EXPERT SYSTEM CONCEPTS FOR HANDLING CHAOS

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INTRODUCION

This paper considers the concepts involved with utilizing an expert system to recognize chaotic behavior.

Chaos is an ubiquitous and robust phenomenon that can occur in almost any man-made or natural system where nonlinearities are present [1]. It has been reported in, virtually, every scientific discipline: astronomy, biology, biophysics, chemistry, engineering, geology, mathematics, medicine, meteorolgy, plasmas and even social sciences [2]. Therefore, it became of interest to search for a tool that would help lay people involved with these fields of study to quickly identify chaos. For this we propose to let experts set up expert systems that will allow nonexperts to make judgements based on their data.

Numerous chaotic systems that have been reported in the literature ever since Lorenz published his seminal paper in 1963 [3] are hypothetical rather than physical. Therefore, it is more challenging for us to build this study on the basis of the physical appearance of the chaotic spectrum in hand, rather than using a mathematical estimation.

The chaotic phenomenon is known to exhibit a random behavior that is difficult to predict unless a computer of infinite word length is used to obtain a response from initial conditions; no long-term prediction of the precise solution waveforms appears to be possible [4]. Thus, the expert system introduced here to recognize chaotic signals is of significance.

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CONCEPTS ABOUT CHAOTIC SYSTEMS

In order to build an expert system that recognizes chaotic behavior, it is necessary to first study the main properties that characterize any chaotic system. this section describes those properties.

Chaos is best defined by its long-term behavior, or by the absence of steady-state response, of a circuit, device, or system after initial transient has decayed to zero, following a change in state, such as, the opening or closing of a switch, or the application of a signal [1].

In general, a chaotic system can be recognized as one whose asymptotic behavior is bounded, but has no equilibrium point, and is neither periodic, nor quasi-periodic. To clarify this, two examples of chaotic trajectories are shown in figure (1). The curves are from the computer simulation of the chaos generator circuit [figure (2)].

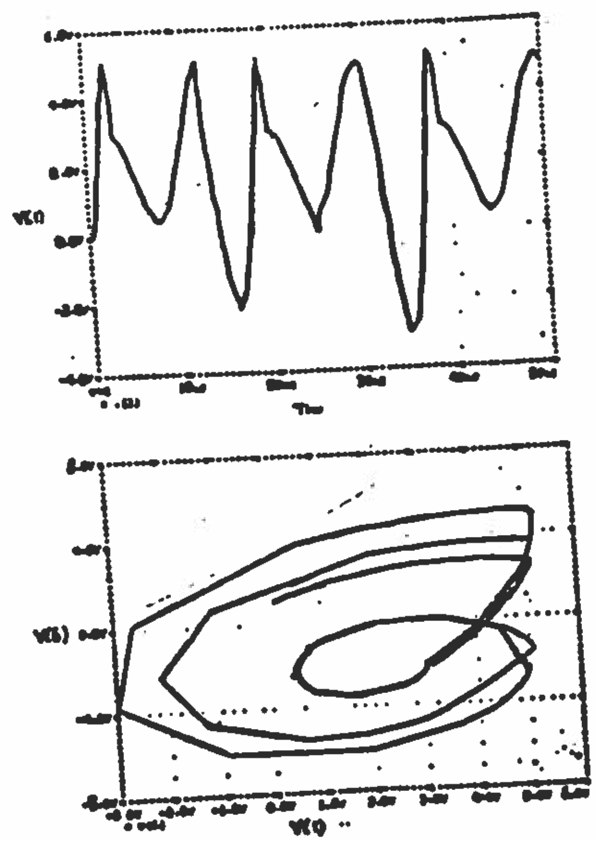


Figure (1). Chaos ocillator circuit responses.

It is evident from these pictures that the trajectories are, indeed, bounded, that they are not periodic, and that they do not have the uniform distribution characteristic of quasi-periodic solutions.

Another property of chaotic systems is sensitive dependence on initial conditions: given two different initial conditions that are arbitrarily close to one another, the trajectories emanating from these points are essentially uncorrelated [5]. This unpredictability is what is usually meant when chaotic systems are referred to as "determinstic systems that exhibit random behavior."

The previous description of chaotic systems is from an engineer's point of view. However, the trajectories of a system in chaos are very complicated when looked at by a novice. As a result, we choose the characteristics that are generally simple and fairly easy to recognize, and use them as inputs to the expert system.

The class of chaotic systems covered in this paper is characterized by nonlinearities that lead to nonperiodic continuous time domain solutions which are noise-like in appearance. The determination of these properties in a rule-based expert system relies on zero crossings, peak values, shape irregularities, phase plane portraits, and spectral data. With those criteria in mind a prototype expert system is developed as a test bed to predict the chaotic mode. This expert system will run alongside an electronic simulation of a chaos generator circuit which is used to produce a transient analysis curve that can be viewed by the user as a possible chaotic spectrum.

CHAOS GENERATOR CIRCUIT

This circuit is used to plot the chaotic signals, and justify the characteristics of the chaotic system in hand. This will later aid in developing the expert system desired.

Here, The particular circuit that demonstrates the chaotic behavior is a second-order, continuous-time, integrable system that is shown to give chaotic responses using binary hysteresis [6]. The significance of this circuit, is that it allows one to

i) build it with only two capacitors (which is the minimum number of reactive elements).

ii) confirm the observed chaotic phenomena by digital computer simulation.

iii) understand the circuit's framework setup (given in [7]) for the design to be realized.

In this section, the chaos generator circuit of [6] is discussed using the following format:

A. Philosophy
B. Circuitry
C. Computer simulation

A. Philosophy

The choatic behavior of electrical circuits is fully justified by nonlinear circuits which are often thought of as linear circuits with distorted behavior. The minimum degree need not be greater than two since degree two chaotic systems have been shown to exist [6][7][8]. The use of degree three systems has been reported in the literature and authors claimed minimality of their circuit implementations based on the Poincare-Bendixson Theorem [9]. However, these circuits are generally not as convienient as the degree two one of [6] which we will use here.

The chaotic responses in a second-order system were achieved by the use of binary hysteresis. The developers of this design explain that the idea, is to create two planes in which second-order linear, but unstable, system "pseudo" trajectories are formed. Via the hysteresis, the true trajectories jump between these "pseudo" trajectories in such a manner that the jump points are eventually fed back inside themselves so that a period-three return map is generated which implies chaos [10]. The idea of using binary hysteresis stems from a comment of Roessler whose papers on the subject of chaos show considerable physical insight into the mechanism involved [11][12].

B. Circuitry

Figure (2) is the RC-op-amp circuit realization of the chaos generator.

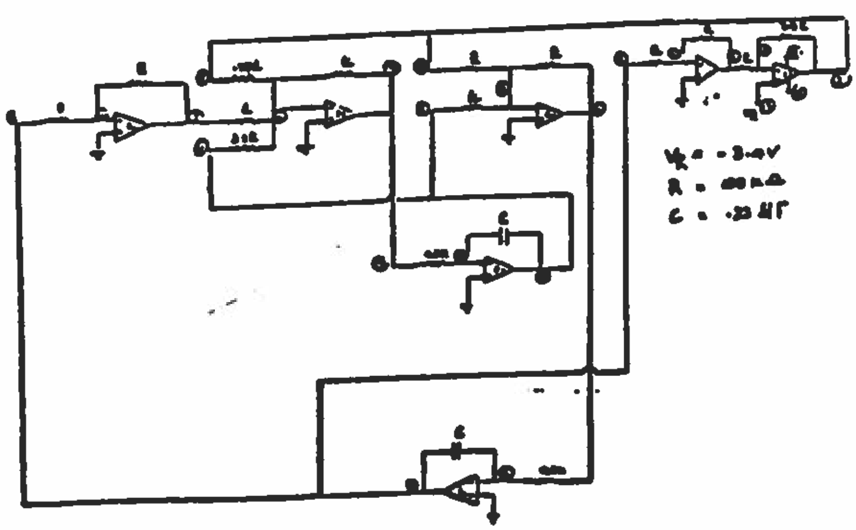


Figure (2). RC-op-amp circuit realization for a Chaos generator.

C. Computer simulation

The PSPICE program was used to simulate the chaos generator circuit (figure (2)). From The curves for the voltage at node 1, $x_1(t)$, the voltage at node 6, $x_2(t)$, and the phase-plane trajectories, $x_2(x_1)$, one can make a decision regarding the presence of a chaotic behavior by noticing the following:

(1) Continuity in the observable time range.

(2) Bounded signals.

(3) Overall noise-like appearance.

(4) Peak variations and unequal intervals.

Having observed, the above basic criteria, we are now ready to use them in building a prototype expert system.

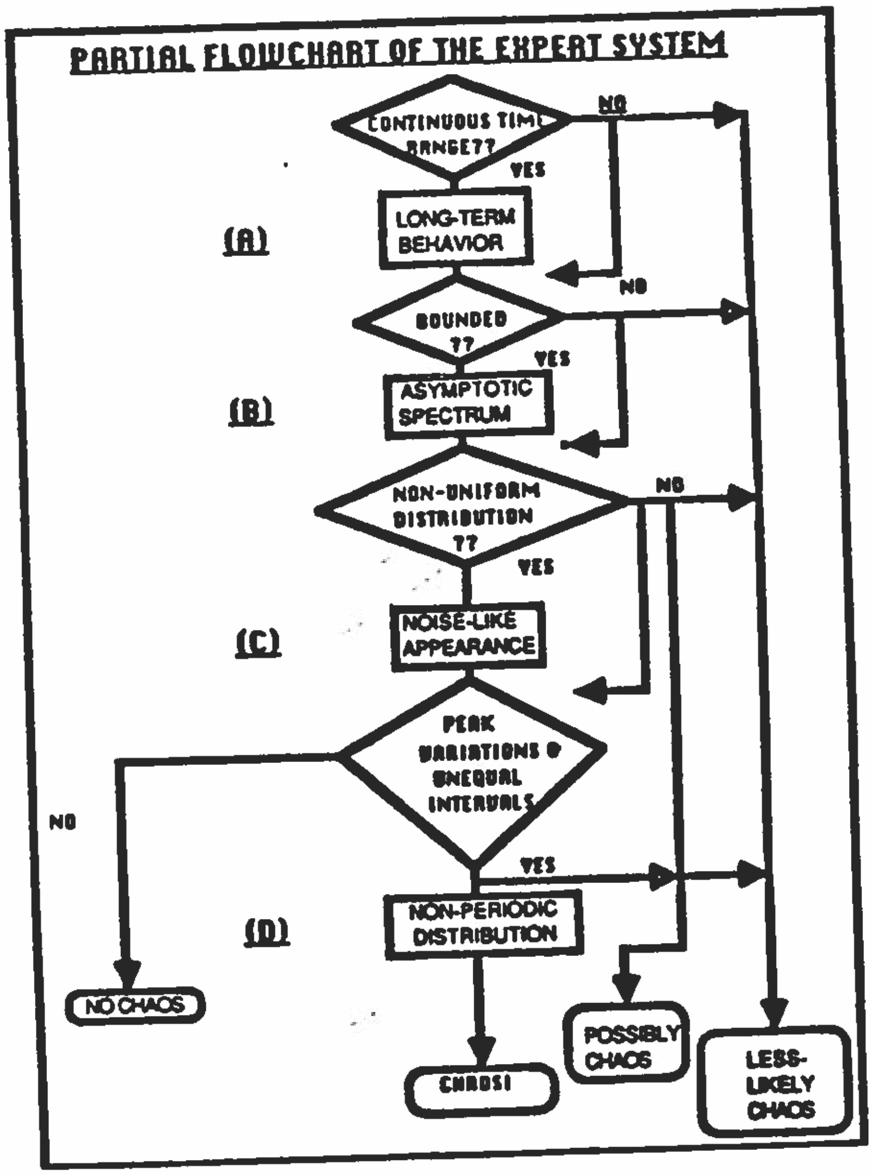
BUILDING AN EXPERT SYSTEM

The philosophy of a rule-based expert system is to use IF-THEN statements that are manipulated by the interface engine to arrive upon conclusions. One of the advantages of an expert system is its English-like rules with which specialized knowlege is captured in a knowlege base and can be accessed to solve primarily nonnumeric problems. Although it seems that an expert system may emulate the virtues of a human expert, it overcomes potential drawbacks in terms of availability, consistancy, and expense.

For our purpose, the prototype system was developed in a Personal Consultant (PC easy) by Texas Instruments. The underlying language is SCHEME, a modern version of LISP. It is comprised of rules that backward chain to obtain the values of the parameters in question.

Figure (3) is the flowchart indication for the rule-based expert system to arrive to a conclusion regarding the presence of chaos.

Figure (4) is the actual rule-base for the prototype expert system. It shows the sequence of rules that are needed to evaluate the expert system parameter "chaos prediction".



PARTIAL FLOWCHART OF THE EXPERT SYSTEM
CONTINUOUS TIME RANGE??
NO
YES
(A)
LONG-TERM BEHAVIOR
BOUNDED ??
NO
YES
(B)
ASYMPTOTIC SPECTRUM
NON-UNIFORM DISTRIBUTION ??
NO
YES
(C)
NOISE-LIKE APPEARANCE
PEAK VARIATIONS & UNEQUAL INTERVALS
NO
YES
(D)
NON-PERIODIC DISTRIBUTION
NO CHAOS
CHAOS!
POSSIBLY CHAOS
LESS-LIKELY CHAOS

FIGURE (3)

BACKWARD CHAINING INFERENCE ENGINE

RULE-BASE

RULE 1: IF CONTINUOUS-TIME RANGE
THEN LONG-TERM OBSERVABLE BEHAVIOR (A)

RULE 2: IF BOUNDED SIGNALS
THEN ASYMPTOTIC SPECTRUM (B)

RULE 3: IF NON-UNIFORM DISTRIBUTION
THEN NOISE-LIKE APPEARANCE (C)

RULE 4: IF PEAK VARIATIONS AND UNEQUAL INTERVALS
THEN NON-PERIODIC TRAJECTORIES (D)

RULE 5: IF [(B), (C) AND (D)] ARE TRUE
THEN "CHAOS PREDICTION=CHAOS"

RULE 6: IF [(A), (B) AND (D)] OR [(C) AND (D)] OR [(A), (C) AND (D)] ARE TRUE
THEN "CHAOS PREDICTION=POSSIBLY CHAOS"

RULE 7: IF [(D)] OR [(A) AND (D)] OR [(B) AND (D)] ARE TRUE
THEN "CHAOS PREDICTION=LESS LIKELY CHAOS"

RULE 8: IF [(D)] IS NOT TRUE
THEN "CHAOS PREDICTION=NOT CHAOS"

FIGURE (4)

CONCLUSION

The purpose of the prototype rule-based expert system discussed in this paper, is to introduce the concepts for building expert systems. As an example, we develped one that concludes whether a particular spectrum is in a chaotic mode. Here, the signals to be analyzed must be viewed by the user while running the expert system.

For a more efficient utilization of such an expert system we are planning to use the HEWLETT PACKARD PC automated test equipment to collect data from an actual electronic circuit and applying the data acquisition software, the ASYST, to put the digitized information into an ASCII file which will make data manipulation on a PC possible. With this process, we can have our expert system directly communicate with the curves generated by the circuit as opposed to querying the user about the characteristics of a plotted curve.

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