPercept"* dataset to first analyse the factors influencing human motion realism, and second, to learn a data-driven model called *"4DHumanQA"* that predicts a perceptual score for 3D human animation realism.

remains challenging. Recently, approaches introducing task-oriented evaluation metrics have been proposed, leveraging neural network training. However, quality assessment measures for animated virtual humans that are not generated with parametric body models have yet to be developed. In this context, we introduced in this work [11] a first such quality assessment measure leveraging a novel data-driven framework. First, we generated a dataset of virtual human animations together with their corresponding subjective realism evaluation scores collected with a user study. Second, we used the resulting dataset to learn predicting perceptual evaluation scores. Results indicate that training a linear regressor on our dataset results in a correlation of 90%, which outperforms a state of the art deep learning baseline.

8.9 DepthLight: a Single Image Lighting Pipeline for Seamless Integration of Virtual Objects into Real Scenes

Participants: Raphaël Manus, Kebing Xue, Samuel Boivin *(contact)*, Marc Christie.

The paper [16] introduces DepthLight, a method to estimate spatial lighting for photorealistic Visual Effects (VFX) using a single image as input. Previous techniques rely either on estimated or captured light representations that fail to account for localized lighting effects, or use simplified lights that do not fully capture the complexity of the illumination process.

DepthLight addresses these limitations by using a single LDR image with a limited field of view (LFOV) as an input to compute an emissive texture mesh around the image (a mesh which generates spatial lighting in the scene), producing a simple and lightweight 3D representation for photorealistic object relighting (see Figure 10). First, an LDR panorama is generated around the input image using a photorealistic diffusion-based inpainting technique, conditioned on the input image. An LDR to HDR network then reconstructs the full HDR panorama, while an off-the-shelf depth estimation technique generates a mesh representation to finally build a 3D emissive mesh. This emissive mesh approximates the bidirectional light interactions between the scene and the virtual objects that is used to relight virtual objects placed in the scene. We also exploit this mesh to cast shadows from the virtual objects on the emissive mesh, and add these shadows to the original LDR image. This flexible pipeline can be easily integrated into different VFX production workflows.

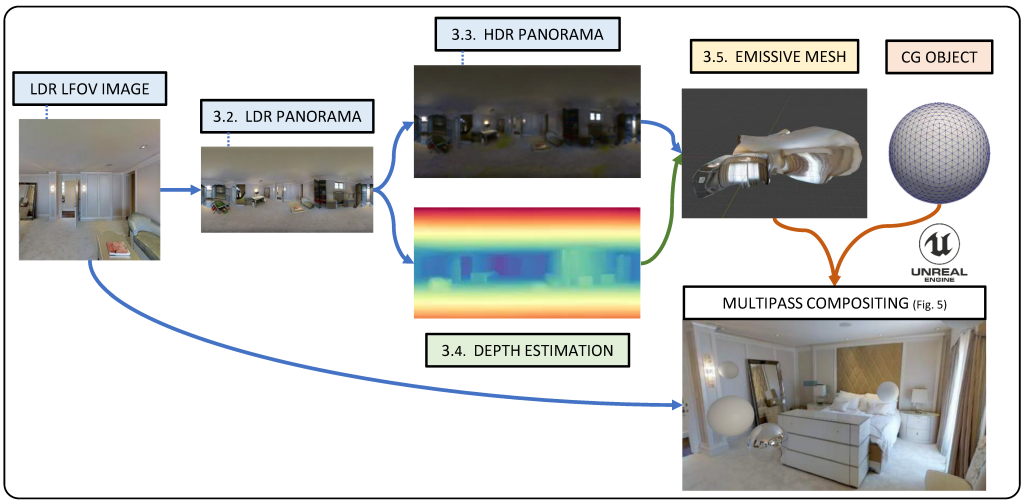


Figure 10: Overview of our DepthLight pipeline. Blue dashed lines represent the possible input points of our pipeline. Our testing involved the whole pipeline using LDR LFOV input images.

In our experiments, DepthLight shows that virtual objects are seamlessly integrated into real scenes with a visually plausible estimation of the lighting. We compared our results to the ground truth lighting using Unreal Engine, as well as to state-of-the-art approaches that use pure HDRi lighting techniques. Finally, we validated our approach conducting a user evaluation over 52 participants as well as a comparison to existing techniques.

DepthLight has shown its limitations in terms of accuracy for the estimation of the light sources, especially regarding complex scenes. We are now inverstigating a very different approach through the AeX Enlight, based on Deep Learning and diffusion-based techniques, and also using Gaussian Splatting.

8.10 New evaluation methods of persistent non-specific low back pain (PNSLBP) using locomotion paradigms.

Participants: Anne-Hélène Olivier *(contact)*.

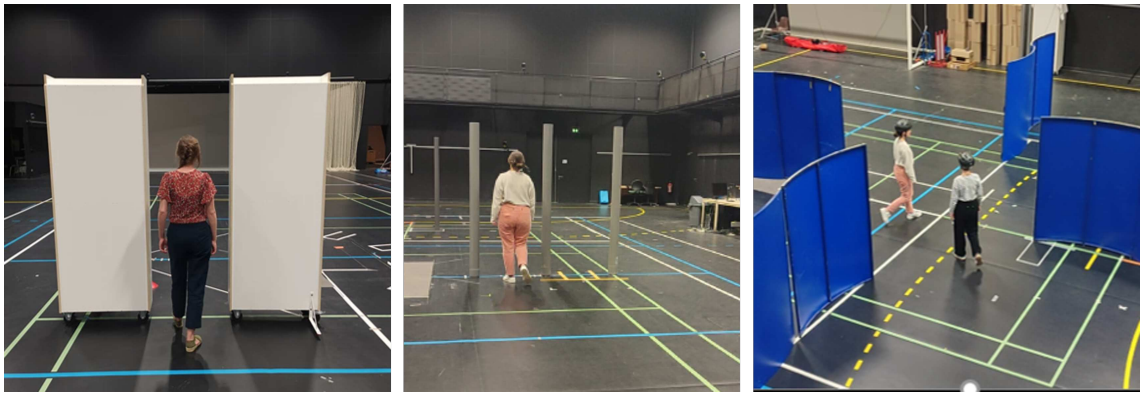


Figure 11: Illustration of the different protocols used to evaluate low back pain individuals.

This research activity has focused on developing novel assessment approaches for individuals with chronic non-specific low back pain (cNSLBP), moving beyond traditional self-reported outcomes toward functional,

behavior-based evaluations grounded in locomotion–environment interactions. We performed a systematic review ([6])of randomized controlled trials highlighting that current clinical assessments in manual therapy predominantly rely on questionnaires targeting pain intensity and perceived disability, with limited use of biomechanical or ecological markers. In parallel, we designed experimental paradigms assessing navigation and decision-making during locomotion in interaction with environmental and social constraints. We demonstrated that individuals with cNSLBP adopt more conservative and less socially modulated navigation strategies, accompanied by slower walking speeds, when crossing apertures in the presence of situational and social challenges ([7]). In another study, we further showed that cNSLBP alters pedestrian–pedestrian collision avoidance strategies, with asymmetric contributions to interaction resolution and a modulation of behavior by pain-related psychosocial factors ([5]).Complementary work showed reduced adaptability and movement complexity in cNSLBP participants, quantified using entropy-based metrics during adaptive gait tasks ([20]). Together, these studies support the relevance of interaction-based locomotor paradigms to capture functional impairments in cNSLBP and lay the groundwork for more ecologically valid clinical evaluation tools.

8.11 Effects of lifestyle activity level on crowd navigation preferences and performances in young adults.

Participants: Anne-Hélène Olivier *(contact)*, Julien Pettré.



Figure 12: Illustration of the virtual crowd used to evaluate the effect of inactivity on navigation in complex environment.

Navigating crowded environments is essential for safe and efficient mobility in daily life. This study [21], conducted within the SocNav associate team, investigated how physical activity levels influence crowd navigation preferences and performance in young adults. Fifteen physically active and fifteen physically inactive participants navigated a virtual park environment with varying crowd densities using an immersive VR setup. Trajectories, walking speed, and gaze behavior were recorded to assess navigation strategies. While no group differences were observed during unobstructed walking, physically inactive participants adopted more conservative strategies in crowds, walking slower and choosing longer paths with larger interpersonal gaps. When following an identical path in a dense crowd, inactive participants showed reduced walking speed during both the approach and navigation phases. Eye-tracking data indicated that inactive participants focused more on nearby agents, suggesting increased attentional demands. Despite these behavioral differences, collision rates and perceived task demands were similar across groups. Overall, the findings suggest that physical inactivity affects confidence and strategy during crowd navigation, with potential implications for daily mobility and social participation.

8.12 GTAvatar: Bridging Gaussian Splatting and Texture Mapping for Relightable and Editable Gaussian Avatars

Participants: Kevin Baert, François Bourel, Marc Christie *(contact)*.



Figure 1: **GTAvatar** broadens applications of monocular Gaussian Splatting head avatars beyond reenactment and relighting, enabling interactive editing of textures for precise control of intrinsic appearance, while preserving training efficiency, rendering speed and visual fidelity.

Figure 13: Our Texture-Gaussian splat method that enables qualitative reconstruction and intuitive editing of physically based rendering characteristics of a human head, from a single monocular video. The result can be re-rendered, re-animated and re-light, while conserving the visual quality of the Gaussian Splat representation.

This research addresses the challenge of creating relightable and editable photorealistic avatar models by combining two complementary 3D representation paradigms: Gaussian splatting and texture mapping. Gaussian splatting provides high-fidelity appearance reconstruction from images but offers limited editability, while traditional mesh-based representations enable intuitive editing at the cost of visual realism. The proposed approach bridges these representations by embedding Gaussian primitives within the UV space of a template mesh, enabling the reconstruction of continuous, editable material textures from a single monocular video. A physically based reflectance model is incorporated to support relighting, allowing the avatar's appearance to respond consistently to novel illumination conditions. Experimental results demonstrate that this hybrid representation achieves high visual quality while supporting intuitive appearance editing and relighting without additional optimization steps. The method balances reconstruction fidelity, relightability, and user-driven control, making it well suited for graphics and virtual production workflows.

8.13 Pulp Motion: Framing-aware Multimodal Camera and Human Motion Generation

Participants: Robin Courant, Marc Christie *(contact)*.

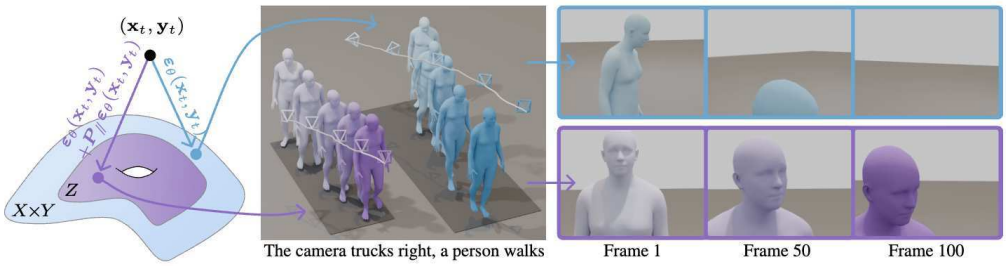


Figure 14: Our dedicated motion diffusion network is able to properly identify the manifolds of character and camera motions from large datasets, and enables relevant text-condtionned generated results that remain within the joint distribution.

This research tackles the problem of jointly generating human motion and camera trajectories while preserving coherent on-screen framing, a fundamental principle of cinematography that is largely ignored by existing generative approaches. Most prior methods treat camera motion and human motion as independent modalities, leading to visually inconsistent compositions. The proposed framework introduces on-screen framing as an explicit auxiliary modality that connects human pose and camera motion. A shared latent space is learned using a multimodal autoencoder, where human motion and camera trajectories are jointly embedded. A lightweight linear mapping aligns this shared representation with a framing latent, ensuring compositional coherence during generation. To enable controllable synthesis, the method employs a latent diffusion process decomposed into framing-aligned and framing-orthogonal components. A new dataset containing paired camera motions, human motions, and textual descriptions is also introduced. Experimental results show improved framing quality and text-to-motion alignment compared to state-of-the-art multimodal generation methods.

8.14 MVAE: Motion-conditioned Variational Auto-Encoder for Tailoring Character Animations

Participants: Jean-Baptiste Bordier, Marc Christie *(contact)*.

This research [13] focuses on simplifying the creation of diverse and expressive character animations through motion-driven control. Instead of relying on textual prompts or predefined action labels, the proposed approach conditions animation generation on continuous motion signals captured via virtual reality controllers. The Motion-conditioned Variational Auto-Encoder learns a latent representation that encodes both global motion intent, such as action type, and local motion characteristics, including speed, rhythm, and amplitude. By sampling this latent space, the system generates varied animation outputs that remain consistent with the user's input motion.The approach enables intuitive exploration of animation variations without extensive manual keyframing, allowing animators to rapidly prototype and refine character movements.

8.15 AKiRa: Augmentation Kit on Rays for Optical Video Generation

Participants: Robin Courant, Marc Christie *(contact)*.

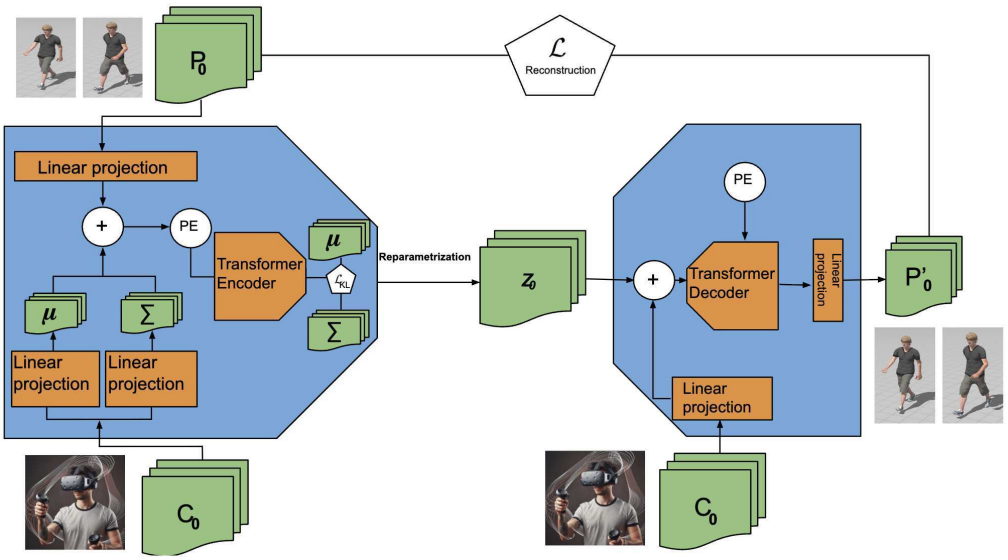


Figure 15: Overview of our motion-VAE learning system that takes as input an original motion together with user inputs, and generates an adpated motion, condtionned by features of the user input (amplitude, frequency, velocity).

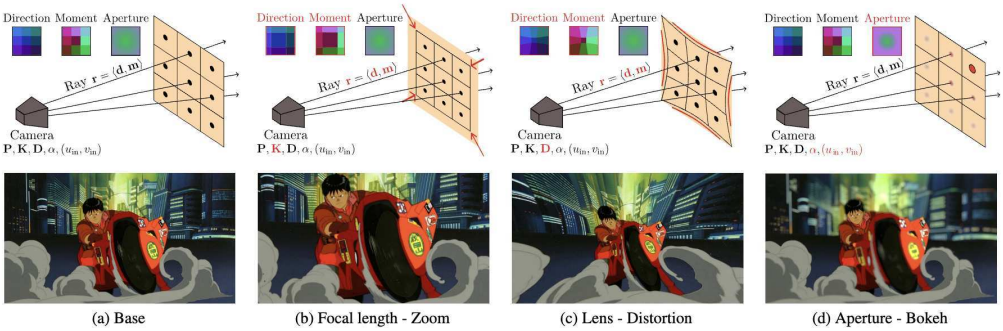


Figure 16: Optical effect overview. Visualization of various optical effects proposed in our system —zoom, distortion, and bokeh—and their impacts on both the camera parameters (top row) and visual output (bottom row). In addition, as with state-of-art techniques, we enable the control of the camera motion.

This research [18] addresses the lack of explicit control over camera motion and optical parameters in text-conditioned video diffusion models. Although recent approaches achieve high visual fidelity, they offer limited control over cinematographic elements such as zoom, lens distortion, depth of field, and focus transitions. The proposed framework, AKiRa, augments existing video generation backbones with a camera adapter based on a physically grounded camera model. By modeling video formation at the ray level, the system enables fine-grained control over focal length, aperture, and lens distortion, allowing the synthesis of cinematic effects such as zooms, fisheye distortion, and bokeh. Experimental evaluations demonstrate that AKiRa supports the composition of complex optical effects while outperforming state-of-the-art controllable video generation methods in terms of realism and visual quality.

8.16 De l'immersion au cinéma

Participants: Marc Christie *(contact)*.

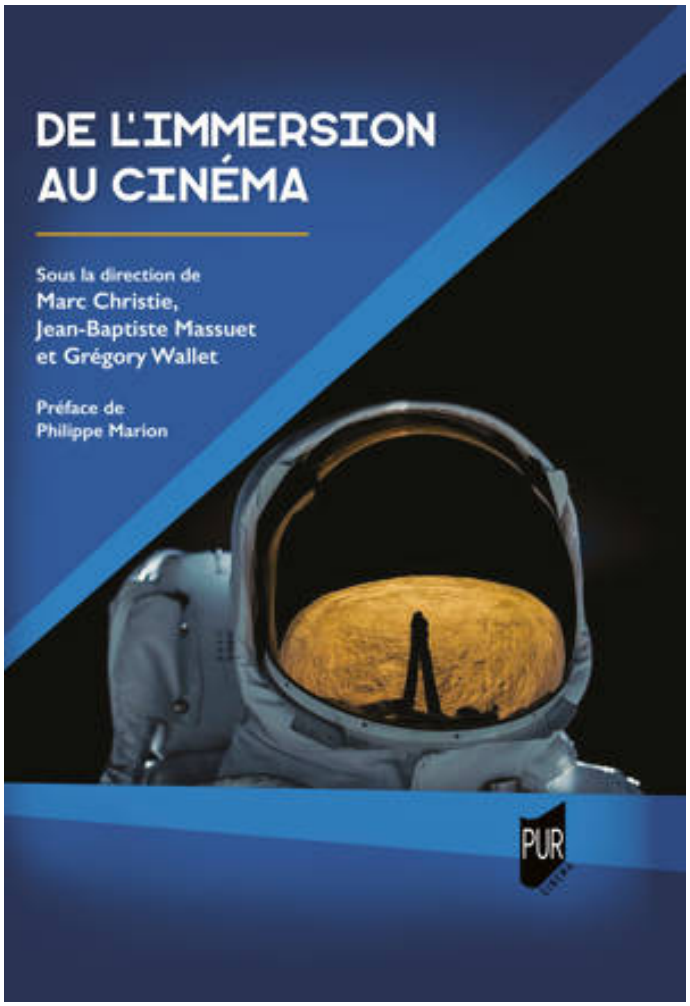


Figure 17: Our recently published book that explores the relation between immersion and cinematography.

This research [19] examines immersion in cinema as both a cognitive and a sensory phenomenon shaping the spectator's experience. Immersion is analyzed through a dual perspective, encompassing mental engagement driven by narrative absorption and physical immersion produced by audiovisual technologies and exhibition environments. The work traces the historical evolution of immersive cinematic practices, from early panoramic and pre-cinematic experiences to contemporary digital cinema and interactive media. It analyzes how technical parameters such as camera mobility, sound spatialization, and display technologies interact with narrative structures to influence perception. By situating immersion within broader aesthetic and epistemological frameworks, this study provides a structured understanding of how cinematic technologies and storytelling techniques jointly contribute to audience engagement.

9 Bilateral contracts and grants with industry

9.1 Bilateral contracts with industry

Cifre InterDigital - Deep-based semantic representation of avatars for virtual reality

Participants: Ludovic Hoyet *(contact)*, Philippe De Clermont Gallerande.

The overall objective of the PhD thesis of Philippe De Clermont Gallerande, which started in February 2023, is to explore novel approaches (including both full body and facial elements) to enable both full body and facial encoding and decoding for multi-user immersive experiences. Objective is also to enable the evaluation of the quality of experience. More specifically, one of the focus is to propose solutions to represent digital characters (avatars) with semantic-based approaches in a context of multi-user immersive telepresence, that are compact, plausible and simulatenously resiliant to data perturbation caused by streaming. This PhD is conducted within the context of the joint laboratory Nemo.ai between Inria and InterDigital, and more specifically within the Ys.ai project which is dedicated to exploring novel research questions and applications in Virtual Reality. This work is also conducted in collaboration between the two Inria teams Hybrid and Virtus, as well as with the Interactive Media team of InterDigital.

Cifre InterDigital - Facial features from high quality cinema footage

Participants: Marc Christie *(contact)*, Kelian Baert.

The overall objective of the PhD thesis of Kelian Baert (started in 2024, funded by VFX company Mikros Image) is to explore novel representations to extract facial features from high quality cinema footage, and provide intuitive techniques to perform facial editing including shape, appearance and animation. More precisely, we search to improve the controllability of learning-based techniques for editing photo-realistic faces in video sequences, aimed at the visual effects for cinema. The aim is to accelerate post-production processes on faces by enabling an artist to finely control different characteristics over time. There are numerous applications: rejuvenation and aging, make-up/tattooing, strong modifications morphology (adding a 3rd eye, for example), replacing an understudy with the actor's face by the actor's face, adjustments to the actor's acting. The PhD will rely on a threefold approach: transfer of features from real to synthetic, editing in the synthetic domain on simplified representations, and then to transfer the contents back to photorealistic sequences using GAN/Diffusion-based models to ensure visual quality.

LCPP (PhD contract) - Immersive crowd simulation for the study and design of public spaces

Participants: Julien Pettré *(contact)*, Ludovic Hoyet, Jordan Martin.

The overall objective of the PhD thesis of Jordan Martin, started in November 2022, is to explore the use of Virtual Reality to better design and assess public spaces. The VirtUs team specialises in the simulation, animation and immersion of virtual crowds. The aim of this thesis is to explore new ways of analysing crowd behaviours in real environments using new virtual reality technologies that allow users to be directly immersed in digital replicas of these situations. More specifically, Jordan explores the technical conditions of Virtual Reality experiments that lead to collecting realistic data. These conditions revolve around the visual representations of virtual humans, as well as display conditions.

CEA (PhD contract) - Generation and control of virtual manikins using machine learning for the simulation of industrial processes using VR

Participants: Thomas Bouyer, Ludovic Hoyet *(contact)*.

The overall objective of the PhD thesis of Thomas Bouyer, started in January 2025 in collaboration with the CEA, is to explore how deep learning based physical simulation approaches can be combined with ergonomic or visual metrics to facilitate the simulation of virtual humans in industrial processes. In such contexts, human movements can be highly constrained by the industrial environment, which currently impair realism (e.g., in terms of posture, effort and interaction with the environment).

9.2 Bilateral Grants with Industry

Vivo mobile phone

Participants: Marc Christie *(contact)*, Lezhong Wang, Alice Phuing-ngoc.

The objective of the Vivo project (2025-27, 320k€) is to perform qualitative transfer of cinematographic sequences to user-captured contents. The challenge is to identify the relevant visual, semantic and geometric features that characterize qualitative camera trajectories, and to design a transfer technique between the extracted features and the target scene, either represented using radiance based techniques (Gaussian Splats) or more implicit visual represetnations such as VGGT.

10 Partnerships and cooperations

10.1 International initiatives

10.1.1 Inria associate team not involved in an IIL or an international program

Participants: Anne-Hélène Olivier *(contact)*, Julien Pettré, Katja Zibrek, Ludovic Hoyet.

SocNav

Title: SocNav - Studying complex social navigation with an innovative, co-developed immersive platform

Partner Institution(s):
- Université Laval Quebec, Canada

Date/Duration: started 2024 for 3 years

Summary: The context of the SocNav team is the study of locomotor navigation in more socially complex environments representative of daily life. When performing goal-directed walking, alone or with others in public spaces, we are continuously interacting with our dynamic surrounding environment, especially avoiding collisions with other pedestrians. However, research to date has mainly considered simple, pairwise interactions and many questions remain. In particular, the combined roles of anticipatory and reactive control underlying locomotor navigation in more socially complex environments with multiple pedestrian interactions should be carried out. This needs to also consider the confounding effects of one's physical limitations due to physical activity level or neurological deficits and for mode of transport (i.e., biped vs wheeled). This work will require the means to create protocols that allow flexible control over environmental factors, something best provided through immersive virtual reality (VR) for which both teams are experts. Therefore, this project has 3 main objectives: 1. Create and evaluate an immersive experimental platform to be used for the study of social navigation in complex social environments 2. Study and model how environmental and personal factors affect the control of navigation in complex social environments in healthy populations 3. Study and model how neurological deficits affect the control of navigation in complex social environments. The parallel development of such an immersive platform will solidify collaborations beyond the granting period as well as provide a tool that can have great potential for application. The findings from the proposed collaborations will not only improve our understanding of the trade-offs in anticipatory and reactive control for locomotor navigation of complex social environments, but will also significantly contribute to improving assessment and training tools, and the development of intelligent mobility aids (smart wheelchairs).

10.2 International research visitors

10.2.1 Visits of international scientists

Other international visits to the team

Krista Best

Status Adjunct professor

Institution of origin: Université Laval, CIRRIS

Country: Canada

Dates: Sept 22 -Oct 31, 2025

Context of the visit: Preparation of an experiment about immersive navigation within a virtual crowd in traumatic brain injury patients, discussion about future projects.

Mobility program/type of mobility: Invited Professor program, University of Rennes 2

Angelo Silvino

Status PhD Candidate

Institution of origin: University of Campania “Luigi Vanvitelli”

Country: Italy

Dates: Sept 2025-March 2026

Context of the visit: Design and conduct an experiment about the role of perceived self-efficacy, belonging, and psychological distance in the ecological transition

Mobility program/type of mobility: PhD scholarship from University of Campania National Recovery and Resilience Plan (PNRR)

Francisco Ortega

Status Associate Professor

Institution of origin: Colorado State University

Country: USA

Dates: July 8-9, 2025

Context of the visit: Visit of the team and presentation of his research

Mobility program/type of mobility: Own budget

Jean-Bernard Hayet

Status Senior Research Scientist

Institution of origin: CIMAT, department of Computer Science

Country: Mexico

Dates: Dec 15-19, 2025

Context of the visit: Ongoing collaboration on crowd simulation topics, ans discussions for future collaborations in the frame of a sabbatical research stay

Mobility program/type of mobility: Own funding

Vinu Kamalasanan

Status Post Doc

Institution of origin: TU Clausthal

Country: Germany

Dates: Sept 1-3, 2025

Context of the visit: Discussion about future collaborations on pedestrian-bicycle interactions.

Mobility program/type of mobility: Tom Troscianko Travel Award

10.2.2 Visits to international teams

Research stays abroad

Céline Finet stayed for 2 months at the CIMAT in Huanajuato (Mexico), working with Jean-Bernard Hayet. She then stayed for 2 months at University of California, Riverside, to work with Ioannis Karamouzas.

Anne-Hélène Olivier, Julien Pettré, Pierre Vauclin, Aline Hufschmitt stayed a week at the CIRRIS, Laval University, Québec. We discuss on the advancements of the SocNav associate team and open discussion for European Funding applications.

10.3 European initiatives

10.3.1 Horizon Europe

META-TOO

Participants: Katja Zibrek.

META-TOO project on cordis.europa.eu

Title: A transfer of knowledge and technology for investigating gender-based inappropriate social interactions in the Metaverse

Duration: From June 1, 2024 to May 31, 2027

Partners:

- INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET AUTOMATIQUE (INRIA), France
- ETHNIKO KAI KAPODISTRIAKO PANEPISTIMIO ATHINON (UOA), Greece
- FUNDACIO DE RECERCA CLINIC BARCELONA-INSTITUT D INVESTIGACIONS BIOMEDIQUES AUGUST PI I SUNYER (IDIBAPS-CERCA), Spain

Inria contact: Ferran Argelaguet(Hybrid)

Coordinator: Maria Roussou (UOA)

Summary: The META-TOO proposal underscores the knowledge and skills transfer from two distinguished European institutions, INRIA and IDIBAPS, each renowned for its research contributions in the digital forefront, to the National and Kapodistrian University of Athens (NKUA), Greece, serving as the coordinating institution representing a Widening country (Greece). Specifically, both INRIA (The French National Institute for Research in Computer Science and Automation) and IDIBAPS (Fundaci de Recerca Clnic Barcelona in Spain) have earned global recognition for their outstanding contributions to Extended Reality (XR) research. It is precisely within this domain that we have elected to focus

the support of INRIA and IDIBAPS (henceforth called mentors) for the National and Kapodistrian University of Athens (coordinator), with a concerted effort aimed at reinforcing research management and administrative competencies, alongside enhancing research and innovation capabilities. The META-TOO also has two important research axes: a) to study and design interaction techniques for mitigating inappropriate social behaviour in Social Virtual Reality (SVR) and b) to conduct studies in harassment prevention through enhancing empathy by perspective-taking and bystander behaviour. The research combines interdisciplinary expertise and strengths of all three partners involved in the META-TOO project.

10.4 National initiatives

Défi Ys.AI

Participants: Ludovic Hoyet *(contact)*, Philippe De Clermont Gallerande.

With the recent annoucements about massive investments on the Metaverses, which are seen as the future of the social and professional immersive communication for the emergent AI-based e-society, there is a need for the development of dedicated metaverse technologies and associated representation formats. In this context, the objective of this joint project between Inria and InterDigital is to focus on the representation formats of digital avatars and their behavior in a digital and responsive environment. In particular, the primary challenge tackled in this project consists in solving the uncanny valley effect to provide users with a natural and lifelike social interaction between real and virtual actors, leading to full engagement in those future metaverse experiences.

ANR Animation Conductor

Participants: Marc Christie *(contact)*, Théo Gérard, Ludovic Hoyet.

Duration: Oct 2023 - Oct 2027

Team funding: 286k€

Partners:
- LiX in Polytechnique
- Dada Animation company

Summary: The fundamental idea of the ANR Animation Conductor project is to (i) express simultaneous multimodal inputs as high-level animation principles into a motion characteristics space, (ii) exploit spatial and temporal characteristics of the input signals to edit existing animations using learning techniques inspired by style transfer, (iii) combine the style transfer techniques with authoring constraints such as physics-based and (iv) co-design interactive tools with creative artists to exploit them in industrial pipelines. More precisely, we first aim at providing new ways of understanding on which part of an animation a “conductor” (i.e. animator or supervisor) is working, to build a correlation between different input signals and output animation curves by designing a dataset with experienced animators. Secondly, we aim at designing new computational models to efficiently modify 3D animations from mimics through the use of individual or combined input modalities - namely records of voices and sounds, video records of body parts gestures, and 3D space-time acquisition from lightweight VR worn or mounted systems, while not requiring full MOCAP infrastructure. To this end, we propose to develop novel methods able to extract the spatial and temporal authoring potential of these modalities into a motion characteristics space, as well as exploring new ways to leverage the use of combined modalities to ease 3D animation control, inspired from style-transfer techniques in animation, and to compose with authoring constraints. This project targets direct applications and prototypes, starting with our open-source one, within French animation studios for the refinement of existing animations for shape and character subparts.

ANR VROOM

Participants: Ludovic Hoyet, Julien Pettré *(contact)*, Anne-Hélène Olivier, Stéphane Donikian.

Duration: 42 months, 2026-2029

Team funding: 205k€

Partners: SNCF, Univ. Gustave Eiffel, Inocess

Summary: The VROOM project (Virtual Reality to Optimize crOwd Management) aims to develop an innovative methodology to improve passenger flow management in railway stations by combining field observation, IoT sensing, and virtual reality. Current crowd management practices remain largely empirical and are limited by legal, technical, and observational constraints. VROOM addresses these limitations by focusing on the acquisition of situation-specific, fine-grained behavioral data. The project proposes the creation of immersive digital twins of train stations, directly grounded in real-world measurements and populated with realistic virtual passengers. These digital twins enable controlled experimental studies of individual and collective behaviors under dense crowd conditions. A key use case concerns automatic ticket control lines, which are major sources of congestion and discomfort. Through VR experiments, VROOM investigates perceptual, cognitive, and behavioral factors underlying passenger navigation and decision-making. The outcomes of these studies are then transferred back to real stations and evaluated in ecological conditions. By tightly coupling field data, immersive simulation, and behavioral experimentation, VROOM seeks to provide scientifically grounded and operational tools for safer, more efficient, and more comfortable crowd management.

AeX Enlight

Participants: Samuel Boivin *(contact)*, Marc Christie, Kebing Xue.

Coordinator: Samuel Boivin
Duration: 36 months (Sept 2025-Sept 2028)
This project focuses on the automatic estimation of the lighting conditions of a real scene in order to seamlessly integrate virtual elements in a visually indistinguishable manner. To this end, we will investigate the joint estimation of light sources and materials using Deep Learning and probabilistic methods, as well as a novel error metric for assessing the qualitative level of photo-realism achieved.

DSR IPiC

Participants: Anne-Hélène Olivier *(contact)*, Ludovic Hoyet, Julien Pettré, Stéphane Donikian.

Duration: 36 months, 2025-2027

Team funding: 130 k€

Partners: Université Gustave Eiffel, Rennes Métropole

Summary: IPiC addresses current challenges related to the growing use of active mobility modes. As walking and cycling increasingly coexist in shared urban spaces, conflicts between pedestrians and cyclists raise safety and comfort concerns. The project aims to better understand the decision-making processes and adaptive movement strategies of both users during such interactions. IPiC adopts an

innovative experimental approach combining real-world observations and controlled experiments both in real environment and in immersive virtual reality. Urban field studies conducted with local authorities will be used to identify representative interaction scenarios, which will then be reproduced in coupled pedestrian and bicycle simulators. Multidimensional data, including trajectories, gaze behavior, perceived risk, and perceived priority, will be collected and analyzed. The project ultimately seeks to inform urban design and policy decisions while contributing to the development of realistic pedestrian and cyclist interaction models for virtual environments.

DSR PERCEPT-PIETON

Participants: Anne-Hélène Olivier *(contact)*.

Duration: 36 months, 2025-2027

Team funding: 27k€

Partners: Université Gustave Eiffel, Aix Marseille Université

Summary: PERCEPT-PIETON addresses the growing safety challenges involving vulnerable road users, particularly pedestrians. Despite overall progress in road safety, pedestrian fatalities, especially among older adults and children, remain a critical issue, most often occurring during street crossings. While pedestrian behavior has been extensively studied, the perceptual, cognitive, and motor mechanisms underlying drivers' and cyclists' responses to pedestrians remain poorly understood. The project aims to investigate how drivers and cyclists perceive and adapt their behavior when confronted with pedestrians intending to cross the road. To achieve this, PERCEPT-PIETON relies on immersive virtual reality and the use of biologically realistic pedestrian avatars generated from motion capture data. The work plan is organized into three phases: (1) building a library of pedestrian digital twins with diverse movement characteristics, (2) developing configurable urban virtual environments, and (3) conducting controlled experiments to measure decision-making, speed regulation, and visual strategies of drivers and cyclists. The project seeks to produce actionable scientific knowledge for public decision-makers and to deliver an open-access VR tool for research, training, and awareness purposes.

10.5 Regional initiatives

Créativité Croisée (Rennes Métropole) - Voyage du Geste

Participants: Anne-Hélène Olivier *(contact)*.

Duration: 12 months, 2025

Team funding: 7k€

Partners: Centre Eugène Marquis, Laboratoire M2S (Univ Rennes 2), artists: Julien Lomet and Pierre Huygue

Summary: Voyage du Geste is a multidisciplinary project exploring the use of immersive virtual reality (VR) to support physical activity and well-being in patients with advanced or metastatic breast cancer. Although physical activity is now recognized as a key therapeutic tool in oncology care, these patients face major barriers to movement, including fatigue, pain, anxiety, reduced upper-limb mobility, and fear of movement. In parallel, VR has emerged as a promising medium to promote motivation, engagement, and safe re-engagement in movement through immersive and adaptive environments. The project aims to (1) develop an artistic immersive VR experience tailored to patients' needs through a co-construction process, and (2) assess the feasibility and acceptability of this experience during

two immersive sessions conducted within the “AVANCER AVEC” workshops at the Eugène Marquis Cancer Center. This exploratory work is intended to lay the foundations for a larger clinical project investigating the therapeutic use of VR to enhance mobility and well-being. The project is built on an interdisciplinary collaboration involving digital artists, movement science and health researchers, VR specialists, and healthcare professionals. Its originality lies in the unique integration of digital art, immersive VR, and movement sciences within a patient-centered, co-designed therapeutic approach.

Inno R&D - LUV

Participants: Marc Christie Olivier *(contact)*, Kelian Baert, Francois Bourel.

Duration: 24 months, 2025-2026

Team funding: 182k€

Partners: Company EMOVA based in Cesson-Sevigne

Summary: The purpose of the LUV project is to improve the state of the art in automated 3D reconstruction of Avatars from a few view inputs (typically 3 to 5 images). The problem is addressed by building a large latent representation of avatar heads from synthetic data, and then inverse optimizing the latent code from the few views, before fine-tuning the results. Our novelty stands in the modality to represent and train Gaussian Splats by using feature-conditionned MLPs. Results will be integrated in the commercial solution of the EMOVA company.

11 Dissemination

Participants: Julien Pettré, Anne-Hélène Olivier, Samuel Boivin, Marc Christie, Katja Zibrek, Ludovic Hoyet, Stéphane Donikian, Aline Hufschmitt
.

11.1 Promoting scientific activities

11.1.1 Scientific events: organisation

General chair, scientific chair

Anne-Hélène Olivier: co-general chair of IEEE Virtual Reality 2025 Conference, Saint-Malo, France

Marc Christie: co-program chair of Pacific Graphics 2025, Taipei, Taiwan

Marc Christie: co-chair of Expressive 2025, London, UK

Member of the organizing committees

Ludovic Hoyet: Co-organizer of the Workshop “Next Generation of Avatars”, IEEE Virtual Reality 2025, Saint-Malo, France

Ludovic Hoyet: Environmental Impact Reduction and Awareness Co-Chair, IEEE Virtual Reality 2025, Saint-Malo, France

Ludovic Hoyet: Diversity, Equity, Inclusion, and Accessibility Co-Chair, IEEE Virtual Reality 2025, Saint-Malo, France

Julien Pettré: Social Events Co-Chair, IEEE Virtual Reality 2025, Saint-Malo, France

Anne-Hélène Olivier, Julien Pettré, Katja Zibrek: Co-organizers of the Workshop "Virtual Humans and Crowds in Immersive Environments", IEEE Virtual Reality 2025, Saint-Malo, France

Anne-Hélène Olivier: co-organizer of the workshop on XR Accessibility, IEEE Virtual Reality 2025, Saint-Malo, France

Anne-Hélène Olivier: Co-organizer of the Symposium "I am my environment: Pushing the theories of adaptive locomotor control", International Society of Posture and Gait Research (ISPGR) 2025, Maastricht, Netherlands.

11.1.2 Scientific events: selection

Chair of conference program committees

Julien Pettré: Editor for the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) 2025 Conference

Member of the conference program committees

Marc Christie: Pacific Graphics 2025, ACM Siggraph Asia 2025, CVMP 2025

Ludovic Hoyet: ACM Siggraph (Conflict of Interest committee), ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games 2025, ACM Symposium on Applied Perception 2025, ACM Symposium on Computer Animation 2025, IEEE Virtual Reality 2026, ACM Motion Interactions and Games 2025.

Katja Zibrek: IEEE Virtual Reality 2026 (committee and supercommittee), ACM Symposium on Applied Perception (SAP) 2025, IEEE International Symposium on Mixed and Augmented Reality (ISMAR) 2025, ACM Motion Interactions and Games (MIG) 2025, Computer Animation and Social Agents (CASA) 2025, Ars Electronica Expanded conference 2025

Anne-Hélène Olivier: ACM Symposium on Applied Perception 2025, IEEE Virtual Reality 2026, ACM VRST 2025, XR en Mouvement 2025

Julien Pettré: ACM SIGGRAPH ASIA 2025, ACM Motion Interactions and Games (MIG) 2025, ACM Symposium on Applied Perception (SAP) 2025, Pedestrian and Evacuation Dynamics (PED) 2025

Reviewer

Marc Christie: ACM SIGGRAPH 2025, ACM SIGGRAPH Asia 2025, CVPR 2025, 3DV 2025

Julien Pettré: IEEE Virtual Reality 2026, International Conference on Extended Reality (ICXR) 2025,

Ludovic Hoyet: ACM Conference on Human Factors in Computing Systems (CHI), IEEE International Symposium on Mixed and Augmented Reality (ISMAR), ACM Siggraph Asia 2024

Katja Zibrek: ACM Symposium on Virtual Reality Software and Technology (VRST) 2025

Anne-Hélène Olivier: IEEE International Symposium on Mixed and Augmented Reality (ISMAR), International Conference on extended Reality (ICXR 2025)

Conference award committees

Anne-Hélène Olivier: Co-chair of the ACM Symposium on Computer Animation 2025 award committee

11.1.3 Journal

Member of the editorial boards

Ludovic Hoyet: Associate Editor for ACM Transactions on Graphics and Computer Graphics Forum.

Anne-Hélène Olivier: Associate editor for IEEE Transactions of Visualization and Computer Graphics (TVCG), and for Computers & Graphics

Reviewer - reviewing activities

Ludovic Hoyet: IEEE Transactions on Visualization and Computer Graphics (TVCG)

Marc Christie: Computers & Graphics

Julien Pettré: Physica A, Computer Graphics Forum

Anne-Hélène Olivier: International Journal of Human - Computer Studies, Computers in Human Behaviours

Katja Zibrek: IEEE Transactions on Visualization and Computer Graphics (TVCG), Computers and Graphics, Plos One, Scientific Reports, International Journal of Human-Computer Studies (IJHCS)

11.1.4 Invited talks

Anne-Hélène Olivier: Virtual reality and complex adaptive behaviours, Human-Centered Technological Innovation - A new HUB for future technologies. Università degli Studi della Campania, Italy, June 9, 2025.

Anne-Hélène Olivier: Se déplacer dans des espaces publics : variables de contrôle des trajectoires locomotrices, enjeux méthodologiques et perspectives ouvertes par la réalité virtuelle. Séminaire de la Commission ARPEGE Réalité Virtuelle, Augmentée et Mixte - La Réalité Virtuelle dans les Sciences du Mouvement Humain. Champs sur Marne, France, April 1st 2025.

11.1.5 Leadership within the scientific community

Anne-Hélène Olivier: Chair of the ACM Symposium on Applied Perception Steering Committee

11.1.6 Scientific expertise

Anne-Hélène Olivier: Initiatives d'Excellence - Rayonnement International 2025, Grenoble

11.1.7 Research administration

Ludovic Hoyet is in charge of the "Virtual Reality, Virtual Humans, Interactions and Robotics" department of the IRISA laboratory (Institut de Recherche en Informatique et Systèmes Aléatoires). This department includes four Inria teams (Combo, Rainbow, Seamless, Virtus) and is aligned with one of the strategic objectives of the Inria Rennes centre described in the Inria COP (i.e., "humans-robots-virtual worlds interactions").

Samuel Boivin is the Head of the program 'Virtual Worlds' of the Program Agency driven by INRIA.

11.2 Teaching - Supervision - Juries - Educational and pedagogical outreach

11.2.1 Teaching

Master: Marc Christie, Head of Master 2 Ingénierie Logicielle (45 students), University of Rennes, France

Master: Marc Christie, "Multimedia Mobile", Master 2, leader of the module, 32h (IL) + 32h (Miage), Computer Science, University of Rennes, France

Master: Marc Christie, "Projet Industriel Transverse", Master 2, 32h, leader of the module, Computer Science, University of Rennes, France

Master: Marc Christie, "Modelistion Animation Rendu", Master 2, 16h, leader of the module, Computer Science, University of Rennes, France

Master: Marc Christie, "Web Engineering", Master 1, 16h, leader of the module, Computer Science, University of Rennes, France

Master: Marc Christie, "Advanced Computer Graphics", Master 1, 10h, leader of the module, Computer Science, ENS, France

Master: Marc Christie, "Motion for Animation and Robotics", Master 2 SIF, Computer Science, France

Master : Ludovic Hoyet, Motion Analysis and Gesture Recognition, 12h, INSA Rennes, France

Master : Ludovic Hoyet, Computer Graphics, 8h, Ecole Normale Supérieure de Rennes, France

Master : Ludovic Hoyet, Réalité Virtuelle pour l'Analyse Ergonomique, Master Ingénierie et Ergonomie des Activités Physique, 21h, University Rennes 2, France

Master : Aline Hufschmitt, Using Unreal Engine for military training simulation creation, 24h, Académie Militaire de Saint-Cyr Coëtquidan, France

Master : Aline Hufschmitt, Multi-user LAN simulation under Unreal Engine, 24h, Académie Militaire de Saint-Cyr Coëtquidan, France

Master : Aline Hufschmitt, Artificial intelligence for simulating AMI/ENI behavior under Unreal Engine, 30h, Académie Militaire de Saint-Cyr Coëtquidan, France

Master : Aline Hufschmitt, Applied project: Unreal simulation for visualizing blue team/red team training in a cyber range, 24h, Académie Militaire de Saint-Cyr Coëtquidan, France

Master : Aline Hufschmitt, Adrenaline Rush Project, 50h, Académie Militaire de Saint-Cyr Coëtquidan, France

Licence : Aline Hufschmitt, C programming, 100h, Académie Militaire de Saint-Cyr Coëtquidan, France

Master : Anne-Hélène Olivier, co-leader of the APPCM Master (50 students) "Activités Physiques et Pathologies Chroniques et Motrices", STAPS, University Rennes2, France

Master : Anne-Hélène Olivier, "Recueil et traitement des données", 26H, Master 1 and 2 APPCM/IEAP/EOPS, University Rennes2, France

Master : Anne-Hélène Olivier, "Méthodologie de la recherche et accompagnement de stage", 15H, Master 1 and 2 APPCM, University Rennes2, France

Licence : Anne-Hélène Olivier, "Analyse cinématique du mouvement", 100H , Licence 1, University Rennes 2, France

Master : Katja Zibrek, supervision of students' internship abroad program, Ecole supérieure d'ingénieurs de Rennes (ESIR), 15h, University Rennes 2, France

Bachelors : Katja Zibrek, études pratiques, 3rd year, 15h, Institut National des Sciences Appliquées de Rennes (INSA), France

11.2.2 Supervision

PhD defended (beginning Nov. 2020, defended July 2025): Emilie Leblong, Prise en compte des interactions sociales dans un simulateur de conduite de fauteuil roulant électrique en réalité virtuelle : favoriser l'apprentissage pour une mobilité inclusive, Anne-Hélène Olivier, Marie Babel (Rainbow team)

PhD defended (beginning Nov. 2021, defended June 2025): Rim Rekik Dit Nekhili, Learning and evaluating 3D human motion synthesis, Anne-Hélène Olivier, Stefanie Wuhrer (Morpheo team).

PhD in progress (beginning Oct. 2021): Xiaoyuan Wang, Realistic planning of hand motions, with Marc Christie, Adnane Boukhayma.

PhD in progress (beginning Oct. 2022): Jordan Martin, Simulation immersive de foule pour l'étude et l'aménagement de lieux destinés à accueillir du public, Ludovic Hoyet, Jean-Luc Paillat, Julien Pettré, Etienne Pinsard.

PhD in progress (beginning Oct. 2022): Alexis Jensen, Simulation de foule dense par modélisation dynamique, Julien Pettré, Charles Pontonnier (Combo team).

PhD in progress (beginning Feb. 2023): Philippe De Clermont Gallerande (CIFRE InterDigital), Deep-based semantic representation of avatars for virtual reality, Ferran Argelaguet (Seamless team), Quentin Avril (InterDigital), Philippe-Henri Gosselin (InterDigital), Ludovic Hoyet.

PhD in progress (beginning Feb. 2023): Tony Wolff, Creating socially reactive virtual characters for enhanced social interactions in Virtual Reality, Ludovic Hoyet, Anne-Hélène Olivier, Julien Pettré, Katja Zibrek.

PhD in progress (beginning Sept. 2023): Celine Finet, Peuplement de scène par simulation de foule basée apprentissage, Julien Pettré.

PhD in progress (beginning Oct. 2023): Kelian Baert, Face Editing for Digital Visual Effects in Film Production, with Marc Christie, Adnane Boukhayma.

PhD in progress (beginning Oct. 2023): Arthur Audrain, Creating digital tools to mitigate harassement in the Metaverse, with Katja Zibrek and Ferran Argelaguet.

PhD in progress (beginning Jan. 2024): Thomas Bouyer, Generation and control of virtual manikins using machine learning for the simulation of industrial processes using VR, with Laurent Dolle (CEA) and Vincent Weistroffer (CEA).

PhD in progress (beginning Jan. 2024): Théo Gérard, A multimodal Deep-Learning approach for intuitive editing of character animations, with Marc Christie and Pierre Hellier (Combo team).

PhD in progress (beginning Oct. 2025): Kilian Marcelin, Immersive Simulation of Dense Crowds with Julien Pettré and Ludovic Hoyet.

PhD in progress (beginning Nov. 2025): Kebing Xue, Lighting estimation from images for seamless integration of virtual objects into real scenes, with Samuel Boivin and Marc Christie.

PhD in progress (beginning Dec. 2025): Bhaswar Gupta, Data-drive crowd analysis and modeling, with Julien Pettré.

11.2.3 Juries

Ludovic Hoyet: M. Ristorcelli (Nov. 2025), “Public speaking training in virtual reality: From virtual audience simulation to multimodal behavioral cues of performance”, Aix Marseille Université, Examiner.

Anne-Hélène Olivier: Julien Lomet (PhD: Nov 2025), "La collaboration dans une oeuvre en réalité virtuelle : du processus de création à la performativité." Université Paris VIII, France - Reviewer.

Anne-Hélène Olivier: Alice Bourdon (PhD: Sept 2025), "Promouvoir l’activité physique par l’indiçage auditif : vers une approche personnalisée du rythme", Université de Montpellier, France - Reviewer

Anne-Hélène Olivier: Charlotte Croucher (PhD: Jan 2025), "Exploration in Virtual Reality: Thematic Analysis of the Natural Walking Literature and Examination of Virtual Environment Design" Tilburg University, The Netherlands, Reviewer.

Katja Zibrek: Tomáš Nováček (PhD: Sept 2025), "Precise Hand Tracking Using Multiple Optical Sensors", Faculty of Information Technology, Czech Technical University in Prague, Czech Republic, Examiner.

Katja Zibrek: Celia Kessassi (PhD: Feb 2025), "Modelling the Induction of Social Stress in Immersive Virtual Reality Simulations", IMT Atlantique, Nantes, France, Reviewer.

11.3 Popularization

11.3.1 Productions (articles, videos, podcasts, serious games, ...)

Ludovic Hoyet's research was highlighted on the Esprit Sorcier video channel : Mouvements Personnalisés pour les Foules, Esprit Sorcier TV, 2025. link

Julien Pettré and Anne-Hélène Olivier particiated to the writing of: Glossary for Research on Human Crowd Dynamics [25] that appeared in the Collective Dynamics collection.

12 Scientific production

12.1 Major publications

[1] A. Bilhaut, E. Vandenberg, M. Ménard, M. Cinelli, O. Roze, A. Baban, P. Carson-Jouzel, A. Crétual and A.-H. Olivier. 'Effects of situational and social factors on locomotor behavior in chronic non-specific low back pain patients walking through apertures'. In: *Scientific Reports* 15 (2025), pp. 1–16. DOI: 10.1038/s41598-025-25011-6. URL: https://hal.science/hal-05397896.

[2] T. Chatagnon, A.-H. Olivier, L. Hoyet, J. Pettré and C. Pontonnier. 'Classification of First Recovery Steps After Quiet Standing Following External Perturbation from Different Directions'. In: *Journal of Biomechanics* (2025), pp. 1–11. DOI: 10.1016/j.jbiomech.2025.112639. URL: https://inria.hal.science/hal-04993981.

[3] R. Rekik, S. Wuhrer, L. Hoyet, K. Zibrek and A.-H. Olivier. 'Quality assessment of 3D human animation: Subjective and objective evaluation'. In: *IEEE Transactions on Visualization and Computer Graphics* (29th May 2025), pp. 1–12. DOI: 10.1109/TVCG.2025.3631385. URL: https://hal.science/hal-05116550.

[4] X. Wang, R. Courant, M. Christie and V. Kalogeiton. 'AKiRa: Augmentation Kit on Rays for optical video generation'. In: CVPR 2025 - IEEE/CVF Conference on Computer Vision and Pattern Recognition. Nashville (Tenessee), United States: IEEE, 2025, pp. 1–17. URL: https://hal.science/hal-05003836.

12.2 Publications of the year

International journals

[5] A. Bilhaut, M. Ménard, O. Roze, S. Ozan, R. Crolan, P. Carson-Jouzel, A. Crétual and A.-H. Olivier. 'Collision avoidance behaviours in chronic non-specific low back pain participants: A prospective cohort study'. In: *Human Movement Science* 100 (2025), pp. 103335–103335. DOI: 10.1016/j.humov.2025.103335. URL: https://hal.science/hal-04982384 (cit. on p. 20).

[6] A. Bilhaut, A.-H. Olivier, J. Draper Rodi, A. Crétual and M. Ménard. 'Assessing the effects of manual therapy on pain in patients living with persistent non-specific low back pain (PNSLBP): Which evaluation criteria and measurement tools are used in randomised controlled clinical trials? A systematic review'. In: *International Journal of Osteopathic Medicine* 55 (2025), p. 100741. DOI: 10.1016/j.ijosm.2024.100741. URL: https://hal.science/hal-04888248 (cit. on p. 20).

[7] A. Bilhaut, E. Vandenberg, M. Ménard, M. Cinelli, O. Roze, A. Baban, P. Carson-Jouzel, A. Crétual and A.-H. Olivier. 'Effects of situational and social factors on locomotor behavior in chronic non-specific low back pain patients walking through apertures'. In: *Scientific Reports* 15 (2025), pp. 1–16. DOI: 10.1038/s41598-025-25011-6. URL: https://hal.science/hal-05397896 (cit. on p. 20).

[8] T. Chatagnon, A.-H. Olivier, L. Hoyet, J. Pettré and C. Pontonnier. 'Classification of First Recovery Steps After Quiet Standing Following External Perturbation from Different Directions'. In: *Journal of Biomechanics* (2025), pp. 1–11. DOI: 10.1016/j.jbiomech.2025.112639. URL: https://inria.hal.science/hal-04993981 (cit. on p. 13).

[9] X. Gong, J. Gain, D. Rohmer, S. Lyonnet, J. Pettré and M.-p. Cani. 'Herds From Video: Learning a Microscopic Herd Model From Macroscopic Motion Data'. In: *Computer Graphics Forum* 44.6 (5th Sept. 2025). DOI: 10.1111/cgf.70225. URL: https://ip-paris.hal.science/hal-05243580 (cit. on p. 13).

[10] P. Mullick, C. Appert-Rolland, W. H. Warren and J. Pettré. 'Eliminating Bias in Pedestrian Density Estimation: A Voronoi Cell Perspective'. In: *Physica A: Statistical Mechanics and its Applications* 657 (2025), p. 130251. DOI: 10.1016/j.physa.2024.130251. URL: https://hal.science/hal-04669293 (cit. on p. 14).

[11] R. Rekik, S. Wuhrer, L. Hoyet, K. Zibrek and A.-H. Olivier. 'Quality assessment of 3D human animation: Subjective and objective evaluation'. In: *IEEE Transactions on Visualization and Computer Graphics* (29th May 2025), pp. 1–12. DOI: 10.1109/TVCG.2025.3631385. URL: https://hal.science/hal-05116550 (cit. on pp. 12, 18).

[12] T. Uboldi, K. A. Macgregor, M.-F. Lavoie, C. W. Mckindsey, Y. Gendreau, J. Pettré, L. Chauvaud, F. Olivier and R. Tremblay. 'Daily and seasonal spatial behaviour of waved whelk Buccinum undatum: implications for fishery management and restoration'. In: *Canadian Journal of Zoology* 103 (2025), p. 0056. DOI: 10.1139/cjz-2024-0056. URL: https://hal.science/hal-04956958 (cit. on p. 15).

International peer-reviewed conferences

[13] J.-B. Bordier and M. Christie. 'MVAE : Motion-conditioned Variational Auto-Encoder for tailoring character animations'. In: Expressive-WICED. Londres, United Kingdom: The Eurographics Association, 2025. DOI: 10.2312/exw.20251059. URL: https://inria.hal.science/hal-05239274 (cit. on p. 22).

[14] P. de Clermont Gallerande, Q. Avril, P. H. Gosselin, F. Argelaguet and L. Hoyet. 'Evaluation of Body Parts Representations in Motion Reconstruction'. In: GRAPP 2025 - International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications. Porto, Portugal, 2025, pp. 1–12. DOI: 10.5220/0013138200003912. URL: https://inria.hal.science/hal-05052074 (cit. on pp. 16, 17).

[15] F. He, J. Yue, J. Zhu, A. Seyfried, D. Casas, J. Pettré and H. Wang. 'Learning Extremely High Density Crowds as Active Matters'. In: CVPR 2025 - IEEE/CVF Conference on Computer Vision and Pattern Recognition. Nashville, United States: IEEE, 2025, pp. 540–550. DOI: 10.1109/CVPR52734.2025.00059. URL: https://inria.hal.science/hal-05244322 (cit. on p. 16).

[16] R. Manus, M. Christie, S. Boivin and P. Guehl. 'DepthLight: a Single Image Lighting Pipeline for Seamless Integration of Virtual Objects into Real Scenes'. In: *ACM/EG Expressive Symposium - WICED: Eurographics Workshop on Intelligent Cinematography and Editing*. Expressive+WICED 2025. London, United Kingdom, May 2025. DOI: 10.2312/exw.20251060. URL: https://hal.science/hal-05091478 (cit. on p. 18).

[17] S. Saint-Auret, F. Multon, R. Gaugne, L. Hoyet, R. Kulpa and V. Gouranton. 'How do people perceive changes in physical bounce model for virtual racket interactions?' In: SAP 2025 - ACM Symposium on Applied Perception. Vancouver (BC), Canada: ACM, 8th Aug. 2025, pp. 1–10. DOI: 10.1145/3736702.3744355. URL: https://inria.hal.science/hal-05225594 (cit. on p. 17).

[18] X. Wang, R. Courant, M. Christie and V. Kalogeiton. 'AKiRa: Augmentation Kit on Rays for optical video generation'. In: CVPR 2025 - IEEE/CVF Conference on Computer Vision and Pattern Recognition. Nashville (Tenessee), United States: IEEE, 2025, pp. 1–17. URL: https://hal.science/hal-05003836 (cit. on p. 23).

Scientific books

[19] M. Christie, J.-B. Massuet and G. Wallet, eds. *De l'immersion au cinéma*. PUR-Cinéma. Presses Universitaires de Rennes, 15th May 2025. URL: https://univ-rennes2.hal.science/hal-05355998 (cit. on p. 24).

Other scientific publications

[20] A. Bilhaut, K. Kodama, M. Ménard, A. Crétual and A.-H. Olivier. 'Gait adaptability in chronic low back pain: reduced complexity during aperture passing'. In: ISPGR 2025 - International Symposium on Posture and Gait Research. Maastricht (Netherland), Netherlands, 2025. URL: https://inria.hal.science/hal-05243509 (cit. on p. 20).

[21] J. Boulo, A. K. Blanchette, J. Pettré, A.-H. Olivier and B. J. Mcfadyen. 'Effects of lifestyle activity level on crowd navigation preferences and performances in young adults'. In: XR 2025 - XR en Mouvement. Limoges, France, 2025. URL: https://inria.hal.science/hal-05243503 (cit. on p. 21).

[22] T. Chatagnon, A.-H. Olivier, L. Hoyet, J. Pettré and C. Pontonnier. 'Let's rock -Classification of Balance Recovery Steps in the Wild: Application to Punk Rock Concerts'. In: ISPGR 2025 - International Society of Posture and Gait Research. Maastricht, Netherlands, 2025, pp. 1–1. URL: https://inria.hal.science/hal-04994003 (cit. on p. 13).

[23] J. Lomet, R. Gaugne, V. Gouranton, A. Rébillard, P. Huyghe, A. Reuzeau, O. Guiffault, A. Le Royer, C. Lefeuvre-Plesse and A.-H. Olivier. 'Voyage du Geste, une œuvre en réalité virtuelle collaborative pour les femmes atteintes d'un cancer du sein'. In: XR en Mouvement 2025. Limoges, France, 2025. URL: https://inria.hal.science/hal-05243501.

[24] A.-H. Olivier, L. Hoyet, K. Zibrek and J. Pettré. 'Du mouvement individuel au mouvement collectif : validation et utilisation de la réalité virtuelle pour l'étude des interactions entre piétons.' In: XR 2025 - XR en Mouvement. Limoges, France, 2025. URL: https://inria.hal.science/hal-05243497.

Scientific popularization

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