1. Flow around a Protoceratopus

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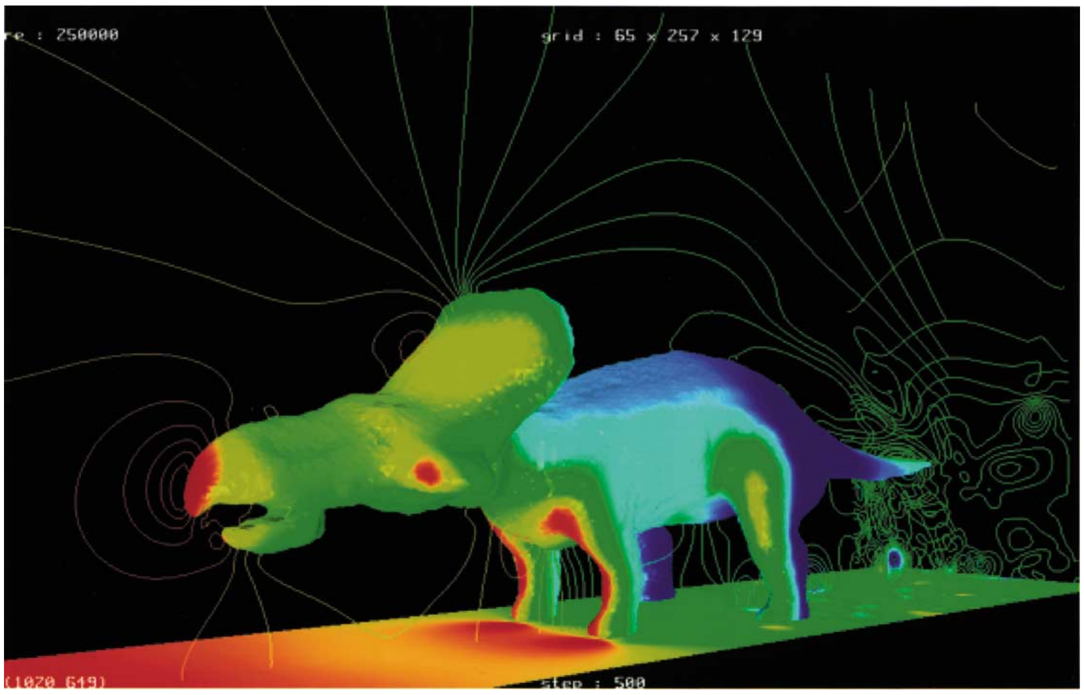

Flow around a complicated shape is very difficult because of the grid generation. In the present approach we used a Cartesian coordinate system with equal spacing for the three directions. Inside the body the velocity components are simply set to be zero. The Navier-Stokes equations are directly solved by a finite-difference method without using any turbulence model at Reynolds number 250 000. The number of the grid points is 64×257×129. The pressure distribution on the surface of the body and the ground is visualized by shading. Also the pressure contour lines in the central plane and in a plane perpendicular to the flow direction are drawn. The computation was performed on DEC alpha based single CPU personal computer ALEPH533.

2. Numerical Simulation of Flowfield around Helicopter Rotor by Moving Overlapped Grid Method

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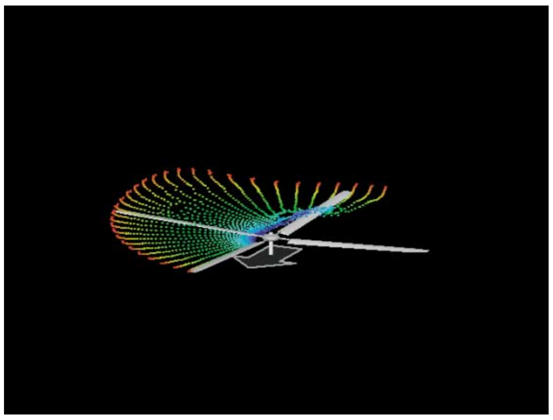
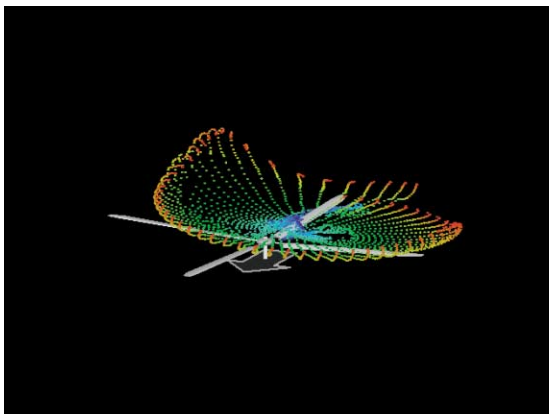


2.1



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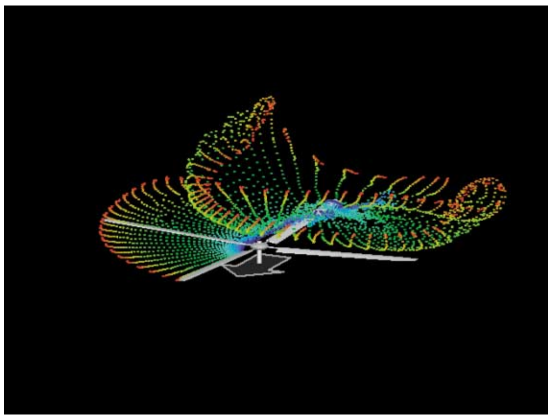

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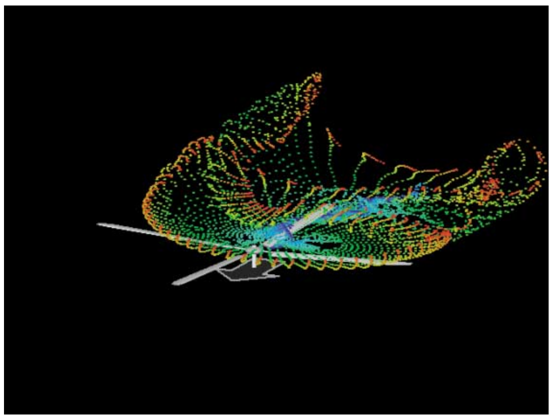

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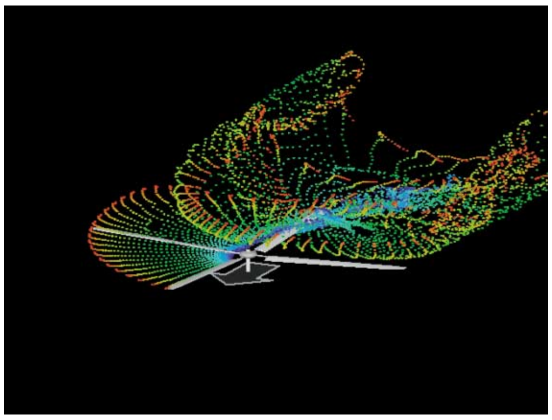

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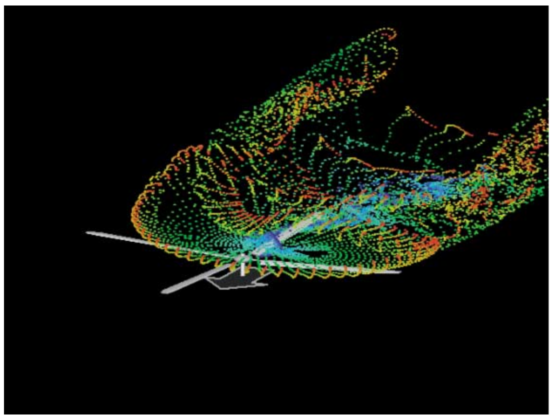

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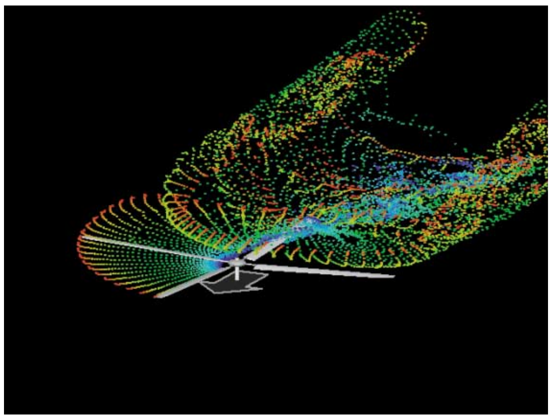
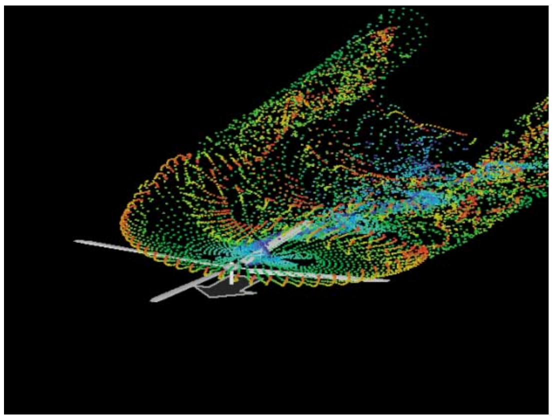


2.7



2.8

The flowfield around a 4-bladed helicopter rotor in a descending flight condition is simulated by an unsteady Euler code and visualized by particle trace in these figures. The phenomenon of roll-up is clearly observed. The Euler code employs a moving overlapped grid method in order to accurately capture the complicated flowfield around a helicopter rotor. The total number of grid points is about 5,320,000. This calculation is performed on a parallel vector super computer, Numerical Wind Tunnel (NWT), in NAL. The CPU time for three rotor revolutions is about 50 hours by using 24 processing elements.

3. Flow Visualization of a Car Flow Field

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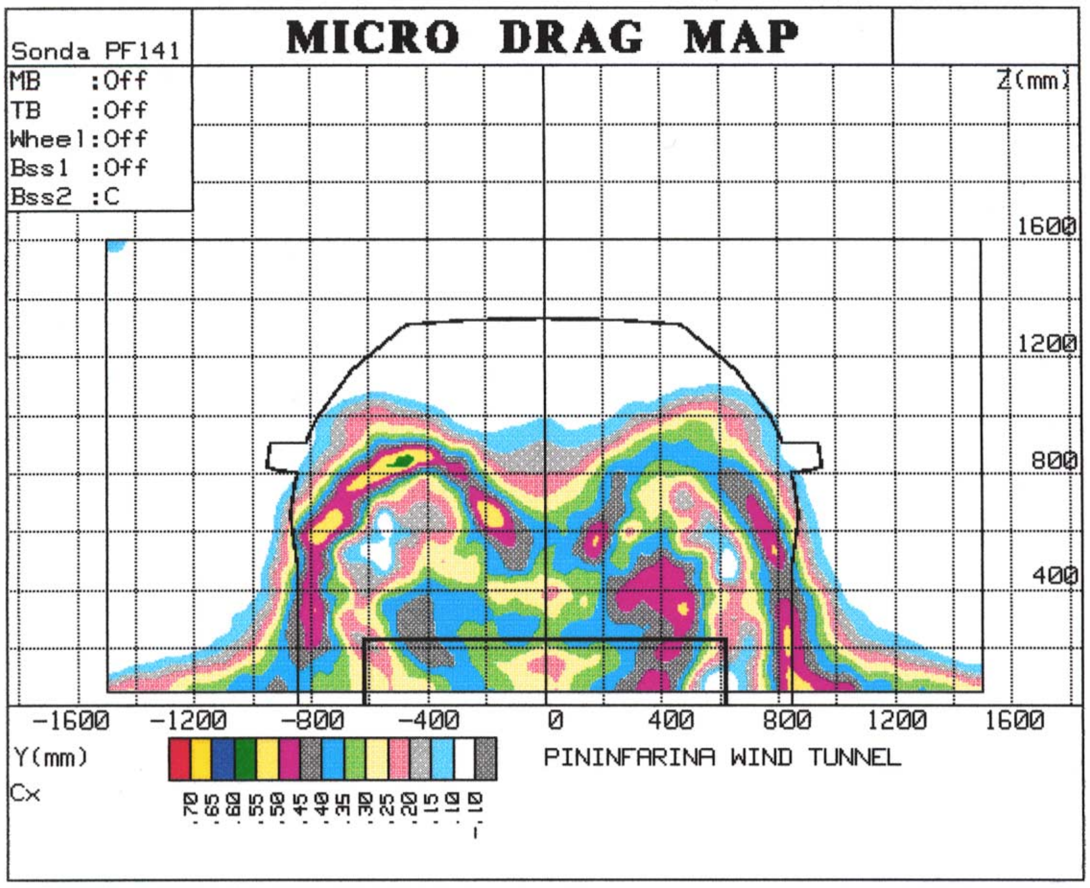
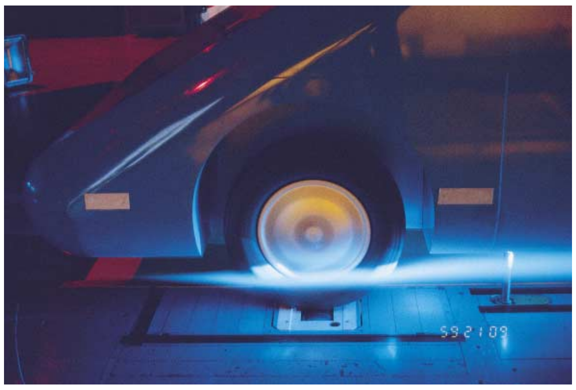


The flow field around a car can be shown either by flow maps, measured by a pressure probe, or by seeding the flow and using a light-sheet. The upper picture shows a flow map, in this case the momentum losses in the flow, as measured by a "14-hole" probe behind a car. The two lower pictures show the flow at the side of a car front wheel, both rotating and static. In this case the light-sheet is made by using an Argon-Ion laser and a multi-mode fiber 40 m long.



4. Time-Domain Simulation of a Berthing Ship

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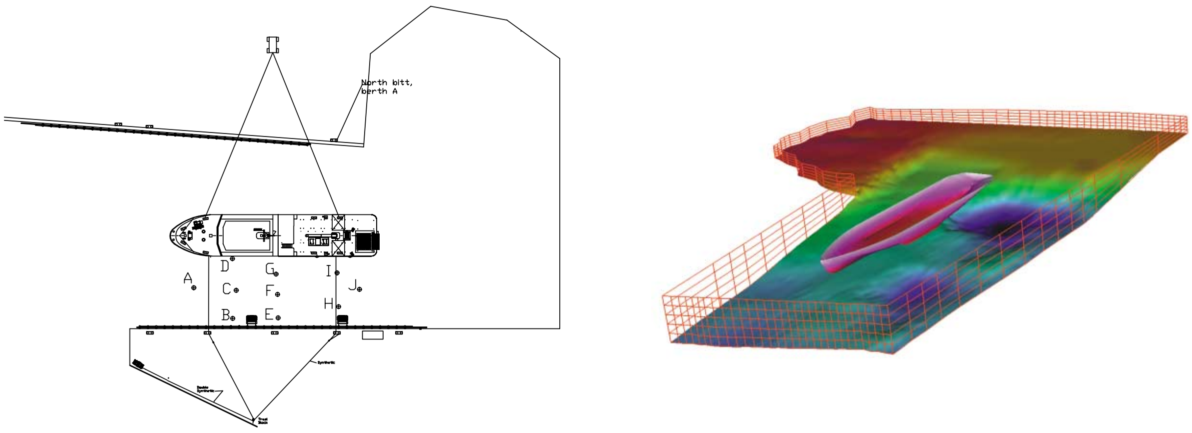
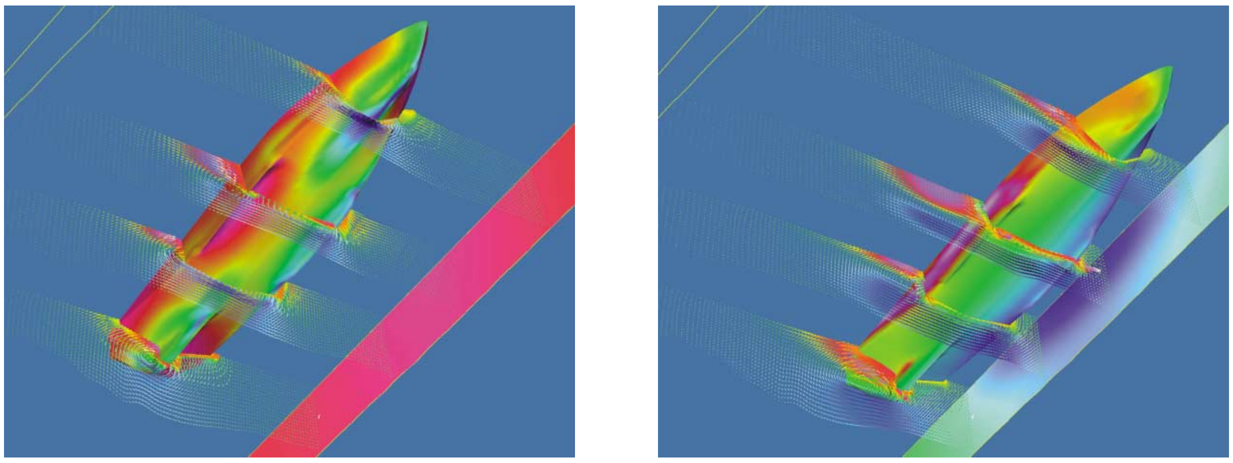


(a) Experimental setup (b) Harbor bathymetry

4.1 Experimental setup and computational domain



(a) t = 255.8 sec (b) t = 349.7 sec

4.2 Velocity vectors and surface pressure distributions

Numerical simulations were performed for turbulent flows induced by the berthing operation of a full-scale ship. Detailed comparisons have been made with the field measurements which were conducted by D. A. Davis, E.T. Huang and W.G. Hatch of Naval Facilities Engineering Service Center in a small harbor at Port Hueneme, California. 4.1 (a) shows the experimental setup with two form fenders mounted near the harbor quay wall. In the present simulation, the form fenders are modeled by elastic elements with a spring constant of 35,000 lbs/ft. The water depth shown in 4.1 (b) varies between 7 ft and 38 ft under mean low water (MLW) level condition. The present method solves the Reynolds-Averaged Navier-Stokes (RANS) equations in conjunction with a chimera domain decomposition approach to simulate the entire berthing process including the hydrodynamic coupling between the ship and the fender systems. 4.2 shows the velocity vectors and surface pressure on ship hull and quay wall at t = 255.8 sec and 349.7 sec (during fender impact) to illustrate the general characteristics of the transient flow field induced by the berthing ship. It is interesting to note that the low pressure region (blue color) shifted towards the quay wall clearance area after the ship touched the fenders. This pressure change is responsible for the drastic increase of hydrodynamic forces during the fender impact.

5. “Natural Rainbow” Schlieren Image of Stratified Flow around Horizontally Towing Cylinder

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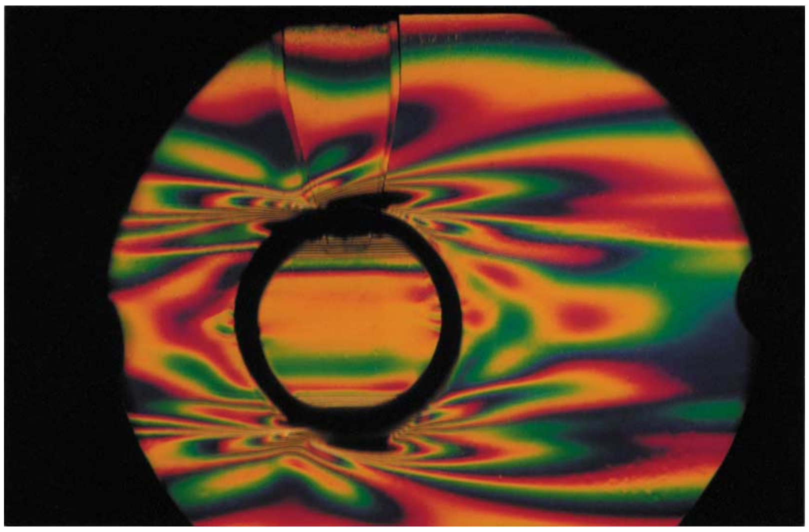
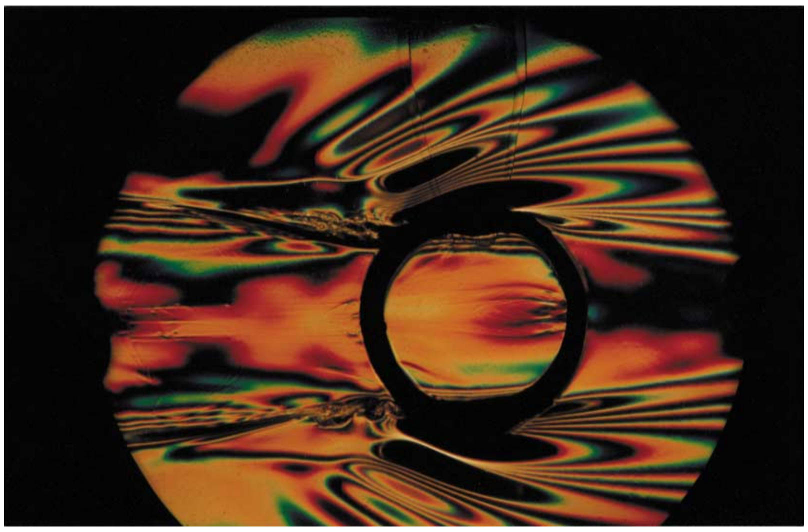


5.1 Pattern of flow around starting cylinder in a continuous stratified salt brine. Buoyancy period T = 6.1 s, body diameter is 7.6 cm, towing velocity is 0.06 cm/s, Re = 48, Fr = 0.01 t = 12 s (motion from left to right). Complex structure of a vertical component of density gradient is observed ahead of the body, where blocked fluid and transient internal waves are formed, and past the body, inside downstream wake separated from adjoin (lee) internal waves by thin high gradient interfaces.



5.2 Pattern of flow past horizontal cylinder (buoyancy period T = 6.1 s, body diameter is 7.6 cm, towing velocity is 0.24 cm/s, Re = 182, Fr = 0.03 (motion from left to right). There is “trauma” of stratification: horizontal interfaces inside adjoins internal waves past the cylinder do not contact with the body or with a vortex.

6. 3D Imaging of Bifurcation Surfaces in Nonlinear Differential Equation

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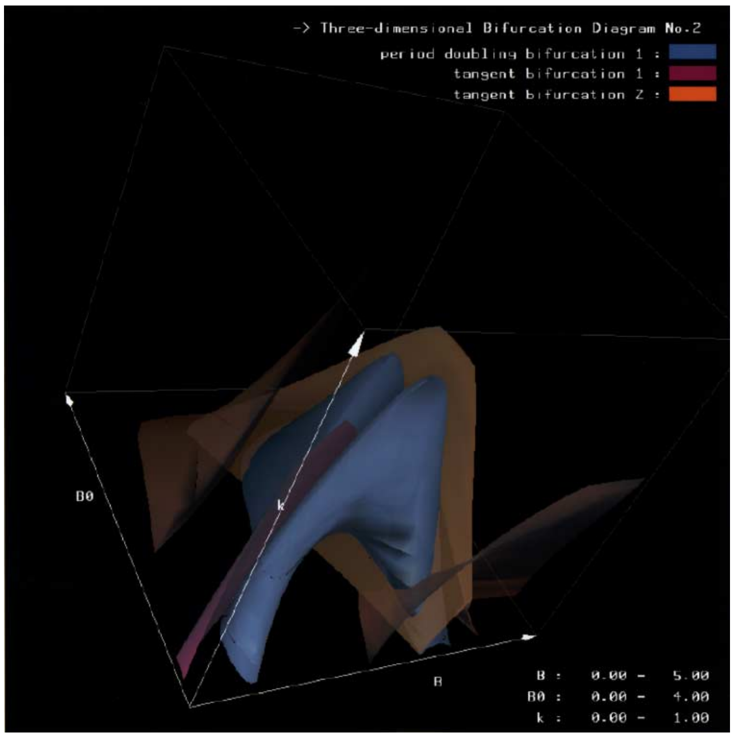

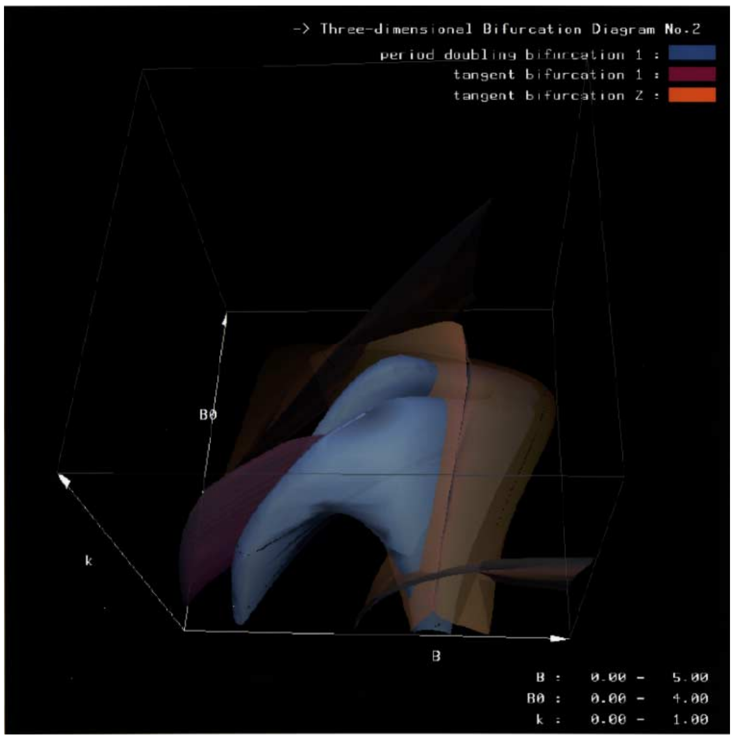

Solutions of dynamical systems described by nonlinear differential equations frequently change their behavior as the parameter varies, e.g., the period has doubled, the solution disappears, and sometimes chaotic motion is appeared. The change of stability for the solution is called bifurcation, and it is important to obtain the bifurcation parameter values to grasp concrete properties of the dynamical system. We develop a visualization system representing solid models as structures of such bifurcation sets in a 3D parameter space by using OpenGL. Here we show the bifurcation surfaces of Duffing's equation. There are period-doubling (blue objects) and tangent bifurcation (others) sets for periodic solutions. It is possible to estimate the parameter location where the system behaves chaotically since there exist period-doubling cascades inside of the period-doubling bifurcation sets.