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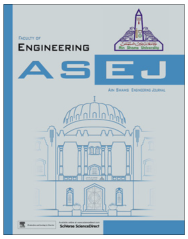

ELECTRICAL ENGINEERING

A novel approach for system change pathway analysis using consolidity charts

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Abstract This paper is directed toward presenting a novel approach based on "***consolidity charts***" for the analysis of natural and man-made systems during their change pathway or course of life. The ***physical significance*** of the consolidity chart (region) is that it marks the boundary of all system interactive behavior resulting from all exhaustive ***internal*** and ***external*** influences. For instance, at a specific event state, the corresponding consolidity region describes all the plausible points of normalized input–output (*fuzzy* or *non-fuzzy*) interactions. These charts are developed as each event step for zone scaling of system parameters changes due to affected events or varying environments "***on and above***" their normal operation or set points and following the "***time driven-event driven-parameters change***" paradigm. Examples of the consolidity trajectory movement in the regions or patterns centers in the proposed charts of various consolidity classes are developed showing situations of change pathways from the unconsolidated form to the consolidated ones and vice versa. It is shown that the regions comparisons are based on type of consolidity region geometric shapes properties. Moreover, it is illustrated that the centerlines connecting consolidity regions during the change pathway could follow some certain type of trajectories designated as "***consolidity pathway trajectory***" that could assume various forms including zigzagging patterns depending on the consecutive affected influences. Implementation procedures are elaborated for the consolidity chart analysis of four real life case studies during their ***conventional*** and ***unconventional*** change pathways, describing: (i) the drug concentration production problem, (ii) the prey–predator population problem, (iii) the spread of infectious disease problem and (iv) the HIV/AIDS Epidemic problem. These solved case studies have lucidly demonstrated the applicability and effectiveness of the suggested consolidity chart approach that could open the door for a comprehensive analysis of system change pathway of many other real life applications. Examples of the fields of these applications are

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engineering, materials sciences, biology, medicine, geology, life sciences, ecology, environmental sciences and other important disciplines.

1. Introduction

The problem of modeling and analysis of system change pathways or their life cycles (course of life) has attracted the interest of many researchers [1–3]. This problem has also been shared by many disciplines as it affects the lifetime of the system. For instance, in engineering and materials the study of this problem is of prime importance as it related to how these systems withstand *internal* and *external* effects such as corrosion, rusts, fatigue, and creep [4–7]. For other disciplines such as medicine and biology, the subject is also very important as it affects the life progress and aging of humans and all living beings [8,9]. In life sciences, ecology and environmental sciences, the problem of system change pathways is still of high priority in solving problems such as river and shores sedimentation and erosion, as well as investigating ecological and environmental growth and balance [10–13].

The study of system change pathways is mainly related to the investigation of all factors affecting such changes. The important parts of these factors are the ones that are taking place "***on and above***" the normal system situation or stands which usually take place outside system control [1–3]. Examples of these affect external or internal excessive influences and happenings affecting the system such as accidents, collisions, impacts, breaks, shocks, collapses, eruptions, and destructions [14,15]. There are no intended timings for such influences and the system is apt to change under their occurrences, which is designated in the literature by "***event-driven***" effect which is governed by the event step "μ" [2]. This is in addition to the well-known "***time-driven***" effect controlled by the physical equations of the system governed by the parameter "t".

The relation between the "***time-driven***" versus "***event-driven***" dilemma was the subject of many studies especially by the computer science researchers [16,17]. As the systems handled by computer science are mainly virtually, their developed approaches could not be replicated to physical system due to difference in their nature [18–21]. Such problem was only solved recently by introducing the "***time driven-event driven-parameters change***" paradigm [1–3]. This paradigm states that each event affecting the system "on and above" its normal situation will yield its change of parameters. This is in fact that real life systems are intelligent and store all their affecting events through consecutive changes of parameters. Due to wide changes in the nature and type of systems, such changes will differ from one system to another depending on their internal property denoted by the "***Consolidity Index***" [22–26]. Such index can be calculated from the knowledge of system physical equations.

Consolidity (the act and quality of consolidation) is measured by the system output reactions versus combined input and system parameters reaction when subjected to varying environments and events [1–3]. Moreover, consolidity can govern the ability of systems to withstand changes when subjected to incurring events or varying environments "***on and above***" normal operation during the system change pathway. In fact, consolidity is the scaling factor of managing system changes. It changes all over the lifetime of the system due to its consecutive changes of parameters. Therefore, the in-depth analysis of such index during the system change pathway will definitely lead to much better understanding of such ways, and its future managing and control will help in enhancing such pathways.

In the following section, the methodology of consolidity charts is developed to identify the various regions and patterns of real life systems during their change pathways. Brief backgrounds of some previous subjects will precede such development to help in better understanding of the new development. The paper will then implement this methodology to four different applications to demonstrate the applicability and efficacy of such novel approach for describing their change pathways. These pathway changes are considered for both ***conventional*** and ***unconventional*** systems change pathways behaviors.[1]

2. Related work

2.1. The "time driven-event driven-parameters change" paradigm

The "***time driven-event driven-parameters change***" paradigm is the central core for investigating the system change pathway or system course of life. This paradigm has three main components as shown in Fig. 1 [1–3]. These components are (i) the lower or time-driven layer, (ii) the upper or event-driven layer, and (iii) the system parameters change mechanism.

The ***first*** component of the lower or time-driven layer is governed by the system physical or dynamical equation(s) of the time state "t". Such equations should give an actual form of the system parameters avoiding any virtual, empirical, statistical, or over-simplified forms. These equations are then represent the basic core of any study and are usually can be written in the form of state space representation of the linear, quasi-linear or nonlinear types. A more convenient form of such state space equations is its matrix form, which permits a direct or equivalent investigation of system basic metrics such as ***stability*** and ***controllability***.

The ***second*** component of the upper or event-driven layer is governed by the affecting event or varying environment(s) "***on and above***" system normal situation or stand of the event state μ. Under this event state, the system undergoes various changes corresponding to $\mu = 0, 1, 2, \ldots, m, \ldots, f$, such that m indicates the intermediate state and f designates the end or final state. These events or varying environments are different that ordinary system disturbances that can be usually absorbed by the system with unappreciable effects. One of the important

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[1] The term ***conventional*** means linguistically to conform to established practice, accepted standards, or traditional behavior. While the term ***unconventional*** means to act, or exist out of the bounds of standard or standard norms.