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A GEOMETRIC METHOD TO TRACE THE N-BODY SIMULATIONS WITH COMPUTER VISION APPLICATIONS

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N-body simulations are very important for several areas of physics, since they are used to simulate the dynamics of particles that interact through mechanical forces, such as imposed by the gravitational field. Many of these computer simulations are widely used in astrophysics to investigate cosmological phenomena, such as the formation of large-scale structures as filaments and dark matter halos in the cosmic web[6] [1, 2]. In this context, machine learning techniques can become extremely useful to compare different cosmologies since they have great performance for pattern classification. Several frameworks have open source code and are available for implementation on several platforms, such as MediaPipe [3] and OpenCV [4]. These machine learning solutions commonly applied to computer vision problems still have a little explored potential in the analysis of data from physical simulations, mainly in pattern recognition during the formation of structures with homogeneous and non-homogeneous models in cosmological scales. Therefore, it is intended to apply these tools in the analysis of large-scale cosmological simulations, such as the Millennium Simulation [5], doing Multiple Object Tracking of particles so that, with machine learning tools (such as deep learning), it can be verified whether it is possible to carry out the analysis of the cosmological parameters by calculating the distance of the centroids formed by the particles along the snapshots of the simulations. In this work we introduce a new metric that contains the minimum geometric information which consists of the triangulation among three particles. An example can be seen in figure 1. Once the particles are chosen, the algorithm allows to follow the evolution of the simulation from the following measure:

$$\Delta_n = |A_1(n) - A_2(n)|/A_1(n) + d(n), \qquad (1)$$

where A_1 is the total area considered, A_2 is the area of the triangle defined by the three tracked particles and d is the distance between the center of A_1 and the centroid of A_2, for snapshot n. We call Δ_n the Score of the technique. Partial results indicate that the evolution of the Score given by the equation 1 is able to trace the evolution of gravitational instability throughout the simulation for different initial conditions, indicating that the technique can be useful for characterizing different simulations, models and validation of the same when compared with observational data to be obtained in the future through new telescopes such as the LSST. The use of the presented method for training models in computer vision will also be discussed.

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[6]Region around a galaxy.

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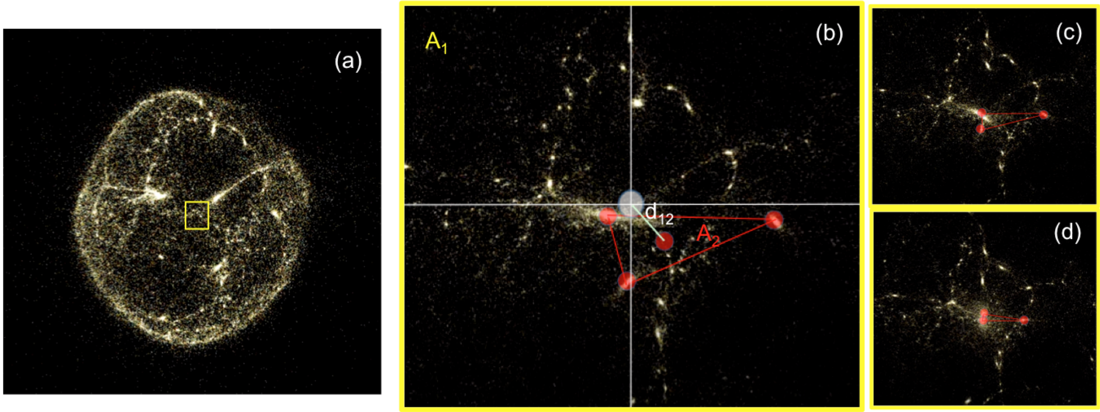

Figure 1: (a) Selection of a generic stamp in the snapshot of an N-body simulation performed with the COLATUS algorithm[2]. (b) Selection of 3 particles to calculate the score Δn along the evolution. (c and d) are examples of an intermediate and final snapshot where the area variation between the selected particles is observed.

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