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The Non-Linear Dynamics in Weather: "The Butterfly Effect"

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Abstract

The Non-Linear Dynamics is one of the concepts in MATHEMATICS, but it has a wide range of applications in both science and technology. My paper deals with one such Non-Linear Dynamical systems 'WEATHER' and elaborates one of the condition through which Non-Linear Dynamics can be explained i.e., 'THE BUTTERFLY EFFECT'. The non-linear dynamics is defined as the study of the systems in which even the small variable change will bring out a large systematic change. These systems are mostly governed by the equations. The Butterfly Effect is the best example for such Non-Linear Dynamics with respect to weather. The Butterfly effect is metaphorical example which results in hurricane, being influenced by minor perturbations caused by very small effect as that of fluttering of the wings of a far-away butterfly, that too quite few weeks earlier (this is mostly found in TEXAS, where the weather conditions are greatly influenced by the minor perturbations). The name, Butterfly effect was first coined by Edward Lorenz. He discovered this effect during experimenting over the runs on his weather model with initial conditions of data that was rounded in a inconsequential manner. This Butterfly Effect deals with the ideas of instability of atmosphere on to the quantitative basis and this also states how everything in this world is interlinked, such that even the removal of a grain of sand from its original position might bring a large change. Thus, this concept can be used eventually in the amplification processes where small inputs can yield high outputs and this creates a revolution in fields of Electronics and communications and also paves a way towards the enhancement in both science and technological aspects.

Keywords: Perturbations, Metamorphic, Chaotic System, topological equivalence

NOMENCLATURE

x,y,z make up the system state

t time interval

γ,ρ,β system parameters

Σ *pronged surface* implanted in space.

f^t some dynamical system for instance at (t≥ 0)

X(*f*) vector feild

f authentic map

f' some map of the period which is close to *f*.

$\varphi^t(\chi)$ trajectory

B some ball where vector field X(*f*) is inserted

I X(*f*â) vector field some map of *f'*

$f_{(a,b)}$ two-parameter set of related maps

1. INTRODUCTION

Butterfly Effect is a poetic impression that the fluttering of a butterfly's wing in Brazil can lay down towards a surge of atmospheric actions which weeks later results in the creation of a tornado in Texas. The butterfly effect can be employed to elucidate why chaotic systems, like the weather can't be predicted in few days advance. Because it is somewhat difficult for one to know about the every single flapping of a butterfly, but there's little hope of predicting the precise point in time and place where a storm will hit a weeks later. The butterfly effect is a minute change at one place of a complex dynamic system that can directs towards a huge and unpredicted results. The dynamic approach to weather emphasizes the complex process that occurs in atmosphere. The butterfly effect was revealed to show the benefits in interdisciplinary research efforts. The meteorologist Edward Lorenz, who first stated about the butterfly effect, observed momentous patterns which appeared to be random events in weather patterns. He studied the patterns mathematically and in due course caught the attention of other meteorologists. These results, notably led towards the new science concept of *chaos* [1] *which* reconciles the essential Unpredictability with the emergence of distinctive patterns. This can be deducible on application of Non linear reasoning. The butterfly effect is one of such non linear phenomenon which is quite agreeable as for the computer replica that led to its invention resembles a butterfly. In 1960s Edward Lorenz created a weather model, named a strange attractor, and noted that the nature of the attractor was enormously sensitive to preliminary circumstances. Moving of its initial position just to a wing's scale in any trend; resulted the line towards a total different and unexpected change which is really very high when compared to initial conditions. This strange attractor led scientists to wind up that, various factual systems such as stock market, the Texas tornado season that ought to be unpredictable. The butterfly effect has sustained and made its vital mark in explanation of chaos theory. Although the Butterfly effect is not that which exactly states that flapping of the wings of butterfly causes tornado in Texas, but it's just an exotic behavior in which even a small negligible change can bring out a large output. In modern sciences, this theory can be applied in full fledge manner in physics, mathematics, engineering, as well as in biology, psychology, and cognitive science. It elucidates why the estimations are frequently imprecise. This recognized the significance of that the foremost circumstances can dramatically enhance the exactness in the scientific predictions. The present paper deals with major objective of exploring the implication of the non linear dynamics in weather through Butter fly effect. The contents that come into play here are the brief explanation about Edward Lorenz model called “Strange attracter”, Lorenz Butterfly effect as seen by mathematicians followed by the non linear dynamical nature found in weather with respect to butterfly and the future scope of Butterfly Effect in the fields of both science and technology

2. EDWARD LORENZ MODEL-STRANGE ATTRACTOR

The attractor which exhibit strange characteristics is defined as a Strange Attracter. The term strange attractor was proposed by David Ruelle and Floris Takens to describe the attractor with help of observations in series of excrescence of a system describing liquefied flow [2]. Strange attractors are frequently distinguishable in a small number of directions, whereas some resembles a Cantor dust, and therefore indistinguishable. Strange attractors are even originating in the existence of noise, where they possibly hold up to unaltering random probability actions of Sinai–Ruelle–Bowen [3]. Henceforth there exist different types of strange attracters such as Henon attracter, double scroll attracter, Rossler attracter, Tamari attracter and Lorenz attracter.

This paper focuses on Lorenz strange attracter. The Lorenz attractor is a group or combination of chaotic solutions of the Lorenz system which will bear a resemblance to a butterfly or number eight when plotted.

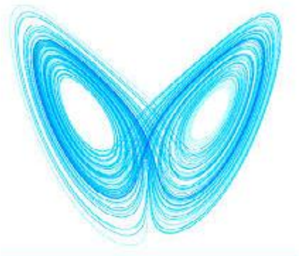

Fig: 1 Lorenz System -Plotted

In general, the system of Lorenz is based upon a set of three common differential equations. These three ordinary differential equations are as follows;

$$\frac{dx}{dt} = \sigma(y - x),$$
$$\frac{dy}{dt} = x(\rho - z) - y,$$
$$\frac{dz}{dt} = xy - \beta z.$$

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The x, y and z present in these equations make up the system state and t states time interval and rho, sigma and beta form as the system parameters. By applying these factors Lorenz performed his experiments. Although it is found to be difficult to analyze the Lorenz attracter, the actions of the differential equation on the attractor is described fairly by a simple geometric model and around in 1961, Lorenz re-examined a sequence of data coming from his model.

Alternatively to the restarting of the complete run, inorder to reduce time span he just restarted the cycle from some point at the middle. He entered the conditions of obtained data at some point near the middle of the previous run, and re-started the model calculation. He observed very unusual and unexpected. The data from the second run is found to be exactly in line with the data with respect the first run. While they coordinated at first, the runs in due course began to diverge dramatically — the second run is found to be losing all resemblance with respect to the first. A sample of the data of two runs obtained by Lorenz in his observations is as follows.

Fig: 2 Sample Data –Two Runs

These runs which were observed in Lorenz model made Lorenz to realize that his dream of long term prediction of weather is hopeless. The simplified weather model of Lorenz was majorly depended on the principle of sensitive dependence which exhibits the phenomenon of sensitive dependence on initial conditions. The major reason behind the Lorenz obtaining these kind of results might be the set of equations that are been used are non linear and are difficult to solve and these nonlinear systems are basically found in chaos theory and regularly show tremendously complex and chaotic performance.

3. MATHEMATICIANS OUTLOOK

To understand Lorenz's butterfly effect mathematically, Guckhenheimer and Williams came up with a "geometrical model" in 1979 [4]. Lorenz had noticed that his dynamics seems to be associated with the iterates of a map *f* from hiatus to itself, even though this interval and this map were only stated within the confines of accuracy of the written values. The foremost proposal of Guckenheimer and Williams is to *initiate* from a map *f* of the interval and to put up some vector field in 3-space whose actions would be similar to that of the Lorenz's equation. The *geometric Lorenz model*, is actually related to the original Lorenz equation which was not measured as imperative. Inspite of everything, the original Lorenz equation was just a rough calculation of a substantial problem and it was indistinct whether it was connected with reality, and moreover mathematicians in this area were not really concerned with the prospects of authenticity.

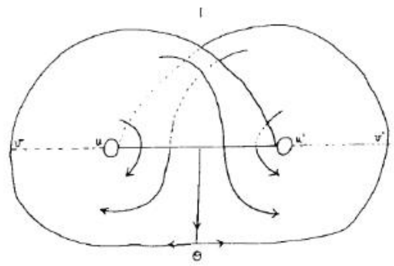

Fig: 3 B*ranched surface* Σ embedded in space

This is a *pronged surface* Σ implanted in space. In defining some dynamical system for instance f^t ($t \geq 0$) on Σ whose trajectories are pictured in the figure: a point in Σ has a expectations but has no times of yore because of the two segments which amalgamate along an period. The first map that returned on this time span is the map *f* given from the interval to itself. The dynamics of f^t easy to recognize: the trajectories turn on the facade, either on right or left of the wing, with respect to the position of the iterates of authentic map *f*. So far, this edifice does not furnish in a vector field. Guckhenheimer and Williams assembled a vector field X(*f*) in some ball B in $\mathbb{R}$, transversal to the margin of sphere, whose dynamics mimics f^t most exactly denoted by $\varphi^t(\chi)$, the trajectories of X(*f*) and by Λ the intersection $\cap_{t\geq 0}\ \varphi^t(B)$. So that for every point *x* in B, the accretion points of the trajectory $\varphi^t(\chi)$ are enclosed in Λ . The vector field X(*f*) is just nearer to Σ and that the trajectories $\varphi^t(\chi)$ shadow f^t. For instant, at every point *x* in Λ, there is a point *x'* in Σ such that $\varphi^t(\chi)$ and $f^t(\chi')$ keep on at a very minute distance for all positive times $t \geq 0$. This vector field X(*f*) is not exclusive but is well defined up to topological uniformity [5], *i.e.* up to some topological isomorphism sending trajectories to trajectories. This justifies Lorenz's insight, according to which the attractor Λ acts as a pronged surface. Moreover, every vector field in B which is nearer to X(*f*) is topologically conjugate upto some extent of X(*f*̂) for some map *f'* of the period which is close to *f*. Furthermore, they create unambiguously the two-parameter set of related maps $f_{(a,b)}$ which corresponds to all possible topological equivalence modules. Just in a summarized way, topological equivalence is the vector fields in which the closed region of X(f) depending on two parameters as that of Lorenz. This is strengthens the property mentioned above. Hence, the set is quite open in the space of vector fields of the type X(*f*) does not hold any structural stability in a vector field. Smale earlier did not know about Lorenz's example, if so he might have saved time. Lorenz's equation did not gratify Axiom A and cannot be estimated with respect to an Axiom A of a system. Therefore the theory of any type, that describing generic dynamical systems should integrate with Lorenz's equation.

4. NON LINEAR DYNAMICAL NATURE OF WEATHER AND BUTTERFLY EFFECT

Weather is the condition of the atmosphere over a small point of time and its outcome is being measured and recorded by a global network of weather stations with the help of satellites. Although these conditions are recorded time to time these are not going to be an appropriate and constant because the weather is the phenomenon which is possessed of non linear dynamical property which is sensitively depended on merely small situations as that even a small change in weather will result in high and unpredictable change which may sometimes cause ironic disasters. The Butterfly Effect is one of such theories which forms as a best example of the concept called non linear dynamics [6] in which even a small change as that is equal to the change caused by the flapping of the wings of a butter fly, may lead to the strange and terrible outcome equal to 'Tornado' at a distant place from the action of butterfly that too several weeks later after the action a butterfly. Even this phenomenon is just a poetic notion which explains the actual concept of butterfly effect which states that a small change in actual being will result in large output. The non linear dynamical theory in correspondance with butterfly effect also strongly supports that everything in the world is inter linked ie, the actions in one place will decides the situations in another place. Henceforth this kind of approach might not helpful exactly in determing the weather conditions, but proper approach this concept with the utilization of modern advanced technology may create scope of yeilding high accurate results which would be really helpful in weather forecasting.

5. FUTURE SCOPE OF BUTTERFLY EFFECT IN SCIENCE AND TECHNOLOGY

Butterfly effect theory is not resistricted only to the field of weather but this can be widely applicable to various other aspects of both science and technology [7]. The application of this theory in electronics and communication sector (especially in amplification processes) can pave a way towards great advancements to the present exsisting technologies and also can be a basic foundation in advent of new innovative modules in gadgets leading towards the prosperity of technical world. This will also results in a great breakthrough even in the case of study of Sciences if applied in a right way. For instant in the fields of medical sciences if this concept is put to study and applied in blood cell deficiency treatment ie, applying this concept in stimulating the main responisible section in the human body for the growth of blood cells with just a small stimuli without much complex medical treatments that sometimes have negative impacts and also expensive to go with.At present this concept is applied in psychiatry [8] in the form of electroconvulsive therapy inorder to judge the moods and disorders in humans. Although this theory was put forwarded by Lorenz to determine the long term weather prediction, which was not yet resolved as weather being a non linear dynamical system.But as we know with the help of present technology there is a chance to predict the short term weather conditons. So keeping this basic successful concept of short term weather predictions in mind and if this theory of Butterfly effect is applied in weather prediction, then there are bright chances to achive long term weather predictions as we observe the growth of science and technology from the time of Lorenz to the present day, it gives a hope that nothing is out of the question and there is a solution for every question in this world of science and technology the only thing required is proper approach towards the problem. Hope the days are not soo far that long term weather predictions can be obtained easily with the help of growing science and technology.

6. CONCLUSION

The father of Butterfly effect Edward Lorenz worked upon his concept of Senstive dependence on his weather model and observed several runs of it and found to be dissatisfied with the results he obtained and finally realized that his dream of long term weather determination(forecasting) is doomed and moreover this theory is not taken into consideration as seriously as that it has to be taken by the other scientists and researchers who came after Lorenz in area of weather determination thinking that it won't work. But there are bright possibilities for its success too, ie., as the classical theory of energy conversion states that energy can be neither created nor be destroyed but it converts from one form to another is proven successfully then the condition can exists in such a way that the initial state before transformation of energy is of low potential and after the transformation it attaians the higher potential and it can be pre-determined on an approximate manner and even in some cases accurately.So if these kind of cases are taken into considerations and applied on the task of attaining long term weather forecasting there are chances to obtain the quite positive results and is left behind for future research studies and experimentations.

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