Offer #2023-06880

Reconstruction of the Cosmic Web skeleton

Level of qualifications required : Master's or equivalent

Fonction : Internship Research

About the research centre or Inria department

The Inria centre at Université Côte d'Azur includes 37 research teams and 8 support services. The centre's staff (about 500 people) is made up of scientists of different nationalities, engineers, technicians and administrative staff. The teams are mainly located on the university campuses of Sophia Antipolis and Nice as well as Montpellier, in close collaboration with research and higher education laboratories and establishments (Université Côte d'Azur, CNRS, INRAE, INSERM ...), but also with the regiona economic players.

With a presence in the fields of computational neuroscience and biology, data science and modeling, software engineering and certification, as well as collaborative robotics, the Inria Centre at Université Côte d'Azur is a major player in terms of scientific excellence through its results and collaborations at both European and international levels.

Context

Context. The large-scale structure of the universe, also called cosmic web, is represented and analyzed through the distribution of galaxies and dark matter. The cosmic web is a dynamic structure that evolves under the effect of gravity and the expansion of the universe. This structure is not random but organized as a network of filaments connecting dense regions of galaxies. Identifying these features and reconstructing the cosmic web with vectorized representations is a key scientific challenge to better understand the structure of the universe. Numerous algorithms have been proposed in the literature for performing these tasks, as underlined in the survey of Libeskind et al [1]. Popular approaches rely upon mathematical tools such as graph theory [2], stochastic geometry [3], or Morse theory [4] to cite just a few of them. Only a few methods have addressed this problem from computational geometry tools that construct space-partitioning data structures to decompose the 3D space into volumes, surfaces and lines. Yet such data structures seem particularly well suited for reconstructed the underlying structure of the universe.

Objectives. The goal of this internship is to investigate new methods for reconstructing the skeleton of the cosmic web that exploit efficient space-partitioning data structures from computational geometry field. This topic is particularly timely. The candidate will study the potential of Delaunay triangulation, Voronoi diagrams and power diagrams for capturing and connecting filaments of galaxies and clusters of galaxies. His/her algorithms will be tested on simulated data with Ground Truth, typically the simulations Gaea, that provide the dark matter distribution, positioning of the galaxies and the halos. Considering as input data, a set of 3D points representing the galaxies, a first objective will be to construct a space-partitioning data structure where edges align with chains of points. One possible solution could be to first group points into either large cluster (ie halos connecting the extremities of filaments) or secondary clusters (contained in the filaments), before connecting them using a Delaunay triangulation. If time remains, one could also imagine adapting a Delaunay triangulation dynamically to the distribution of dark matter with a Delaunay point process [5].

This is a fast-growing topic with the imminent start of major new generation galaxy surveys performed with the recently launched ESA Euclid mission and the Large Synoptic Survey Telescope at Rubin Observatory. which will enable unequaled tri-dimensional mapping of the galaxy and dark matter distribution.

Keywords: Geometry processing, computer vision, cosmology, massive point clouds, point set processing, geometric data structures

Candidate profile: The ideal candidate should be student in M2 or M1 in Computer Science or Mathematics, have good knowledge in 3D geometry and applied mathematics, be able to program in C/C++, be fluent in English, and be creative and rigorous.

Application deadline: December 18, 2023

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Location: Inria Sophia Antipolis with visits at the Observatoire de la Côte d'Azur

References

[1] Libeskind et al. Tracing the Cosmic web. Monthly Notices of the Royal Astronomical Society, Volume 473, 2018

[2] Bonnaire et al. T-ReX: a graph-based filament detection method. Astronomy and Astrophysics, volume 637, 2020

[3] Tempel et al. Bisous model - Detecting filamentary patterns in point processes. Astron.Comput. volume 16, 2016

[4] Sousbie. DisPerSE: robust structure identication in 2D and 3D. ArXiv 1302.6221, 2013

[5] Favreau et al. Extracting Geometric Structures in Images with Delaunay Point Processes, IEEE Trans. on Pattern Analysis and Machine Intelligence (PAMI), Vol. 42(4), 2020

Assignment

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Main activities

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Benefits package

- Subsidized meals
- Partial reimbursement of public transport costs
- Leave: 7 weeks of annual leave + 10 extra days off due to RTT (statutory reduction in working hours) + possibility of exceptional leave (sick children, moving home, etc.)
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)
- Social, cultural and sports events and activities
- Access to vocational training
- Social security coverage

General Information

- **Theme/Domain :** Interaction and visualization
  Biologie et santé, Sciences de la vie et de la terre (BAP A)
- **Town/city :** Sophia Antipolis
- **Inria Center :** Centre Inria d'Université Côte d'Azur
- **Starting date :** 2024-04-01
- **Duration of contract :** 6 months
- **Deadline to apply :** 2024-04-30

Contacts

- **Inria Team :** TITANE
- **Recruiter :**
  Lafarge Florent / Florent.Lafarge@inria.fr

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

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.