3D Visual Simulation of Fish School

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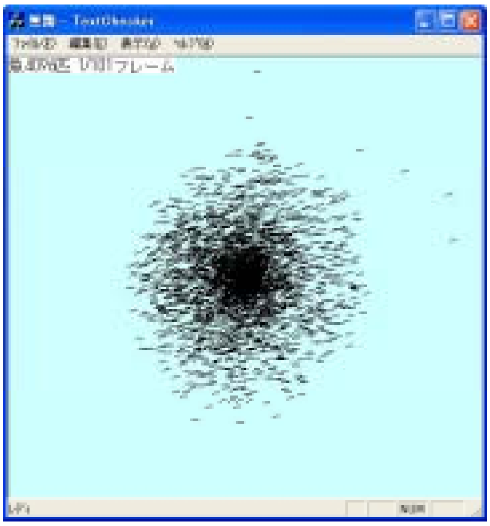
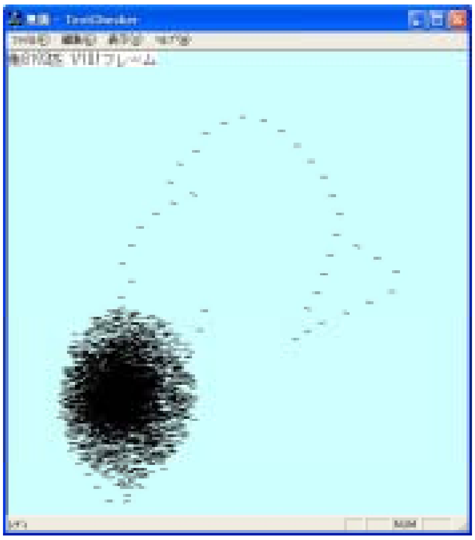


School of size: 4096



School of size: 8192

Value and outline of research on "fish school" simulation

Watching a group of animals, such as a school of hundreds of fish can be amazing because the separate fish often move as if they possess a single mind. Fish at aquarium, such as sardine, keep people entertained with synchronized swimming or collective behavior. But, in reality, it is not easy to observe sardine schools in the sea. There are some hypotheses about fish school, which are made from the fragmentary observed information, but it is hard to verify them. This is the value of fish-school research with simulation. The computer simulation with Monte Carlo method is very effective research approach for the investigation into fish school, which is intricately intertwined with many factors.

The method which uses "random numbers" to imitate the natural or social phenomena is called as Monte Carlo method. First of all, "Monte Carlo" was the code name of nuclear reaction simulation at World War 2. It was similar as gamble, such as domino and roulette, so the name was taken from the casino on Monaco.

The research of fish school has long history. The beginning of history was the assignment at 1927 that Hantarou NAGAOKA（1865-1950, physicist who is famous for the theory of atom model） gave Morisaburo TAUTI（1892-1973） who was a student of Torahiko TERADA（1878-1935, physicist who was a student of Soseki NATUME）. The answer showed us that physical analysis is effective into the exposition of fish schooling phenomena. In 1973, Sumiko SAKAI hypothesized "fish dynamics" from a physical viewpoint. She ran extensive computer simulations of school behavior, and showed that the fish school is formed and maintained by mutual attraction and alignment with swim velocity matching. Then, the use of computer simulations advanced the research of fish school very much.

After those pioneering researches, in the 1990s, the physical analysis and the simulations about schooling phenomena were evolving significantly. Then, these theoretical and numerical approaches dug out complex adaptive system construct of the school: local interaction between each component（fish） makes global order in the group, and then, it is also reflected in local interaction. This is the self-organized system of group commanded action without leader.

Now, the research of schooling phenomena is in the next stage because of speeding up and technical advantages of computer. For example, we run the simulations of fish schools under more real conditions. Until now, we had been treating their behavior as two-dimensional. But the real fish school's construction is in three dimensions: they swim in various directions. Moreover, the real fish school is so large; for example, the school of Japanese sardine（*Sardinops melanosticta*） consists of one million fish and spreads to 100 meters laterally.

"Development of simulation model for fish schools toward stock abundance estimates" of NRIFE（National Research Institute of Fisheries Engineering） runs the large scale simulation in a three-dimensional space, and works toward applied use for the biomass estimates in fish schools. It cannot run the simulation about the school with one million fish. But it is success of it with ten thousand fish. Our Monte-Carlo simulations of fish schooling have been conducted using Mersenne Twister, a pseudorandom number generator, on shared-memory multi-vector-processor（NEC SX-5/16Be） and scalar（SGI Origin 3800） servers with MPI, at the Computer Center for Agriculture, Forestry and Fisheries Research, MAFF, Japan. The simulations run stably based on school dynamics in 3D: attraction between neighboring fish maintains cohesion of the school; a tendency to align with neighbors produces collective motion of the school. Animation GIFs of fish schooling in 3D are available online. We use the result from the simulation to clarify the fish school conformations. The 3D simulation is informative in underwater observations of schooling species with fish-finder or ultrasonic scanning equipment.

3D Visual Simulation of Fish School

As a part of our research subject, numerical fish-school simulations for computer graphics applications were projected to create a 3D digital movie software for visualizing the simulated 3D data. The project was a collaboration with Computer Center for AFFR, SGI Japan, and Silicon Studio Corporation. The 3D digital movie software will be the first content for the digital library collection of the VC hall at the Digital Community in the Agriculture, Forestry and Fisheries Research Council. The 3D animation movie for virtual schools of Japanese sardine runs at the VC hall on a visual computing system, SGI Onyx 3200. The figures above are example images of developing Digital Movie Software（alpha version）.

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