IS THERE ’CHAOS’ IN MANAGEMENT OR JUST CHAOTIC MANAGEMENT?

by

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Abstract

Due to chaos small causes may evolve in time and have tremendous effects. It leads to very important effects in science and engineering. But does it have implications for management and business? This article discusses possible causes of chaos from a managerial perspective. In science there are some rules how and when chaos is easy to describe. The present paper shows their implications for business situations. It explains how to recognize chaos in business situations. It gives advice how to deal with chaotic systems. It concludes that considering chaos is indispensable for managers and consultants.

Keywords

chaos, general management, business, economics, stock market, decision making, forecast

1. Introduction

Almost everybody might have some understanding of the word chaos. At least in the sense as an ordinary dictionary defines it (e.g. as great disorder or confusion). There is also a more elaborate definition of chaos in science and mathematics. About 25 years ago avalanches of publications dealing with chaos have come into motion. Unlike in many other such cases, they have left traces in "daily life". Recently [1], chaos was used to show that Taylor's management theory [2] can't be correct. The present article will not deal with possible shortcomings of Taylor's theory [2], [3]. It will give hints where scientific considerations of chaos will become important for business and management. Quite often it is argued that in the microscopic world of quantum mechanics the uncertain principle makes the world non-deterministic. And due to chaos similar things do appear in the macroscopic world of daily life. Beside the fact that both statements are wrong they are not helpful.

Therefore I will explain as briefly as possible what chaos means in science. From that I will show that chaos has to do with many things in daily life and especially business. Then I will go back to science and explain why one can sometimes deal with chaos perfectly well and partly not at all. After that, conclusions for daily life will become almost trivial.

2. What is chaos?

The word has its root in the Greek word Χαοσ. Its original meaning was something like "empty space, void". Later, the Roman influence changed its meaning to "disordered mass". The latter meaning can still be found in the e.g. Christian mythology where in the book of Genesis it is written that God created heaven and earth from chaos. Our word "gas" has its origin in the word Χαοσ, too. Historically, gas was very hard to describe because it moves around "chaotically". Indeed the roughly 300,000,000,000,000,000,000 molecules in a cubic centimeter of air move around very chaotically (in the sense of modern science). Their global behavior is nevertheless easy to describe in most situations (It is an example where chaos is easy to handle. But this will become much clearer further below.).

A precise definition of chaos may run as follows. Given is a set of things (e.g. particles, stocks) and their state (e.g. position, velocity, value, yield) at an initial time. Because our world is deterministic [4], their state (e.g. position, velocity, value, yield) can be determined for a later time. Of course, the process of doing it can be extremely tedious. For the above mentioned cubic centimeter of air even the biggest computer in the world cannot determine all paths of all the molecules, though the algorithm is trivial. To do it in principle one has to know the initial state (Nobody can calculate how long a stone will fall if dropped in a well, if it is not known how deep the well is.). Needless to say, if the initial states will vary so will the final one. Sometimes the difference in initial states will grow exponentially [5] in time (or faster). I.e. even the smallest initial difference will become big after a long enough period of time. Exactly this is called chaotic behavior or in short chaos.

There are various indicators and definitions for chaos. For a scientist it is important to prove which are identical and which exclusive. The details may be found in a standard text book, e.g. [6]. I will give some less precise but easy to understand examples from daily life.

First consider two cars driving on a fixed route through a big city (e.g. a loop of 50 miles in length). Let them both start at the same time but 1 mile apart. If neither of them is speeding their distance will remain roughly 1 mile. Their exact positions are difficult to determine due to traffic lights, etc. (Note that in principle everything is strictly deterministic.) This first example does not show chaotic behavior, if one takes the (average) distance between the cars as output variable.

In the second case I will assume the same initial state (two cars in a big city, 1 mile apart). But now the drivers are not supposed to drive on a fixed route. At every intersection they decide where to drive by the rule to minimize their stopping time (In the case of several choices they may have a rule like first straight, then right, and least preferred left). At least if you perform this experiment in Los Angeles on a Friday afternoon, the distance of the cars will grow rapidly. It is a typical example for chaotic behavior. But there are a few important remarks. As in the first example the position of each car (and their distance) is strictly deterministic. The chaotic behavior will also occur if the initial distance is much smaller than 1 mile (Even if they start bumper to bumper.). Their initial distance will change the "onset point" of chaos. Here it is the first intersection where they take different routes.

There is an immediate learning from the two examples. In both cases there are simple and clear-cut rules to predict the future. However, only the first set of rules is useful to predict the future in the real world. You may perform the first experiment on different days in different cities, but its outcome will roughly be the same. I can predict from theory (i.e. the rules) that their distance will remain roughly 1 mile. In the second case I see no way to estimate the distance of the cars after say 3 hours. Even if you tell me that they will both start on a particular day at 12 p.m. on Western corner to Hollywood and Western corner to Melrose (heading south) in Los Angeles, respectively. With the help of traffic forecast and the exact switching times of traffic lights one may write a complicated computer program to simulate the situation. Nevertheless, the outcome will be pretty disappointing (one pedestrian crossing the street 3 seconds later can change the entire picture!).

In business and management one often has models to predict cost or time. They are not fundamentally different from my two examples. A computer program for e.g. optimizing warehousing may be based on a set of rigorous and logic rules. Given the same input the computer will also give the same output each time. But this is also true for the computer program simulating example 2 as mentioned above. Nevertheless, its output will have nothing to do with reality. Whether the computer program is in itself chaotic (and therefore useless) can be checked. E.g. by varying the input variables and intrinsic parameters randomly by a reasonable amount of uncertainty. This will yield the amount of uncertainty in the result, which should stay reasonably small. But even if the program is sufficiently robust, the reality maybe chaotic. I.e. the computer program is useless because it does not describe what it should. And if it would, it would be impractical.

Before I will give some guidelines how to handle such cases, I will give some hints when one should watch out for chaos.

3. How to smell chaos without being burned by it?

Which system will show chaos and which won't is one central question in most scientific work about chaos. (The second question is how to describe it, if it is chaotic. It will be the central question of my next section.) Unfortunately, a global answer to the question has not been found yet. In science and math systems are normally defined by a set of equations. If all equations are entirely linear, chaos won't appear. This is obvious, because in a linear world everything is proportional to everything. I.e. a doubling of something will double other things but not quadruple. Therefore the above mentioned exponential growth [5] can't be observed. However, linearity is in most cases only an approximation to the real world. From this I have the bad news that chaos might lurk everywhere. The good news is that it will disappear, if nonlinearities are small enough. I.e. one can give (for certain classes of equations) exact proofs, whether their nonlinearity is big enough to cause chaos. For two reasons this is not too helpful for the present purpose. Firstly, the proofs are different for each class of equations and, evidentially, the infinite number of classes of equations couldn't have been considered. Secondly, in management we often have rules how systems will evolve. Though they can be as rigorous as equations (cf. examples 1 and 2 above), their translation into math is not always possible.

I will close this section with some rules of thumb. For pure statistical reason chaos becomes more and more likely with growing complexity of the system. Likely sources for chaotic behavior are "if...then..." decisions. In my above mentioned second example they are given by e.g. "if there is only a green arrow to the left, then turn left". But also implicitly in the first example by e.g. "if the car arrives between 2.15 p.m. and 2.17 p.m. at a certain intersection, then it must stop for some time". If...then... decisions are mathematically equivalent to discontinuous functions. A discontinuity is of course a non-linearity. How strong this non-linearity is depends heavily on the difference of the two choices within an if...then... decision. In my first example the maximum effect was a delay of a few minutes, and there is a good chance of averaging out. In the second example its effect will be a different direction (in addition to the delay). And there is no realistic chance that it will be averaged out.

After having given a few guidelines how to detect chaos, I will now deal with the maybe most important question.

4. How to handle chaotic systems?

The best advice is to stay out of them. Of course, that is not always possible. The second best advice is not to "fight" the almighty enemy. Though it sounds ridiculous, I've seen many people trying to calculate solutions for chaotic problems by using bigger and bigger computers.

As you might guess already, this section will not end with a standard recipe to handle chaos. However, I will shed some light on the different approaches. In order to gain some inside, I have to go back to science. Consider e.g. a simple substance like water. It consists of many molecules and they move around very chaotically. Though the rules of interactions between the molecules are well-known and quite simple, no super-computer can handle a gallon of water. (Besides being chaotic, it is also the large number of molecules which makes it difficult.) On the other hand, the flow of water is very well understood. As an example I suggest a tube filled with water. When a pressure difference is applied to the ends, the water starts to flow. Doubling the pressure difference will double the flow. Or less trivial, doubling the diameter will increase the flow 16 times. In predicting the mass flow of water in this experiment, I am predicting an <u>averaged</u> quantity (in contrast to the motions of particular molecules). Of course, nobody is interested which path molecule # 5648 will take. How many gallons per second are flowing out of the tube is of much more importance. The above mentioned process of "averaging" is also known under the name hydrodynamics [7]. It is basically understood. (Note that one needs not to have any understanding of the interactions of the molecules to determine the hydrodynamic behavior of water!) It sounds like very good news for stockbrokers. The daily variation of a particular stock lok pretty chaotic. However, by applying hydrodynamics [7] one should be able to predict the average value of the Dow Jones Index for each week of the following year. Because I am telling it so candidly, you will guess already that I used faulty logic somewhere. To show the point I will go back to my experiment of water flowing through a tube. I was too bold when I told you that I can predict the outcome of the experiment. I can if the pressure difference is not too big. However, reaching a certain pressure difference or more precisely a threshold flow velocity, the smooth flow pattern will change in a chaotic one. Historically, this form of chaos is called turbulence. To understand turbulence would be a big success in science and engineering. It is a good suggestion to apply the hydrodynamic procedure to the turbulent flow of water. There is little interest in the detailed flow pattern. The average amount of water coming out of the tube is for sure more important. Why don't we apply the hydrodynamic procedure for turbulent flows? - How would the result look like? Exactly those questions I had been asked some years ago by a then colleague at the California Institute of Technology. I will spare you with the details of the answers. I will give you three major necessities to work out a hydrodynamics for an underlying chaotic system (i.e. to predict averaged quantities). But I will not give you the reason for the three necessities, because it would go beyond the scope of the present paper (Part of it can be found in ref. [7].). From this it will become obvious, why the above mentioned approach to the stock market won't work.

First one needs a complete set of macroscopic variables to describe the system. Macroscopic means that they are observable (measurable) on a macroscopic scale. In the case of water that may be the flow velocity rather than the velocity of a single molecule. Complete means that the set of macroscopic variables give an unambiguous description of the system. For water only 5 variables are necessary (Two glasses of water showing the same value in the 5 variables are indistinguishable.). That one needs macroscopic variables for a macroscopic description seems to be trivial. Though finding the particular ones is far from being straightforward. For a hydrodynamics of turbulent water I would use the same 5 variables as mentioned above (though I am not 100 % sure about it). For the stock market I would suggest value and yield as variables. However, quantities like market to book ratio, etc. are also likely. I can't give the final answer yet. Though I think finding the right variables does not make the stock market problem insolvable.

The second necessity is a difference in scales. (It will lead to the range of validity of our hydrodynamics.) For simplicity consider the time scale. In the case of water the molecules move back and forth in a time of roughly a trillionth of a second. Therefore one can only predict the macroscopic flow in intervals of say a billionth of a second. This is still pretty small and no real restriction. In the case of turbulence particular water droplets may swing back and forth on a time scale of seconds or less. Therefore a macroscopic description will give at best an average over many seconds. It is already a much severer restriction, though it would be still worth a try. The value of a particular stock will adjust say every hour. A macroscopic approach would yield an average over many hours or at least a week. But this would be still a very desirable result.

The third and last necessity deals with the direction of interaction between the worlds of different (time) scales. I.e. stirring a cup of water may directly influence the motion of a particular molecule but not vice versa. There is no physical law why all the crazy motions of particular water molecules shouldn't add up to a spontaneous macroscopic flow. But one can calculate that it is very unlikely (So unlikely that the age of the universe is a far too short period of time to see it once.). It is the reason why one can tell whether a movie showing flowing water is running backward. In the case of turbulence the interaction is almost symmetric. Imagine a macroscopic flow and an underlying turbulence. There will be times when the flow is changing the turbulence but also vice versa. From this nobody could judge whether the movie is running backward. That's the reason why there is no simple macroscopic description of turbulence. Unfortunately the same does apply for the stock market. A massive fall in the Dow Jones may be due to the summing up of little wiggles in individual stocks. It is rarely due to e.g. takeovers of companies. In other words, little fluctuations (or wiggles) can be the (only) cause for macroscopic changes. In other words, nobody can tell whether a movie is running backward, if it only shows the value of the Dow Jones Index.

So far for the three necessities of a macroscopic (hydrodynamic) description of chaotic systems. If they are all fulfilled, a hydrodynamic description is possible. In such cases I would call the chaotic system easy to handle as I mentioned in the introduction. In the rest of the paper I will comment on other attempts to deal with chaos. They are indispensable, if the hydrodynamic approach fails. Unfortunately, they are still in their infancies.

To describe and predict the directly observable quantities in chaotic systems seems to be hopeless (e.g. the position of the cars in my second example). Maybe the obvious variables aren't reasonable ones. The Theory of Relativity or Quantum Mechanics gave rise to many mystic stories. But they are completely resolved, if one departs from thinking in variables such as three dimensional coordinates, or positions and velocities of particles. In the case of chaotic systems one has things (particles, cars, stocks) which change their position, value, etc. in time. Instead of looking for e.g. a value as a function of time one may consider the different rates or frequencies of change. The set of frequencies can be displayed as a function, too. The latter function is called the "Fourier transformed" (FT) of the original one. There is an easy way to handle back and forth calculation between FT and the original function. Maybe the chaotically varying value of stocks looks very nice if FT. Unfortunately it appears to be even more chaotic. However, if one compares different chaotic systems in an FT world, they show some similarities. Up to now they are not too well understood and almost no conclusion could be drawn. Nevertheless, further research appears to be very promising.

In business and management chaotic systems (e.g. stock market) are compared with nature's chaotic systems [7]. Of course, biology gives rise to much more chaotic systems than the simple world of physics. Such mapping is essentially correct, but not of too much use. It may be good for simulation purposes. E.g. one may use a chaotic system known from science to create a computer program simulating different stock markets. It can be used by stockbrokers like flight simulators by pilots. In doing so one can gain some "feeling", which is often more useful than understanding. But it is neither an understanding nor a prediction. One does not explain system A by comparing it to system B, which isn't understood either. Neither can one predict the future of A by saying it will behave like B, if one does not know anything about the latter one.

5. Conclusions and summary

I've shown that due to chaos little changes may evolve in time and have big effects. And that may happen in daily life (example of cars) as well as in science. There is no standard approach to deal with chaos. For sure a super-computer is not much of a help. To consider averaged quantities is much more promising. However, a standard hydrodynamic approach is not always possible (due to the three necessities). Needless to say one should apply hydrodynamics whenever possible. A "generalized hydrodynamics" would be very desirable. Though it appears to be a tough problem to tackle.

Nowadays management decisions and consultants' advice are based more and more on calculations (e.g. computer programs for optimizing warehousing, activity based costing, complex project plans [8], etc.). The advantage is that they yield a clear-cut answer. That maybe the psychological reason why most people take the result for granted. The existence of chaos should provoke afterthoughts. One should never base any important decision only on the result of a calculation. Even when I worked as a scientist (in theoretical physics), I performed calculations only to get a first impression or to support my explanation. Understanding came always from an array of logic arguments and an intense "feeling" that it is right. Or in the words of the late physic's Nobel laureate Richard Feynman: "To understand something means to be able to explain it to college freshmen."

References

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[3] The reason why Taylor was useful in his time but isn't nowadays has not primarily its origin in the discovery of chaos. A more likely candidate is the fact that processes of management are much closer to their optimum than they used to be and also a different attitude of employees. Therefore, improvement needs finer tools (e.g. process management).

[4] Observation taught us that the world is deterministic. Of course, there is no proof that causality is always valid. It is important and interesting to discuss possible violations. However, this paper assumes a deterministic world. Any different assumption will not change my general message, but it may lead to confusion.

[5] Exponential growth means that there is a certain fixed time period over which the growing object doubles. (E.g. 7.7 % interest per year means that your capital will double every 9 years.) Here, the time period is called Liapunov exponent. A positive one refers to exponential growth (chaotic behavior), a negative one to exponential decay (non chaotic behavior).

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