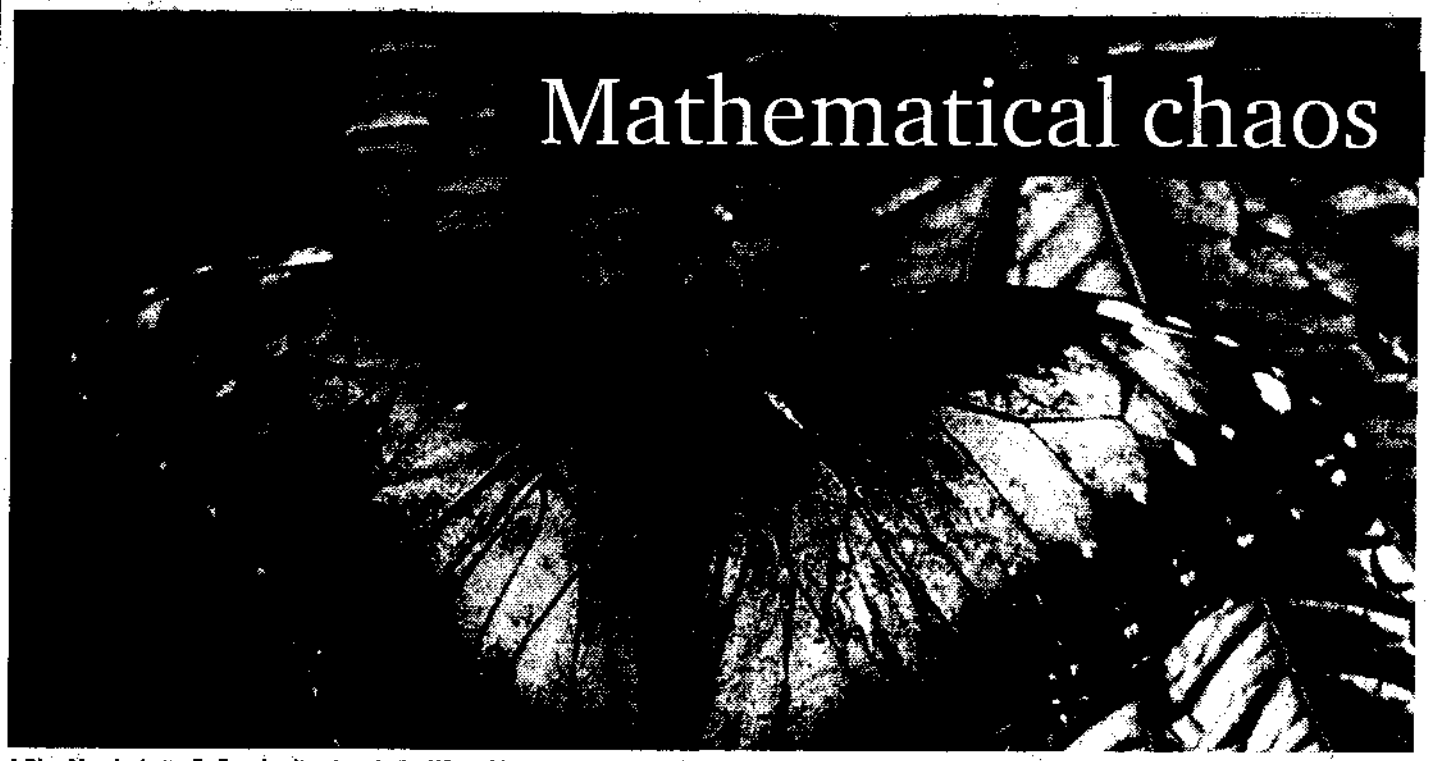
Mathematical chaos



A Blue Morpho butterfly flapping its wings in the US could create a tornado in China, according to a theory known as the Butterfly Effect. REUTERS

Math SERIES

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Weather forecasting has always been difficult. We all know that people who tell us what the weather is going to be tomorrow are not always accurate, but most of us do not know why.

Basically how forecasting the weather works is that a meteorologist uses atmospheric data collected from receiving stations all around the country to determine the current atmospheric conditions. By matching the current conditions to similar conditions from previous years, they can make a guess as to what the weather will do. They can also use a specialized weather computer, enter the current atmospheric conditions into the computer, and have it try and make the prediction for them.

Most of the time forecasting is accurate but the failures can have dire consequences. Sometimes weather forecasting fails spectacularly as in the case of the India Meteorological Department forecasting a fourteenth consecutive monsoon season in 2002, when in fact most of the country experienced a major drought that year.

Why does it fail?

The problem with forecasting the weather is that in order to have an accurate forecast you need to know what the conditions are all over the country. The more places you know, the more accurate the predictions you can produce. However it turns out that even small variations of atmospheric measurements between points can produce unexpected results. The flap of the wings of a butterfly in China has famously been said to be able to, in theory, cause a tornado in the US.

The reason why this happens is because of a sensitivity to initial conditions that occurs in the mathematical equations that represent the weather. Our earth's climate is a complex dynamic system, and the simplest mathematical models for weather include "non-linear" terms. Mathematicians call systems that exhibit this type of behavior "chaotic".

Edward Lorenz was an early pioneer in the modern day field of meteorology. He was using a computer to run a simplistic mathematical model and used 3 decimal places of accuracy to run one trial instead of 6 decimal places, and when he came back to check the progress of the computer, he was astonished. A difference of less than a thousandth part in his initial conditions had resulted in widely different results. This discovery showed that long-range weather forecasting is doomed.

Other examples

There are many other examples of chaotic systems. If you keep track of the time between drips of water from a leaking faucet, you'll find that although there is definitely a pattern to the drips, the length of time between drips is largely random.

Any gravitation system, such as our solar system, with three or more bodies is largely chaotic. This means that although you may be able make short-range predictions about the positions of the planets, predicting their positions in a thousand years is impossible. Our immutable heaven with the planets in their carefully arranged orbits is an illusion.

Another simple example of the chaos theory is created when one free swinging pendulum has another pendulum mounted to its end. After only a couple of swings the second pendulum seems to be moving somewhat randomly. If you raise the pendulum to the same apparent level as the previous swing and release the pendulum again, the motion that results will very shortly not look the same as the original swing.

Market traders consider short-term stock market fluctuations to be chaotic in nature. This means that although long-term projections of the stock market may be possible, short-term predictions are impossible.

The future

If the people of Myanmar had known in advance the destruction the cyclone would cause, they may have been able to protect against some of it. They could have been better prepared for the tragedy. Unfortunately prediction of such a violent storm is possible only at most a few days in advance.

Since long-term weather forecasting is impossible, we need to concentrate on other alternatives to help nullify future catastrophes. Having the mechanisms already in place to assist people who are victims to the weather would greatly ease the pain and suffering that occurs when such a natural disaster occurs.

Activity: Use a leaking faucet to measure the time between drops. Experiment with the flow rate of the water from the faucet and determine at what rate the behavior of the drops becomes chaotic (random). Then, based on your records, try to predict when the next drop will fall. Let me know if you get it right!

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