Offer #2024-07826

PhD Position F/M Generation and control of virtual manikins using machine learning for the simulation of industrial processes using virtual reality

Contract type : Fixed-term contract

Level of qualifications required : Graduate degree or equivalent

Fonction : PhD Position

About the research centre or Inria department

The Inria Rennes - Bretagne Atlantique Centre is one of Inria's eight centres and has more than thirty research teams. The Inria Center is a major and recognized player in the field of digital sciences. It is at the heart of a rich R&D and innovation ecosystem: highly innovative PMEs, large industrial groups, competitiveness clusters, research and higher education players, laboratories of excellence, technological research institute, etc.

Context

This thesis will be conducted in collaboration between the CEA (LIST and Pays de la Loire) and the Virtus team at the Inria Centre of the University of Rennes. It will be based mainly in Paris, with visits planned to partner centres (covered by the employer). The start date of the thesis is indicative and may depend on the administrative processing of the recruitment.

The thesis focuses on the simulation of virtual manikins in an industrial context using virtual reality. The virtual operator is meant to realize different tasks (manipulate, screw...) in virtual environments with different levels of constraints. The movements of the operator must be as faithful as possible to reality, in terms of posture, efforts and interactions with the environment.

Considering the sophistication of the gestures to reproduce and the number of parameters to define manually, it becomes too complex to use classical control methods. In the literature, studies using imitation learning methods show promising results. These methods however have important drawbacks, such as the use of big samples databases and important training times.

The aim of the thesis is to bring substantial modifications to existing methods and to propose a new one that can learn and coordinate, using a database of moderate size, movements and interactions of a virtual manikin necessary to the realization of tasks in an industrial context. Great attention will be given to generated efforts to produce the movements and their adequacy with physical realism. The new method will be applied to industrial use cases and simulations using virtual reality.

Assignment

The aim is to simulate a digital human in the context of an industrial process in virtual reality. This digital operator is called upon to carry out various tasks (handling, screwing, etc.) in more or less constrained virtual environments. We want the operator's movements to be as faithful as possible according to the following criteria:

- The operator's gestures and body movements must be faithful to those performed in the real world.
- The forces applied by the operator's body must be consistent and realistic

- Obstacles and sources of interaction in the virtual environment must be taken into account and the virtual operator must act accordingly (go around an obstacle, open a door, bend down, etc.).
- Movements and gestures must be consistent and follow changes in the virtual operator's morphology (weight, height, disability, etc.).

In a virtual reality context, additional constraints arise: not only must the virtual operator's movements meet the above criteria, but they must also follow instructions given by a real user (joysticks, virtual reality headsets and controllers). One of the difficulties is generating realistic movements by processing a limited amount of input data.

Given the complexity of the kinematic chain of a digital human, conventional control methods (e.g. PD controllers governing each joint) become complex to implement once the gesture to be reproduced reaches a certain level of sophistication, as the number of parameters to be defined manually becomes too large.

In the literature, the work closest to these concerns concerns the automatic animation of avatars in animation or video games and uses learning techniques to generate movements, mainly following two approaches [1] :

- Kinematic approaches, where the animation of the avatar is mainly the result of learning statistical laws extracted from a database of existing movements. The absence of physical constraints makes this approach obsolete for our purposes.
- Physics-based approaches, where knowledge of the laws of physics is used to generate realistic animations, for example by training an agent in a virtual environment using a physics engine.

Among the work resulting from this latter approach, those using learning by imitation methods show promising results [2], such as the possibility of transferring an animation from one type of character to another [3] or generating interactions between the dummy and the environment [4]-[6], or between several agents [7]. Some of these methods also make it possible to apply the same movement to dummies with different morphologies [7], [8] or in environments with objects of different sizes and shapes.

In these works, reinforcement learning is used to train an agent to reproduce a target movement in a virtual environment, while being compared with similar movements from a database of real movements. However, these methods suffer from major limitations, which we encountered in our case study:

- They require a large amount of movement data acquired by gesture capture. While public databases can be used to learn simple, general movements (climbing stairs, sitting down, etc.), movements specific to the operations we want to reproduce need to be acquired, and these will only be available in limited quantities.
- Training times, during which the agent interacts in the virtual environment, are very long, on the order of several days on high-performance hardware.
- For each different movement, a different agent has to be trained, which means additional training time [9].
- The generation of new movements that are absent from the databases remains a difficult problem, even if work has proposed solutions such as ‘mixing’ movements [6], [10].

Main activities

The aim of this thesis is therefore to make substantial modifications to existing methods, and if necessary to propose a new one, which learns and coordinates, from a database of modest size, the movements and interactions of a virtual dummy required to carry out tasks in an industrial environment in virtual reality. A great deal of attention will be paid to the efforts generated to obtain the movement and their adequacy with physical realism. Although learning methods based on imitation are the preferred starting point, other approaches could be tackled and investigated (supervised and/or self-supervised learning to make the most of the data, Graph Neural Networks for representation learning, etc.).

The PhD student will carry out a bibliographical study to establish an exhaustive overview of recent methods for generating movements. He/she will then implement the most relevant method(s) for our case study and evaluate their performance. A new

method will then be proposed, providing a substantial improvement over the state of the art on one of the above-mentioned points. Finally, its implementation on a representative industrial case will enable its performance to be evaluated within virtual reality simulations.

This work will lead the PhD student to develop a new motion generation method.

This work will be supported by at least one publication in an international peer-reviewed journal and several papers in international peer-reviewed conferences.

The work can be broken down as follows:

- To - To+3: Getting to grips with the subject (bibliographical study)
- To+3 - To+12: Implementation and comparison of existing generation methods
- To+12 - To+23 : Proposal for a new motion generation method
- To+23 - To+33 : Experimentation on case studies
- To+33 - To+36 : Writing of the manuscript

The thesis will be supervised by three partners: CEA LIST, CEA Pays de la Loire, INRIA (Rennes University Centre). It will take place mainly at the CEA LIST Nano-innov site, with periods spent visiting the other partners.

Bibliography

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3. *B. Peng, Z. Ma, P. Abbeel, S. Levine, et A. Kanazawa, « AMP: Adversarial Motion Priors for Stylized Physics-Based Character Control », ACM Trans. Graph., vol. 40, n^{o} 4, p. 1□20, août 2021, doi: 10.1145/3450626.3459670.*
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9. *Won, D. Gopinath, et J. Hodgins, « A scalable approach to control diverse behaviors for physically simulated characters », ACM Trans. Graph., vol. 39, n^{o} 4, août 2020, doi: 10.1145/3386569.3392381.*
10. *Xu, X. Shang, V. Zordan, et I. Karamouzas, « Composite Motion Learning with Task Control ». 5 mai 2023. doi: 10.1145/3592447.*
11. *Zhong, V. Weistroffer, P. Maurice, C. Andriot et F. Colas, « Interacting with a Torque-Controlled Virtual Human in Virtual Reality for Ergonomics Studies ». IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW), 2022, pp. 678-679, doi: 10.1109/VRW55335.2022.00190.*

Skills

The candidate must have MsC in computer sciences, ideally with a focus on machine learning. Knowledge of physical simulation, computer graphics or virtual reality is a plus. In addition, the candidate should be comfortable with as much of the following items as possible:

- Deep learning / Deep Reinforcement Learning

- Development of 3D/VR applications (e.g. Unity3D) in C# or C++.
- Evaluation methods and controlled users studies.
- Computer graphics and physical simulation.

The candidate must have good communication skills, and be fluent in English.

Benefits package

- Subsidized meals
- Partial reimbursement of public transport costs
- Possibility of teleworking (90 days per year) and flexible organization of working hours
- Partial payment of insurance costs

Remuneration

Monthly gross salary amounting to 2100 euros for the first and second years and 2200 euros for the third year

General Information

- **Theme/Domain :** Interaction and visualization
  Software Experimental platforms (BAP E)
- **Town/city :** Paris
- **Inria Center :** Centre Inria de l'Université de Rennes
- **Starting date :** 2025-01-01
- **Duration of contract :** 3 years
- **Deadline to apply :** 2024-08-31

Contacts

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- **PhD Supervisor :**
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About Inria

Inria is the French national research institute dedicated to digital science and technology. It employs 2,600 people. Its 200 agile project teams, generally run jointly with academic partners, include more than 3,500 scientists and engineers working to meet the challenges of digital technology, often at the interface with other disciplines. The Institute also employs numerous talents in over forty different professions. 900 research support staff contribute to the preparation and development of scientific and entrepreneurial projects that have a worldwide impact.

Warning : you must enter your e-mail address in order to save your application to Inria. Applications must be submitted online on the Inria website. Processing of applications sent from other channels is not guaranteed.

Instruction to apply

Please submit online : your resume, cover letter and letters of recommendation eventually

Defence Security :
This position is likely to be situated in a restricted area (ZRR), as defined in Decree No. 2011-1425 relating to the protection of national scientific and technical potential (PPST).Authorisation to enter an area is granted by the director of the unit, following a favourable Ministerial decision, as defined in the decree of 3 July 2012 relating to the PPST. An unfavourable Ministerial decision in respect of a position situated in a ZRR would result in the cancellation of the appointment.

Recruitment Policy :
As part of its diversity policy, all Inria positions are accessible to people with disabilities.