Chaos Theory Essay, Research Paper

A General View of the Chaos Theory

Abstract

This paper shows the development and uses of the chaos theory through its initial beginnings to its modern day principles. It will discuss the early pioneers in this science along with the developments that have occurred more recently. The chaos theory will be explained and defined in such a way as to make it understandable for anybody with a basic understanding of mathematics. The chaos theory is not just a formula, but a whole new way of examining data to determine the outcome of a system. This paper will also show modern uses of this theory and the potential uses of it in the future.

Introduction

Throughout history, educational methods and theories have mirrored the beliefs of the times about the workings of the human mind. As our technology has grown, our understandings of the universe and its abstract happenings have also. In order to fully understand these new discoveries we must continually develop new formulas. Not only do these formulas and ideas help us solve complex math problems, but they also lead to new insights in both the natural world and the human body. In addition to insights, these new ideas create more problems to be solved, in a never-ending process of learning. In the beginning of this century human kind believed that they had the universe nearly figured out. Then Albert Einstein arrived to enlighten and astound people with their misunderstanding. His new theories and formulas completely revolutionized the patterns of thought. Although the chaos theory probably won’t have the similar broad effect, it has already begun to have a major impact on our lives.

Main Body

“Many people believe that chaos theory is about disorder, but order is at the very heart of chaos.” The chaos theory as we know it had its beginnings in the in the late nineteenth century. Henri Poincare, a great French theoretical scientist, won a contest created by King Oscar II of Sweden. The solution to this contest was the first known work upon the Chaos theory. The contest read:

“Given a system of arbitrarily many mass points that attract each other according to Newton’s Laws, try to find, under the assumption that no two points ever collide, a representation of the coordinates of each point as a series in a variable that is some known function of time and for all whose values the series converge uniformly.”

This problem is called the n-body problem, and Poincare solved it, but only in a few specific cases. His work upon the problem comprised several books, but through these contributions he began the ability to find insights into chaos.

“The modern study of chaotic dynamics maybe said to have begun in 1963, when meteorologist Edward Lorenz demonstrated that a simple, deterministic model of thermal convection in the Earth’s atmosphere.” Lorenz was one of the earliest pioneers of chaos theory, and a meteorologist at MIT. “In 1960, Lorenz began a project to simulate weather patterns on a computer system. Lacking much memory, the computer was unable to create complex patterns, but it was able to show interactions between major meteorological events.” Lorenz, in a later attempt to duplicate the project, accidentally entered data that was off by under one-millionth of the original. When the computer played out this scenario, the result was drastically different from the original. “This discovery created the groundwork of the chaos theory: In a system, small deviations can result in large changes. This concept is now known as the Butterfly Effect.” After viewing the results of this mistake, Lorenz was able to deduce some astounding theories.

“He demonstrated visually that there was structure in his chaotic weather model that, when plotted in three dimensions, fell onto a butterfly-shaped fractal set of points of a type now known as a strange attractor. Lorenz rediscovered chaos and proved that long-range forecasting of the weather was impossible”

After seeing this plot he attempted more experiments that would show the same results. His most famous attempt was a water wheel.

“Examining the motion of his chaotic water wheel, Lorenz was able to model its motion using a series of equations and three variables. Lorenz hypothesized that a graph of these variables would stop at a given point or that a loop would eventually be reformed and retraced.”

Contrary to Lorenz’s prediction neither happened. “It traced a strange, distinctive shape, a kind of double spiral in three dimensions, like a butterfly with its two wings. The shape signaled pure disorder, since no point or pattern of points ever recurred.”

This new pattern discovered by Lorenz was iteration. Iteration is important to the understanding of chaos. There are five types of outcomes for consecutive number iterations. “The equation may converge, or it may become intermittent. The equation may increase quickly or become periodic, but the most interesting case is chaos.” It is this last type of iteration that is most important to the chaos theory. Lorenz’s experiment, when graphed, represented a new iteration. It was named “Lorenz’s Strange Attractor” and, when plotted, was this pattern:

This butterfly shaped graph has become one of the most important in the science of chaos since its invent.

The third famous researcher of chaos, and perhaps best known because of a type of set named after him, is Benoit Mandelbrot.

“He was a mathematician, but he relied upon the formulation of shapes in his head to solve problems, rather than the traditional algebraic approaches. Although this ostracized him from his colleagues, Mandelbrot’s unique ability proved invaluable.”

While he worked at IBM, Mandelbrot was asked to figure out a problem that was occurring in data transfer. Whenever large electronics transmissions were being sent, electronic noise would sometimes interfere with the data. This noise created many errors. Mandelbrot saw that the interference appeared only in clusters, with many errors at once followed by very few. Mandelbrot’s observation and further examination led him to the discovery that on any scale of time magnification of the errors, the proportion of error-free transmission to error-filled transmission stays constant. His explanation was an exact reiteration of the Cantor Set, an earlier discovery by George Cantor, a nineteenth century mathematician. The Set is constructed in this manner:

“First construct a line of finite length. Then, divide the line into thirds, and remove the middle third. This creates two smaller segments. One can then iterate on the two segments to make four. Actually, the operation can be iterated infinitely revealing an infinite number of sparnessness. Strangely, Mandelbrot had managed to apply a mathematical thought experiment to a natural occurrence.”

Another form of the chaos theory graphed, and perhaps the most famous, is the Mandelbrot set. Created by Mandelbrot in 1979, by the formulation of the simple equation: nn + 1 = n^2 + c. The way the number to be graphed is to be determined is as follows:

“Where c is the complex value that is being tested and n is the starting number (called the seed), which is initially 0. This fractal is graphed by the properties a particular a particular point has after being iterated a number of times by the equation. To compute the first iteration, we would take the seed (in this case 0), square it (it’s still 0), and add c (the value of point we picked). This new value is now designated as n. In the second iteration, we square n once again and add c.”

When this set is graphed, each of the five types of iteration appears in the pattern. What makes the pattern so beautiful is using a different color for the iteration. As this set is expanded, each small detail can be examined more closely, and each of those more closely, to an infinite amount of possibilities. These examinations and millions of possibilities based upon the starting point are the essence of the chaos theory.

Formally, the chaos theory is defined as the study of complex nonlinear dynamic systems. Complex implies just that, nonlinear implies recursion and higher mathematical algorithms, and dynamic implies non-constant and non-periodic. Thus the chaos theory is the study of forever changing complex systems based on mathematical concepts of recursion, whether in the form of a recursive process or a set of differential equations modeling a system. Many people hold misconceptions about what the chaos theory really is, and even looking at this definition some may still. “Jurassic Park” contained a direct explanation of the “Butterfly effect” with the following example: “Often called the Butterfly Effect, it is the notion that a butterfly stirring its wings in Peking can transform storm systems in New York.” Through this definition many people were led that chaos is the study of undefined variables in a random or disorderly system. This is hardly the case. The “chaos” in chaos theory is order – not simply order but the very essence of order. While it is true that the chaos theory says that minor fluctuations can cause huge fluctuations: “It is a theory describing the complex and unpredictable motion or dynamics of systems that are sensitive to their initial conditions,” one of the main concepts is that while impossible to exactly predict the state of a system, it is usually possible to model the overall behavior of the system.

The other basis for the chaos theory is that the exact patterns of a system are based upon the starting variables, and any slight and unaccounted for variable may easily change the course of the system. A good example of this phenomenon is the Lorenz Attractor, which represents the behavior of a gas at any time. If the initial conditions in the equation are changed by a tiny amount, great changes result. If someone plotting the Attractor were to change the initial conditions by the inverse of Avogadro’s number, checking the Attractor at a later time will yield numbers totally new and different from the original plot. This is because small numbers propagate themselves recursively until numbers are entirely dissimilar to the original system. Yet, with these new numbers, the plot of the two systems will still look incredibly close to identical. Even with these new number the plot of the system, and the overall behavior of both systems, remains very close. These shows that the chaos theory is not about the unpredictability of the end state, but instead is a representation of the predictability of the behaviors in the system, even the most unstable systems.

“Until recently, it was believed that if the dynamics of a system behaved unpredictably, it was due to random external influences.” Because of this scientists felt that if they could control the external influences of a system, the outcome could be predicted indefinitely. “It is now known that many systems can exhibit long-term unpredictability even in the absence of random influences. This is another reason that the chaos theory is so valuable it allows us to predict endings, even in the most complex and previously incalculable systems.

Now that you understand the chaos theory, you are probably wondering what good it is to society. First and foremost, it is still only a theory, but that doesn’t detract from its usefulness. The chaos theory is a great way of looking at events, which happen apart from the more traditional views, which have dominated science since Newtonian times. It allows scientists to look at events with a phase diagram, which rather than describing the exact position of a variable with respect to time, shows the overall behavior of the system. This new found ability to examine complete behaviors may become invaluable in the future, but currently has only a few uses. “New chaos-aware control techniques are being used to stabilize lasers, manipulate chemical reactions, encode information, and change chaotic heart rhythms into healthy, regular heart rhythms.” In addition to this, scientists are using the chaos theory to better understand the cosmos. “Many bodies in the solar system alone, for example, have already been determined to exhibit chaotic orbits, and evidence of chaotic behavior has also been found in the pulsation’s of variable stars.” “Observations and computer simulations of the irregular tumbling motion of Hyperion, a potato-shaped moon of Saturn, have provided the first conclusive proof that objects in the solar system can behave chaotically.” In addition to this proof there are other instances of probable chaos in our solar system. “Recent computer simulations have also shown that the orbit of Pluto, the outermost planet of the solar system, is chaotic.” There is also evidence of chaos in other every-day activities and body functions. “It is found in the dynamics of animal populations and of medical disorders such as a heart arrhythmia and epileptic seizures. Attempts are also being made to apply chaotic dynamics in the social sciences, such as the study of business cycles and the modeling of arms races.” The uses of it in business are growing too. “It is suspected that even economic systems, such as the stock exchange, may be chaotic.” If people are able to use the chaos theory to predict such systems as the stock market before the mass public, it could represent an amazing get-rich-quick ability. These are many of the beneficial uses of chaos, but there are many more in addition to them. It has also led to the creation of other minor fields in chaos theory, including fractals and chaotic dynamics. “The term chaotic dynamics refers only to the evolution of a system in time. Incorporating spatial patterns into theories of chaotic dynamics is an active area of study.” The chaos theory aids scientists daily in both fields of mathematics and experimentation, and will continue to grow for years to come.

Conclusion

Chaos theory is among the youngest of the sciences, and has rocketed from its obscure roots in the seventies to become one of the most fascinating fields in existence. It is at the forefront of much research on many medical fields. Chaos science promises to continue to yield absorbing scientific information, which may shape the face of science in the future. Not only will it have an impact on science, but it also points to a new direction in thinking that is more natural, albeit much more complex. These changes are far down the road, but not as far as most would imagine. This report has just scratched the surface to the uses and benefits that chaos may someday provide. Although its still just in its infancy many people are already comparing its effects on science to quantum physics and relativity. Only time will tell if it really will change our lives and beliefs so drastically.

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