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Immersive 4-D Interactive Visualization of Large-Scale Simulations

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Abstract. In dense clusters a bewildering variety of interactions between stars can be observed, ranging from simple encounters to collisions and other mass-transfer encounters. With faster and special-purpose computers like GRAPE, the amount of data per simulation is now exceeding 1 TB. Visualization of such data has now become a complex 4-D data-mining problem, combining space and time, and finding interesting events in these large datasets. We have recently starting using the virtual reality simulator, installed in the Hayden Planetarium in the American Museum for Natural History, to tackle some of these problem. This work[2] reports on our first "observations," modifications needed for our specific experiments, and perhaps field ideas for other fields in science which can

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[2]`http://www.astro.umd.edu/nemo/amnh/`

benefit from such immersion. We also discuss how our normal analysis programs can be interfaced with this kind of visualization.

1. NEMO, Starlab and GRAPE

NEMO[3] (Teuben 1994) and Starlab[4] are traditional programming environments with which N-body simulations can be setup, run, and analyzed. NEMO also has a number of tools to import and export data in tables, CCD type images, FITS files, and a large number of other N-body formats. NEMO is geared more towards collisionless stellar dynamics, while Starlab has more sophisticated programs to deal with close encounters, and can now also incorporate stellar evolution through the SEBA package (Portegies Zwart et al. 2001). NEMO and Starlab present themselves to a user as a large set of programs, often glued together using pipes in shell scripts to set up and run complex simulations. For the programmer, a large set of classes and functions are available to construct new integrators and analysis programs. For example, in the following Starlab example an anisotropic King model with 2048 particles has been evolved with 50% binaries (i.e., 3096 actual stars) and stellar evolution:

```
mk_aniso_king -i -n 2048 -u -w 4 -F 3                         |\
  mkmass -i -u 100 -l 0.1 -f 3                                |\
  mksecondary -f 0.5 -l 0.1                                   |\
  addstar -Q 0.5 -R 2.5                                       |\
  scale -M 1 -E -0.25 -Q 0.5                                  |\
  mkbinary -f 2 -l 1 -u 1000000 -o 2                          |\
  kira -a 0.1 -d 1 -D 25 -n 25 -t 4000 -Q -G 2 -u -B -z 1 > run001
```

The GRAPE special purpose hardware (Hut & Makino 1999), now running at 100 TerraFlops speed, has been successfully interfaced with Starlab, and now is starting to produce massive datasets. Analysis and visualization techniques of those dataset are becoming increasingly challenging.

2. AMNH, Virtual Director, and Partiview

The American Museum for Natural History (AMNH) in New York City has recently renovated its planetarium, and converted it into a state-of-the-art digital planetarium with capabilities for scientific visualization. Their computer system consists of an Onyx2, with 28 CPUs, 14 GB of memory, 2 TB diskspace and 7 graphics pipes. Each graphics pipe controls one of 7 projectors which illuminate the dome in a dodecahedral pattern. The software that drives most visualization is an NCSA product called Virtual Director[5] (`virdir`), that we have now been

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[3] `http://www.astro.umd.edu/nemo/`

[4] `http://www.manybody.org`

[5] `http://virdir.ncsa.uiuc.edu/virdir/virdir.html`

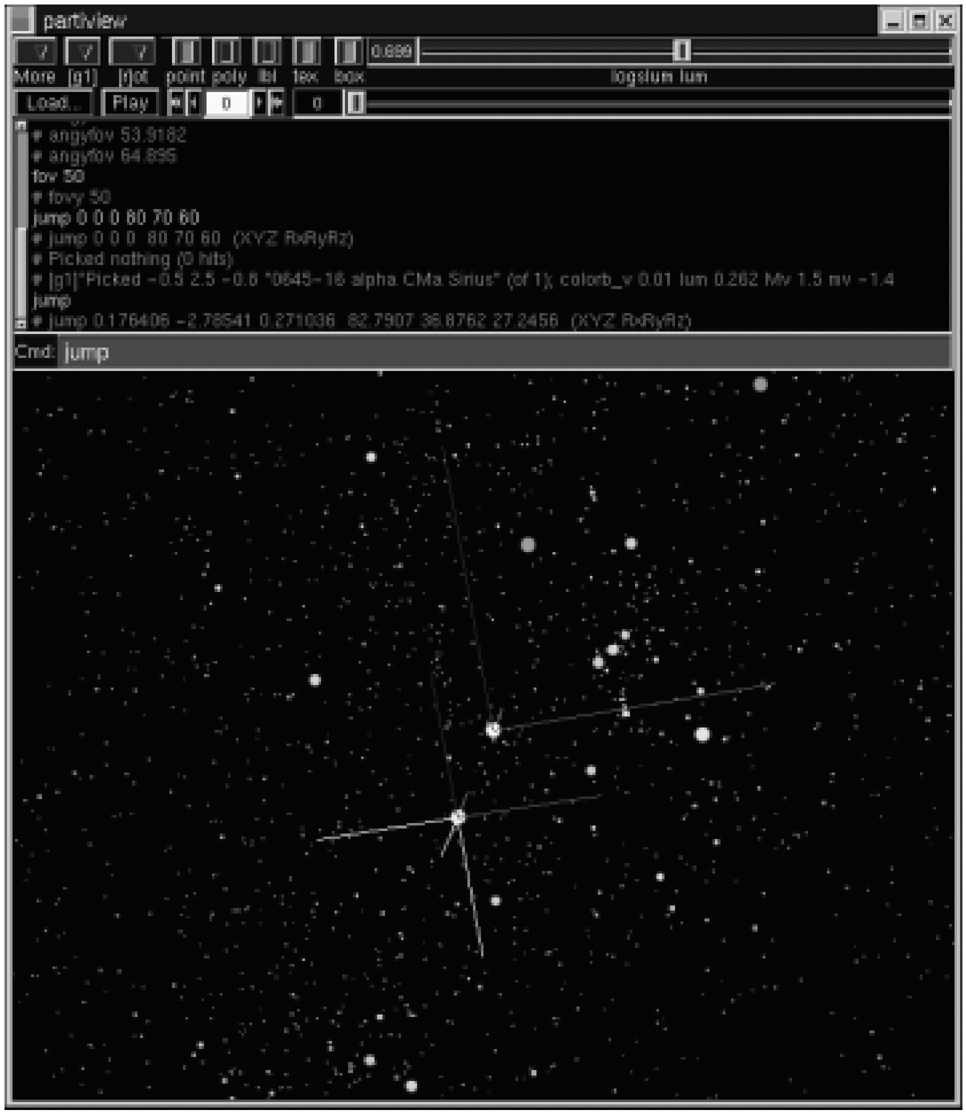

Figure 1. Partiview in action: after loading a 4-D dataset, the mouse in the window controls motion and spatial orientation, the jog-wheel at the top right controls animation, either manually or via the CD-like control buttons to the right. Partiview also has a command language, commands are entered in the `Cmd` window in the middle, right below the scrolling logfile window.

using during a number of night sessions in the dome, much like optical observers (during daytime the planetarium is of course used for public viewing). It allows us to "fly" through the data, in space and time. By adding complete orbital information for a select number of stars we have started fully interactive data mining of our 4-D spacetime histories of these star cluster simulations runs. In order for us to test new visualization techniques, algorithms and interfaces with the Starlab environment, we used an existing program `partiview`, which had been derived from `virdir`, and which can be run on a normal workstation or laptop. It uses the FLTK and MESA/OpenGL libraries for its user interface and fast graphics. A screenshot of `partiview` in action can be seen in Figure 1. We have modified `partiview` to understand our Starlab simulation data, and added interfaces that allow this workstation version to animate and move in time and space. `partiview` comes with a small but powerful set of commands with which dataselections and viewing can be made, and we hope to expand this into a more mature scripting language. It is also fairly straightforward for other packages to benefit from using `partiview`.

3. Future Plans

In the spirit of the federated model of archiving observational data, recently proposed by the National Virtual Observatory (NVO) initiative, we will develop a Starlab-based archive. A simulation of a globular cluster with a million stars stars for ten billion years will generate 100 TB of raw data, of which we would like to store at least 1 TB, and preferably more, for 4-D visualization of the full history of the evolution of a star cluster. Although our main goal will be to enable rapid and intelligent access to our simulation output files, we will simultaneously develop a flexible and transparent interface with the NVO database and protocols. Our Starlab policy will be to make all simulation results freely and publicly available to 'guest observers.'

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