LabWork #11
MAT 116E-Advanced Scientific and Engineering Computing (MATLAB)
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Main Task

In 1963, Edward Lorenz developed a simplified mathematical model for atmospheric convection. The model is a system of three ordinary differential equations now known as the Lorenz equations:

$$\begin{aligned} \frac{dx}{dt} &= \sigma(y - x), \\ \frac{dy}{dt} &= x(\rho - z) - y, \\ \frac{dz}{dt} &= xy - \beta z. \end{aligned} \tag{1}$$

The equations relate the properties of a two-dimensional fluid layer uniformly warmed from below and cooled from above. In particular, the equations describe the rate of change of three quantities with respect to time: x is proportional to the rate of convection, y to the horizontal temperature variation, and z to the vertical temperature variation. The constants σ, ρ and β are system parameters proportional to the Prandtl number, Rayleigh number, and certain physical dimensions of the layer itself. In this task, they can be taken as $\sigma = 10$, $\rho = 28$ and $\beta = 8/3$.

Write a MATLAB program to solve and plot the Lorenz system (1) by using *ode*45.

Submission Information

Any LabWork submitted after class will be subject to a 20-point deduction per 24 hour period. Extensions should be requested at least 3 days in advance and will only be granted for exceptional reasons (e.g., conference submission). You may work with your friends. Collaboration is strongly recommended. However, each student should be able to present his/her program.

Historical Remark-Edward Norton Lorenz

Edward Norton Lorenz (May 23, 1917 - April 16, 2008) was an American mathematician, meteorologist, and a pioneer of chaos theory. He introduced the strange attractor notion and coined the term butterfly effect.

Lorenz was born in West Hartford, Connecticut. He studied mathematics at both Dartmouth College in New Hampshire and Harvard University in Cambridge, Massachusetts. From 1942 until 1946, he served as a meteorologist for the United States Army Air Corps. After his return from World War II, he decided to study meteorology. Lorenz earned two degrees in the area from the Massachusetts Institute of Technology where he later was a professor for many years. He was a Professor Emeritus at MIT from 1987 until his death.

During the 1950s, Lorenz became skeptical of the appropriateness of the linear statistical models in meteorology, as most atmospheric phenomena involved in weather forecasting are non-linear.

His work on the topic culminated in the publication of his 1963 paper "Deterministic Nonperiodic Flow" in Journal of the Atmospheric Sciences, and with it, the foundation of chaos theory. He states in that paper:

Two states differing by imperceptible amounts may eventually evolve into two considerably different states ... If, then, there is any error whatever in observing the present stateand in any real system such errors seem inevitablean acceptable prediction of an instantaneous state in the distant future may well be impossible....In view of the inevitable inaccuracy and incompleteness of weather observations, precise very-long-range forecasting would seem to be nonexistent.

His description of the butterfly effect followed in 1969. He was awarded the Kyoto Prize for basic sciences, in the field of earth and planetary sciences, in 1991, the Buys Ballot Award in 2004, and the Tomassoni Award in 2008.

In his later years, Lorenz lived in Cambridge, Massachusetts. He was an avid outdoorsman, who enjoyed hiking, climbing, and cross-country skiing. He kept up with these pursuits until very late in his life, and managed to continue most of his regular activities until only a few weeks before his death. According to his daughter, Cheryl Lorenz, Lorenz had "finished a paper a week ago with a colleague." On April 16, 2008, Lorenz died at his home in Cambridge at the age of 90, having suffered from cancer.

Awards

- 1969 Carl-Gustaf Rossby Research Medal, American Meteorological Society.
- 1973 Symons Gold Medal, Royal Meteorological Society.
- 1975 Fellow, National Academy of Sciences (U.S.A.).
- 1981 Member, Norwegian Academy of Science and Letters.
- 1983 Crafoord Prize, Royal Swedish Academy of Sciences.
- 1984 Honorary Member, Royal Meteorological Society.
- 1989 Elliott Cresson Medal, The Franklin Institute
- 1991 Kyoto Prize for his boldest scientific achievement in discovering "deterministic chaos" .
- 2000 International Meteorological Organization Prize from World Meteorological Organization
- 2004 Buys Ballot Medal of the Royal Netherlands Academy of Arts and Sciences.
- 2004 Lomonosov Gold Medal of the Russian Academy of Sciences

References

[1] `https://en.wikipedia.org/wiki/Lorenz_system`

[2] `https://en.wikipedia.org/wiki/Edward_Norton_Lorenz`