Simulation of Galaxies for Real World Scenario

Problem Statement

The main objective of the project is to simulate computer aided experiments which will show the shape like existing galaxies on the simulated images and videos. The galaxies were formed after the initial Big Bang due to gravitational pull between matter particles, gases to form stars and their groups called galaxies. One of three form of galaxies: elliptical, spiral or irregular can be synthesized by writing computer programs by giving the input as initial form of cosmos and laws of gravitation working between each star and gases like Hydrogen between them. Complex Physics laws are programmed, and parallel processors are used to predict what final shape the group of stars nearby tend to form in the presence of driving force of gravitation between them.

Background

The galaxies are studied why their shapes are like each other and generally in three patterns. This helps scientists to know what will be galaxies shape in billion years from now. The galaxy formation process is understood using these simulations and reason behind their shape is ascertained by these massive CPU time taking and complex programs.

Reference url: http://www.rhysy.net/galaxy-simulations-1.html
https://www.space.com/28140-best-galaxy-simulation-eagle-video.html

The supercomputer is used to show how loose assembly of matter takes the form of a spiral shaped galaxy. The simulation also helps us view the 3-D aspect of galaxies as we see only 2-D images of galaxies.

[1] Volker Springe et al. proposes N body simulation to study the formation of Galaxies 380,000 years after Big Bang. Authors show the process with large N = 10^{10} (hence named as Millennium simulation due to its size). The dominant mass component which is the cold dark matter, is assumed to be made of elementary particles interacting only gravitationally. Hence, this collision less dark matter fluid was represented by a set of discrete point particles. With this process of simulation author demonstrates the formation and evolution of galaxies, and predict positions, velocities and other properties of all galaxies brighter than the Small Magellanic Cloud.

[2] R. G. Bower et al., observes that the most massive galaxies are old and red and not young and blue as expected in existing models. Existing galaxy formation models results in the formation of the unobserved population of extremely massive, blue galaxies. These are all due to neglect of an important phenomena: the impact of the formation of supermassive black holes at the centers of galaxies. This phenomenon has been recently recognized.

[3] Joop Schaye et al. describes the feedback process from star formation. Existing experiments physics do not include these feedback process and impose velocities and mass loading factor of galactic winds due to radiation pressure. Due to high heating temperatures the star formation suppresses initial radiative losses. These heating factors are synthesized using some observed to real data. Thus, authors tried to solve the discrepancies in simulation predicted galaxy shapes to

the existing real shapes.

[4] Wellons Sarah et al. investigates the formation processes of Massive, quiescent galaxies at high redshift in Illustris through a suite of hydrodynamical cosmological simulations which incorporates a sufficiently large volume to include rare objects, alongwith simultaneously resolving the internal structure of galaxies.

Methodology

I Step 1. Complex code is written using Physics laws of Gravitation and motion.

Law 1 used: F = G*M*m/R*R. G is the Newtons gravitational constant and M mass of 1^{st} star and m mass of 2^{nd} star. R is the distance between stars.

Law 2 used: F = m * a. When gravitation pull exerts bodies closer they move with acceleration equal to Force divided by mass of the object. Thus, objects either merge or start rotating due to circular acceleration equal to gravitational force on body.

Step 2: The particles final position is compared with galaxy shapes and correctness of algorithms is proved to show reason for spiral and elliptical shapes having stars in them. Irregular shape is explained by the presence of dust and Hydrogen gas in these galaxies.

Figure below shows simulation result of such super computer programs by The Virgo Consortium, Schaye et. al. When we enlarge portion of cluster formation then we see it is quite similar to a galaxy in real universe.

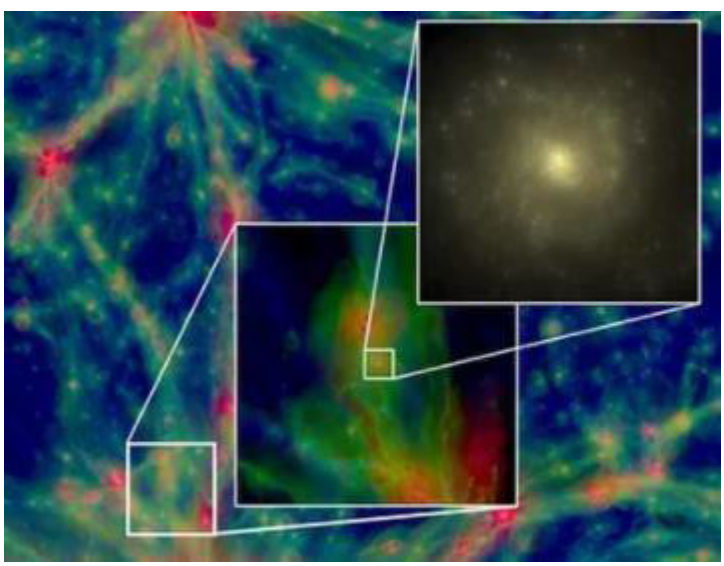

Fig 1 Cluster in galaxy simulation showing the elliptical shape of galaxy [1]

II We can use CNN for learning from the simulation experiments as training data and then give test data as present galaxy structure of few close galaxies. It can then predict the shape of those galaxies after billion years and tell which galaxy will merge into a bigger galaxy and disappear in future.

III Deep Convolutional Generative Adversarial Networks (DCGANs) can also be used to give synthesized images of galaxy simulation. Generative Adversarial Models are used to learn the distribution describing the complex structures of the galaxy web. CNN can be trained on 2D images of galaxy web from N-body simulations and used to generate synthetic galaxy web. DCGAN-generated images are very similar to the ones from N-body simulation: it captured the complex structures of halos, filaments and voids.

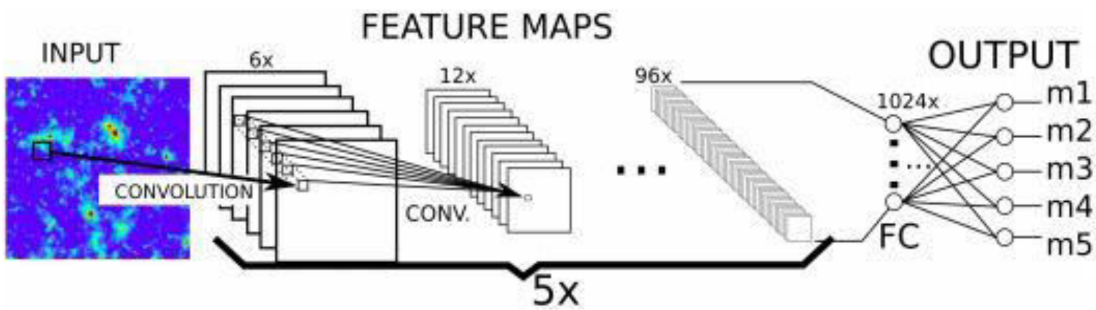

Fig 2 Training of a CNN with 5 by 5 filter and 6 feature map in 1st layer and keeps doubling in each layer with filter size same. The output classes show the future shape of the nearby galaxies.

Experimental Design

Step 1: Giving the input as loosely assembled particles and forces of gravitation and motion working on them.

Step 2: Design a PC for mammoth display of millions of particles to view the shape of galaxies from the simulation output.

Step 3: Design a CNN with experiments conducted as training data and predict future shape of present galaxies. It can also be used to simulate bigger experiments.

Evaluation Measures:

The pattern formed by physics laws is compared with actual shape of galaxies and found that it resembles the shapes closely.

Software and Hardware Requirements:

A parallel multi-processor GPU and programming by scientists having thorough knowledge of laws of physics and coding will be utilized to show the galaxy structure from the shape taken by loose particles.

The simulations need creation of videos for the particle interaction and their movement to show the process of galaxy formation in several thousand years. This solved the question of missing galaxies which might have merged with larger galaxies near to them.

Anaconda/python based spyder tool will be used with keras and tensorflow libraries to create the CNN.

Reference url for supercomputer simulation:

http://www.caltech.edu/news/recreating-our-galaxy-supercomputer-51995

https://www.space.com/28140-best-galaxy-simulation-eagle-video.html

References:

[1] Simulating the joint evolution of quasars, galaxies and their large-scale distribution, Volker Springe et al., Journal reference: Nature 435:629-636, 2005, DOI: 10.1038/nature03597

[2] Breaking the hierarchy of galaxy formation, R. G. Bower et al., Monthly Notice Royal Astronomical Society 370:645-655,2006

[3] The EAGLE project: simulating the evolution and assembly of galaxies and their environments, Joop Schaye et al., Monthly Notice Royal Astronomical Society 446, 521–554 (2015)

[4] The formation of massive, compact galaxies at z = 2 in the Illustris simulation, Wellons Sarah et al., Monthly Notices of the Royal Astronomical Society, Volume 449, Issue 1, p.361-372