Solving Job Sequencing Problems with Fuzzy Processing Times

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ABSTRACT

In this paper, we proposed a solution procedure to solve fuzzy job sequencing problem, where processing time being taken as Trapezoidal Fuzzy Numbers (TrFN). Here, Yager's Ranking Index method has been applied to transform the fuzzy processing time into crisp ones. The optimal solution (order) of the job and idle time for each machine is obtained by solving corresponding crisp sequencing problems using existing method. A numerical example has been considered and solved for illustration purpose.

Keyword: - *Job sequencing problems, Fuzzy processing times, Fuzzy number, Yager Ranking Index*

1. INTRODUCTION

In our daily life decision making problems, viz., job sequencing, assignment, game theory, replacement of items etc. it is sometimes required to take the decision where the values of parameters are ambiguous i.e., parameters involved in the problem are imprecise [3,5,6] . Job sequencing problem is a mathematical way out for finding a series, in which a few jobs or tasks are to be done in an order for which total processing time is minimum. Generally, in job sequencing problems, the processing times are precise valued. But in reality, it is observed that the processing times during performance of the job are imprecise. To handle impreciseness fuzzy set theory [8] plays an important role as fuzzy set is a best mathematical way for representing impreciseness or vagueness. In this paper, we have treated imprecise parameters considering fuzzy numbers. Therefore, the concept of fuzzy job sequencing problem provides an efficient framework which solves real-life problems with fuzzy processing times. In the past, a few attempts have been made in the existing literature for solving job sequencing problem with fuzzy processing times [4, 6]. In this paper, a job sequencing problem [1] has taken into consideration. The processing times are considered to be Trapezoidal fuzzy number. Then the corresponding problem has been converted into crisp equivalent job sequencing problem using defuzzification of Trapezoidal fuzzy numbers. Here, widely known Yager's ranking index method [7] has been used for defuzzification of fuzzy number. The optimal order and idle time for each machine is obtained by solving corresponding crisp sequencing problems using the existing method. Finally, to illustrate the proposed method, a numerical example has been solved and results have been presented.

2. SOME DEFINITIONS

In this section, some definitions and Yager's Ranking Index method are presented.

Definition 2.1 (*Fuzzy Set*) Let X be a non empty set. Then a fuzzy set $\tilde{A}$ in X is a set of ordered pair given by $\tilde{A}=\{(x,\mu_{\tilde{A}}(x)):x\in X\}$, where $\mu_{\tilde{A}}:X\rightarrow[0,1]$ is a function such that $0\le\mu_{\tilde{A}}(x)\le 1\,\forall x\in X$, and $\mu_{\tilde{A}}(x)$ represents the grade of membership of x in $\tilde{A}$.

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A Genetic Algorithm Based Hybrid Approach for Reliability-Redundancy Optimization Problem of a Series System with Multiple-Choice

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AN APPLICATION OF INTERVAL SYSTEM OF LINEAR EQUATIONS IN CIRCUIT ANALYSIS

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ABSTRACT

This paper deals with application of interval system of linear equations (ISLE) in circuit analysis (CA). In CA problems, each circuit consists of resistance, inductance and capacitance and each circuit has been mathematically modeled as a system of linear equations. An interval valued current or interval valued voltage in the circuit is more important measure relative to crisp/precise value because of some factors such as environmental conditions, tolerance in the units/elements and leakage of power harmonics. For this purpose introduction of interval system of linear equations (ISLE) are highly important. Here, an interval valued linear system has been introduced and a numerical example has been presented for illustration purpose.

Keyword: - *Interval linear system, circuit analysis, interval number, current, voltage, Kirchhoff's Voltage Law*

1. INTRODUCTION

System of linear equations plays an important role in many areas such as economics, physics, engineering, statistics and management science. Recently, in many applications some or all of the system parameters and their measures are considered using imprecise valued rather than precise valued [8]. To overcome the problem with imprecise measured generally stochastic, fuzzy and fuzzy-stochastic approaches are used. In stochastic approach, the parameters are assumed as random variables with known probability distribution. In fuzzy approach, the parameters are considered as fuzzy sets with known membership functions or fuzzy numbers [2,6, 9]. On the other hand, in fuzzy-stochastic approach, some parameters are viewed as fuzzy sets and other as random variables. However, for a design engineer to specify the suitable membership function for fuzzy approach and probability distribution for stochastic approach and both for fuzzy-stochastic approach is a very hard task. To avoid these difficulties for representation of imprecise numbers by several approaches, one may represent the same by interval number as it is the best representation among others [1, 4, 5]. Therefore, it is very important to develop mathematical models that would handle interval linear system. Any design of circuit may be represented in the form of interval system of linear equations. Studies of the circuit analysis problems where the current and/or voltage are fuzzy valued have already been initiated by some authors like [7, 10]. In this paper, we have considered interval valued current and/or voltage. For this purpose, we have introduced interval system of linear equations and its solution methodology has been presented. This proposed method has been illustrated with a numerical example arises in a circuit theory. As a special case considering the lower and upper bounds of interval valued voltage as same, the resulting problem becomes identical with the existing problem available in the literature.

2. ASSUMPTIONS AND NOTATIONS

A circuit analysis problem is formulated under the following assumptions and notations:

Assumptions:

(i) The current flow of a circuit is imprecise and interval valued.
(ii) The source voltage of a circuit is imprecise and interval valued.
(iii) The Resistance of a circuit is fixed and/or precise valued.

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Genetic Algorithm Based Approach for Reliability Redundancy Allocation Problems in Fuzzy Environment

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Abstract
This paper presents the use of genetic algorithm to solve reliability redundancy allocation problem of complicated system in fuzzy environment. Generally, this problem has been formulated as single objective integer non-linear programming problem with several resource constraints. In this paper, the reliability of each component as well as other parameters related to the problem is considered to be fuzzy valued. In this work, the corresponding constrained optimization problem has been transformed to crisp constrained optimization problem using defuzzification of fuzzy number. Here, widely known Yager ranking Index has been used for defuzzification of fuzzy number. The Big-M penalty function technique has been used to transform the constrained optimization problem into an unconstrained optimization problem. The converted problem has been solved with the help of real coded genetic algorithm. To illustrate the proposed methodology, a numerical example has been considered and solved. To study the performance of the proposed genetic algorithm, sensitivity analyses have been done graphically.

Keywords- Redundancy allocation problem, Genetic algorithm, Fuzzy number, Defuzzification technique, Yager Index.

1. Introduction

Due to the development of ultra-modern highly reliable system, the reliability of a system is highly dependent on the selection of components as well as increase of component reliability. Generally, selection of components as well as increase of component reliability are evaluated by solving nonlinear integer programming problem, which is known as reliability redundancy allocation problem. For such reliability system with known cost, component reliability, weight, volume and other parameters related to that system, the corresponding design problem is described as a constrained non-linear integer programming problem. The objective of the redundancy allocation problem is to select the number of redundant components that maximize the overall system reliability and/or minimize the overall system cost subject to the given linear/nonlinear resource constraints. As redundancy allocation problem is a nonlinear integer programming problem, so it cannot be solved easily by applying gradient based or mixed search methods due to discrete search space of the feasible region of the problem. The redundancy allocation problem has been well developed by Tillman et al. (1977), Kuo and Prasad (2001). In the literature, it has been noticed that several optimization methods, viz. heuristic methods (Nakagawa and Nakashima, 1977; Kim and Yum, 1993; Aggarwal and Gupta, 2005; Ha and Kuo, 2006), branch and bound method (Kuo et al., 1987; Sun and Li, 2002; Sung and Cho, 1999), reduced gradient method (Hwang et al., 1979), integer programming method (Misra and Sharma, 1991), dynamic programming (Nakagawa and Miyazaki, 1981; Hikita et al., 1992) etc. were used to solve such types of problem. Indeed, these methods have some advantages as well as disadvantages also. Dynamic Programming (DP) technique cannot be applicable in solving such complicated problem as the problem cannot be decomposing into several smaller problems. In branch and bound method (B & B), the efficiency depends on the sharpness of the bound of the

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An approach for solving fuzzy matrix games using signed distance method

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Abstract. The goal of this paper is to solve a matrix game with fuzzy payoffs. In this paper, a fuzzy matrix game has been considered and its solution methodology has been proposed. In this paper, fuzzy payoff values are assumed to be trapezoidal fuzzy numbers. Then the corresponding matrix game has been converted into crisp game using defuzzification of fuzzy number. Here, widely known signed distance method has been used for defuzzification of fuzzy number. The value of the matrix game and strategy for each player is obtained by solving corresponding crisp game problems using the traditional method. Finally, a numerical example has been presented and solved.

Keywords: matrix games; muzzy payoff,fuzzy number; signed distance method.

1. Introduction

In every competitive situation, it is often required to take the decision where there are two or more opposite parties with conflicting of interests and the action of one depends upon the action which is taken by the opponent. A variety of competitive situation is seen in real life society like, in political campaign, elections, advertisement, marketing, etc. Game theory is a mathematical way out for describing the strategic interactions among multiple players who select several strategies from the set of admissible strategies. In 1944, Von Neumann and Oscar Morgenstern [1] introduced game theory in their most pioneer work "Theory of Games and Economic Behavior". Since then many diverse kinds of mathematical games have been defined and different types of solution methodologies have been proposed. The participants in the game are called the players. During the past, it is assumed that all the information about game is known precisely by players. But in traditional game theory, the precise information about the game is more difficult to collect due to the lack of information about the exact values of certain parameters and uncertain measuring of several situations by players. To overcome these types of situation, the problem can be formulated using the concept of uncertainty theory and the domain of payoffs are considered from uncertain environment like fuzzy, interval, stochastic, fuzzy-stochastic environment etc. In such cases fuzzy set theory is a vital tool to handle such situation. Fuzzy set theory, introduced by Zadeh [2], has been receiving considerable attention amongst researchers in game theory. Several researchers have applied the fuzzy set concepts to deal with the game problems. Fuzziness in game problem has been well discussed by Campos [3]. Compos introduced fuzzy linear programming model to solve fuzzy matrix game. Sakawa and Nishizaki [4] solved multi-objective fuzzy games by introducing Max-Min solution procedure. Based on fuzzy duality theory, Bector et al. [5, 6, 7] and Vijay et al. [8] proved that a two person zero-sum matrix game with fuzzy goals and fuzzy payoffs is equivalent to a pair of linear programming problems. Nayak and Pal [9,10] well discussed about interval games as well as fuzzy matrix games. Çevikel and Ahlatçıoglu [11] described new concepts of solutions for multi-objective two person zero-sum games with fuzzy goals and fuzzy payoffs using linear membership functions. Li and Hong [12] gave an approach for solving constrained matrix games with payoffs considering the triangular fuzzy numbers. Bandyopadhyay et al. [13] well studied a matrix game with payoff as triangular intuitionistic fuzzy number. Mijanur et al. [14] introduced an alternative approach for solving fuzzy matrix games. Effect of defuzzification methods in solving fuzzy matrix games has been discussed by Sahoo [15]. Very recently, Sahoo [16] introduced a new technique based on parametric representation of interval number for solving fuzzy matrix game. In this paper, we have treated imprecise parameters considering fuzzy numbers. Therefore, the concept of fuzzy game theory provides an efficient framework which solves real-life conflict problems with fuzzy information. In this paper, a matrix game has taken into consideration. The element of payoff matrix is considered to be trapezoidal fuzzy number. Then the corresponding problem has been converted into crisp equivalent matrix game using defuzzification of

Experimental Determination of η/s for Finite Nuclear Matter

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We present, for the first time, simultaneous determination of shear viscosity (η) and entropy density (s) and thus, η/s for equilibrated nuclear systems from $A \sim 30$ to $A \sim 208$ at different temperatures. At finite temperature, η is estimated by utilizing the γ decay of the isovector giant dipole resonance populated via fusion evaporation reaction, while s is evaluated from the nuclear level density parameter (a) and nuclear temperature (T), determined precisely by the simultaneous measurements of the evaporated neutron energy spectra and the compound nuclear angular momenta. The transport parameter η and the thermodynamic parameter s both increase with temperature, resulting in a mild decrease of η/s with temperature. The extracted η/s is also found to be independent of the neutron-proton asymmetry at a given temperature. Interestingly, the measured η/s values are comparable to that of the high-temperature quark-gluon plasma, pointing towards the fact that strong fluidity may be the universal feature of the strong interaction of many-body quantum systems.

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The understanding of fluidity of matter, measured by the ratio of shear viscosity (η) to entropy density (s), has been the subject of intense investigations in different areas of physics. The crucial ratio of η/s is related to the Reynolds number and is well defined for both relativistic and nonrelativistic fluids [1]. The temperature variation of η/s also provides the crucial signature for liquid-gas phase transition in matter. String theoretical calculations have put a universal lower bound, known as the Kovtun-Son-Starinets (KSS) bound, such that $\eta/s \geq \hbar/4\pi k_B$ [2], k_B being the Boltzmann constant. In strongly coupled systems, momentum transport is highly inhibited, resulting in a small shear viscosity. The prime examples of such highly correlated systems are the Bose and the Fermi liquids [3–5] at extremely low temperatures and the quark-gluon plasma (QGP), produced at high temperatures [6–8]. These quantum systems have very low η/s ($\sim 5 - 10\,\hbar/4\pi k_B$) [1] and behave as nearly perfect fluids.

An atomic nucleus is a many-body quantum system in which the constituent particles, called nucleons, are governed by strong interaction and show highly correlated behavior. A finite nucleus, therefore, is an ideal system to search for near perfect fluidity in matter. Different model-dependent calculations for η/s have been performed earlier at intermediate-energy heavy ion collisions in search for a liquid-gas phase transition [9–12]. The first theoretical study for η/s in relation to the damping of giant resonances in nuclei was done by Auerbach and Shlomo [13] within the framework of Fermi liquid drop model (FLDM) [14]. They showed that η/s values for heavy and light nuclei were $\sim (4 - 19)\hbar/4\pi k_B$ and $(2.5\text{–}12.5)\ \hbar/4\pi k_B$, respectively. Recently, Dang [15] has proposed a formalism, based on the Green-Kubo relation and the fluctuation dissipation theorem, relating the shear viscosity to the width and the energy of giant dipole resonance (GDR) in hot finite nuclei. The empirically calculated values of η/s for different systems have been compared with various model calculations. A model-independent high-temperature limit of η/s has also been proponed for finite nuclear systems.

Viscosity is inherently related to the damping of the GDR, which is conceived, macroscopically, as out of phase oscillation (isovector) of the proton fluid against the neutron fluid. It is a highly damped motion characterized by a very small lifetime ($\sim 10^{-21} - 10^{-22}$ sec). According to the Brink-Axel hypothesis [16], the GDR can be built on the ground state as well as on every excited state of the nucleus. The GDR built on the ground state (henceforth called as the ground state GDR) is studied by photo absorption reactions, while that built on excited states is studied by fusion evaporation and inelastic scattering reactions. The line shape of the GDR is a Lorentzian, characterized by the peak energy (E_{GDR}), the width (Γ_{GDR}), and the resonance strength (S_{GDR}). It is observed, both experimentally and theoretically, that the E_{GDR} and S_{GDR} do not depend on the excitation energy (E^*), but Γ_{GDR} increases with the increase in E^*. Γ_{GDR} also depends on the angular momentum (J), owing to the J-induced change in

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Level density and thermodynamics in the hot rotating ^{96}Tc nucleus

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Evaporated neutron energy spectra have been measured in coincidence with low-energy discrete γ rays in the reaction ^{4}He + ^{93}Nb at $E(^{4}\mathrm{He}) = 28$ MeV. The low-energy light-ion beam provides the scope of extracting the experimental nuclear level density (NLD) in the compound nuclear reaction. Angular-momentum gated NLDs have been extracted in the excitation energy range of $E^{*} \sim 5$–15 MeV from the measured neutron energy spectra. The extracted NLDs have been compared with different theoretical calculations such as the exact pairing plus independent particle model at finite temperature (EP+IPM), Hartree-Fock plus BCS (HFBCS), and Hartree-Fock-Bogoliubov plus combinatorial method (HFBC). Interestingly, the experimental NLDs are in good agreement with the results of the EP+IPM, whereas the HFBCS and HFBC fail to describe these data. Consequently, the thermodynamic properties of ^{96}Tc at finite angular momentum have been extracted using the EP+IPM NLDs. Through the analysis of the calculated thermodynamic quantities, it is shown that no pronounced bump is seen in the heat capacity of ^{96}Tc, in opposition with the earlier results of ^{96}Mo, which showed a prominent bump at $T \sim 0.7$–1 MeV. This difference is understandable since pairing in the even-even system (^{96}Mo) is always stronger than that in the odd-odd one (^{96}Tc).

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I. INTRODUCTION

One of the basic aims in diverse fields of science (physics, chemistry, and biology) is understanding the small system, which manifests many striking properties due to its tiny dimension. Some popular examples of such systems are atomic nuclei, nanoparticles, magnetic domain in ferromagnets, quantum dots, biological molecular machines, and solidlike clusters, which are important in the relaxation of glassy systems, etc. [1]. The study of thermodynamic properties of these systems, in spite of being an arduous task, is highly imperative as those properties describe how such systems respond to the changes in their environment [2].

The atomic nucleus is a well-known example of a small system, which shows the prototypical behavior of a complex miniature arrangement that goes beyond the simple sum of individual nucleon properties. Nuclear thermodynamics was essentially initiated by Bethe in 1936 [3], which explains the nuclear bulk properties instead of the individual nucleon ones and demonstrates the energy exchange process of a macroscopic system [4]. The knowledge of nuclear thermodynamics also enables us to understand the presence of pairing phase transition in the nucleus, whose effect was included in the nuclear theory after the Bardeen-Cooper-Schrieffer (BCS) theory [5]. As a result, the study of nuclear thermodynamics has gained much enthusiasm in the recent past [6–9].

Measuring the nuclear level density (NLD) is the starting point to obtain the thermodynamic quantities (TQs) of atomic nuclei. The introduction of the collective enhancement into the description of NLD has removed many contradictions of the previous analyses of experimental data, as has been reviewed in detail in Ref. [6]. In the past, nuclear researchers lacked proper experimental methods to measure the TQ until recently, when nuclear experimentalists proposed a unique technique to simultaneously extract the NLD and radiative γ-ray strength function [10]. This achievement has opened up a new horizon in this field. They have extracted the level density for $^{93-98}$Mo and obtained the S-shape canonical heat capacity as an indication of pairing phase transition at a critical temperature of $T_c = 0.7$–1.0 MeV [11,12]. In the recent past, Schiller *et al.* [7] and Melby *et al.* [8] observed steplike structures in the level densities around excitation energy $E^{*} \sim 1$–7 MeV, most probably because of the breaking of nucleon Cooper pairs, which leads to a gradual decrease of pairing correlations. However, they have extracted the level density below the particle threshold energy at very low angular momentum J

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Signature of clustering in quantum many-body systems probed by the giant dipole resonance

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The present experimental study illustrates how large deformations attained by nuclei due to cluster formation are perceived through the giant dipole resonance (GDR) strength function. The high energy GDR γ rays have been measured from ^{32}S at different angular momenta (J) but similar temperatures in the reactions $^{4}He(E_{lab} = 45\,MeV) + ^{28}Si$ and $^{20}Ne(E_{lab} = 145\,MeV) + ^{12}C$. The experimental data at lower J ($\sim 10\hbar$) suggests a normal deformation, similar to the ground state value, showing no potential signature of clustering. However, it is found that the GDR lineshape is fragmented into two prominent peaks at high J ($\sim 20\hbar$) providing a direct measurement of the large deformation developed in the nucleus. The observed lineshape is also completely different from the ones seen for Jacobi shape transition at high J pointing towards the formation of cluster structure in superdeformed states of ^{32}S at such high spin. Thus, the GDR can be regarded as a unique tool to study cluster formation at high excitation energies and angular momenta.

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I. INTRODUCTION

The nucleus is a dynamic finite-size system consisting of protons and neutrons, where their velocities can reach a significant fraction of the speed of light. The description of nuclear dynamics at such velocities is predominantly based on the concept of independent nucleons moving in a mean-field potential. However, in spite of their independent random motions, the nucleons also have a propensity to congregate, i.e., these nucleons possess correlations [1,2]. The fact that the clustering of nucleons leads to the occurrence of molecular states in the atomic nuclei was already realized in the earliest days of nuclear physics study [3]. The nuclear cluster phase is considered as the transitional state between the crystalline and quantum liquid phases of a fermionic system, which is linked to the studies of the "nuclear pasta phase" in the crust of neutron stars [4].

The nuclear structure data in the s-d shell region provide a wonderful opportunity to study the clustering phenomena since the densities of the deformed one-body states often exemplify a significant cluster structure in this region [5]. Kimura and Horiuchi showed [6] that the superdeformed (SD) band members of ^{32}S have a considerable amount of the $^{16}O + ^{16}O$ cluster component. The reaction calculations, using a deep $^{16}O + ^{16}O$ potential appropriate to the entrance channel, suggested the existence of $^{16}O + ^{16}O$ cluster bands in ^{32}S [7]. A similar SD band was obtained using the alpha-alpha double folding potential [8]. Recently, evidence of such cluster formations was also predicted by the macroscopic-microscopic potential energy surface calculations for ^{32}S [9]. Ichikawa *et al.*, emphasized the inclusion of the rotational energy contribution and showed that the nuclear densities in the SD band became cluster-like at high angular momentum (J). Experimentally, the inelastic scattering and the damped fragment yields, in the reaction $^{20}Ne + ^{12}C$, indicated the survival of an orbiting dinuclear system [10–12]. It is now well known that these cluster structures are associated with strongly deformed shapes of nuclei. The deformations, estimated from the respective α-particle evaporation spectra in the reaction $^{20}Ne + ^{12}C$, have been found to be much larger compared to normal deformation attained by hot rotating composites at similar excitation energies [13]. However, there has been no direct measurement of this deformation at high excitation energies and angular momenta.

One of the probes to study this deformation experimentally at high excitation energies and angular momenta is the γ decay from the giant dipole resonance (GDR) built on excited states. It is the prime example of collective nuclear vibration, which can be understood macroscopically as the out-of-phase oscillation between the protons and neutrons, and microscopically in terms of coherent particle-hole excitations [14,15]. The GDR emission occurs early in the decay of excited nuclei and also couples directly with the nuclear shape degrees of freedom. Therefore, it is highly important to investigate experimentally the shapes of ^{32}S at different angular momenta to study how cluster formations are manifested in the GDR strength function. The GDR lineshape should reveal direct information about the geometrical configurations of the nuclei, which can provide vital clues about the underlying mechanism to understand the nuclear structure and collective dynamics at extreme conditions of T and J.

It is very interesting to note that, in the long-wavelength limit, the $E1$ decay of the GDR γ rays (isovector in nature) from self-conjugate nuclei is hindered since decays from the same isospin (I) states are forbidden [16]. The yield,

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Nonlinear dynamics of a class of derivative controlled Chua's circuit

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Abstract A derivative control technique has been proposed to control the chaotic behavior of a Chua's circuit. The chaotic oscillations of the system can be controlled externally by adjusting the feedback resistance in the derivative control arm. For a proper choice of the feedback resistance the system initially in chaotic region can be driven to the steady state region. In addition to that the shifting of the chaotic attractor for different parameter set has been observed. Moreover, the same technique can be used to generate chaotic oscillations in a Chua's circuit, which would otherwise exhibit steady behaviour. The analytical predictions along with the numerical analysis and experimental results have been reported to establish the present work.

Keywords Chua's Circuit · Derivative control · Nonlinear dynamics · Shifting of attractor

1 Introduction

Chua's circuit is a structurally simple nonlinear electronic circuit but complex dynamically. It is one of the most popular nonlinear electronic circuits for generation of different nonlinear dynamical phenomena. For the last three decades, Chua's circuit has been studied extensively to explore the rich variety of its inherent dynamical behaviors. A review of these studies can be found in [1–10] and the references therein. For the past years, different chaotic systems have been intensively investigated by using different control techniques in order to realize a desired system response (chaotic, periodic or steady behaviour). Generally speaking, the studies on controlling chaotic dynamics was triggered by the pioneering work of Ott et al. [11] which is popularly known as OGY (Ott–Grebogi–Yorke) method of controlling chaos. The method is based on making a small perturbation in the form of feedback to an accessible system parameter or a dynamical variable of the chaotic system. But this technique of intermittent perturbation commonly used is quite inconvenient and sometimes it becomes very difficult to search for an adjustable parameter for perturbation. To avoid these problems, continuous feedback control method was developed later on.

A plenty of works on controlling the chaos in Chua's circuit using feedback controller are available in the literature. Chen [12] applied a linear feedback control for guiding the chaotic attractor of the circuit to a desired trajectory, such as, an unstable limit cycle. Hartley and Mossayebi [13] showed the control of modified Chua's circuit systems and demonstrated how to design a controller for tracking the capacitor voltage of the system. Hwang et al. [14] proposed a feedback control on a modified Chua's circuit with cubic nonlinearity and have successfully controlled the chaotic dynamics to fixed points. An adaptive modular backstepping controller has been derived in Maganti and Singh [15] for precise tracking of the reference trajectory and suppression of the chaotic motion in a Chua's circuit. A novel impulsive controller design procedure was proposed by Yong-Bin Yu et. al.[16] using time delay feedback. He et. al. [17] proposed an adaptive tracking control for a class of Chua's chaotic systems.

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