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Modeling and optimal control of nonlinear fractional order chaotic models of factors affecting auditors' stress and burnout using evolutionary algorithms

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ABSTRACT

The aim of the current research is to present the model and optimal control of the nonlinear fractional order chaotic system of the effective factors of stress and burnout of auditors using evolutionary algorithms. Mathematical models related to auditors' stress and burnout were built with the help of fractional differential calculus. Chaotic and fractional non-linearity of the proposed models and the need for optimal control were investigated. Then the presented nonlinear fractional order chaotic models were optimally controlled. Genetic algorithm and particle swarm optimization algorithm were used to implement the model simulation process and their optimal control. The results of the research showed that the use of the proposed research method will improve the optimal control of chaotic models of factors affecting auditors' stress and burnout; reduce errors and increase accuracy and reliability.

Keywords: auditor burnout, modeling, optimal control, evolutionary algorithms

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1. Introduction

Occupational stress is the most important psychologically damaging factor in the workplace. Job stress occurs when job requirements in a specific job do not match the abilities of the person working in that job. With the progress of science and technology and machine life, the amount of social stress and also occupational stress increases day by day. The word stress means pressure and force, and the common usage of this word means psychological pressures on humans. Accumulation of various events, including life, social, work events, etc., which disrupts a person's adaptation to the existing situation, causes stress. Any stimulus that creates tension in a person and provokes a response in him is known as a stressor. This factor may be an event, situation, condition, problem, person, object, job, etc. As a result of the presence of stress, diseases may develop in the working person, the most important of which are: increased blood pressure, cardiovascular diseases, asthma and depression, in the end, if the stress continues and the person is unable to cope with the stress, he will develop a condition. became unable to do anything and will lose the power of any reaction, resistance and collision [1]. Stress that occurs in a certain area of life and certain factors play a role in its emergence. Stress is one of the most important and increasing problems of occupational health, and it is considered one of the inhibiting causes from an economic point of view. The accumulation of job-related factors or situations that are usually stressful also cause job stress. Job stress is the stress that a certain person undergoes due to a certain job. Depending on the experience of the working person, his strength and weakness in facing the existing conditions and his personality, he may suffer from problems that include mental, physical and behavioral problems. Among psychological problems, job dissatisfaction can be mentioned, which causes a person to come to work reluctantly and late, which causes absenteeism, leaving the job, increasing accidents caused by work, and reducing productivity [2]. It is defined as harmful emotional and physical responses, and occurs when job requirements do not match employees' abilities, resources, and needs. Occupational stress has been recognized as a major psychological, physical and organizational health challenge worldwide. Stressed employees are more likely to be unhealthy, poorly motivated, less productive, and feel less safe at work. Their organizations are less likely to succeed in a competitive market. According to some estimates, work-related stress results in intermittent national economic costs such as sick treatment, lost productivity, health care, and litigation costs [3]. Job stress at a certain level can create morale. , but if the pressure is too much, many problems will follow. Work pressure and lack of sufficient knowledge of auditors in some cases can bring stress to them, in other words, stress can affect the performance of auditors and the quality of the audit process, which is not only for the auditing profession but also for the users of financial information. will hurt In order to increase their efficiency and control job pressures, auditors can increase their knowledge and experience through resilience and tolerance in the auditing profession, on the other hand, the high experience and skill of employees can be effective in managing stress in this field[4]. Financial crises and putting excessive pressure on auditors to achieve a certain result lead to creating stress on auditors, which affects the performance and quality of audit work. Excessive stress affects concentration, makes it difficult to make decisions and reduces self-confidence. Stress can weaken the achievement of goals for both individuals and organizations, so managing stress in the workplace is very important [5]. Occupational stress is a series of physiological, psychological and behavioral responses due to the continuous impact of one or more stressors on an individual or organization. Occupational stress means difficulty and workload, which includes the amount of work, conflict of time and role that a person experiences while performing job duties. Individual response to occupational stress can affect mental and physical health, work quality and even organizational behaviors through the stimulus and response system. Auditing companies should pay more attention to auditors' job stress and clearly justify the allocation of their audit resources to ensure audit quality. Contrary to the fact that auditors' job stress is familiar to us in practice, but academic studies have dealt with this issue less [6,7]. Researchers identified theories related to job stress by using role theories. Job stress can be classified as follows: role ambiguity theory, role conflict theory, role burden theory. The first theory is related to role ambiguity, which refers to the confusion of a person in how to play his role, when people do not have the necessary information about their roles, they face role ambiguity [8]. He mentioned that according to this theory, role conflict occurs when there are two or more demands that require different roles at the same time and a person can fulfill his role in all those situations. The third group is the theory of role overload, which states that in Work environments when people are faced with tasks and requests beyond their ability and work resources available, they experience job overload. Based on the proposed theories, which are all related to occupational stress factors, there is a need for stress management techniques to prevent the increase of employee stress [9, 10]. In many studies, there are factors such as work load in financial employees and auditors. A lot of work, the need to be very precise and focused on monetary and financial figures, ambiguity in duties, sense of responsibility, lack of support, conflict of individual duties with organization's requests, etc. have been introduced as causes of occupational stress in accountants. In most of the studies done on occupational stress in different occupational groups such as nurses, teachers, accountants, auditors and even doctors, it has been emphasized that employees with less work history and experience suffer more occupational stress. The reason for this can also be the fact that this group of employees is new to work and their lack of familiarity with the work environment and their less mastery of their work. It can also be said that experienced employees can predict the existence of stressful factors in certain conditions and situations and use appropriate problem-solving methods to deal with them[11]. The most important factor causing occupational stress in the bar auditor community Work is a role, and organization, role responsibility, role scope, and the physical environment of the workplace are also stressful factors, and role inadequacy, personal relationships with supervisors and supervisors, and role duality are the next priorities. There are different definitions about role workload. It has taken place, among other things, that the necessary support duties are not being carried out due to the heavy burden. Stress caused by heavy workload is defined as continuous pressure caused by work and reluctance to work, which manifests with general symptoms of physical, mental and behavioral stress. The most important factors that cause work stress in accountants can be explained as ambiguity in the role, conflict in the role, and then too much workload and uncertainty in the future of work. The most stressful factors faced by employees are the amount of work load or role workload, diversity in workload and role responsibility, and a small number of employees reported role conflict and role duality as stressful factors [12]. Job burnout is a state of lack of energy and vitality in a person. In general, a person suffering from job burnout has a feeling of boredom towards performing work behavior. This state is a result of constant and frequent pressure, and the result is a feeling of reduced energy. Job burnout is a type of mental exhaustion. Which is combined with psychological pressures or job-related stresses, according to Mazlock, burnout is a syndrome that the response to psychological pressures includes three components: fatigue or environmental analysis, alienation or depersonalization, and lack of personal success or progress. Job burnout is probably the result of the type of duties and responsibilities of such jobs. Job depression is associated with pressure, role confusion, and poor job performance. This situation occurs mostly in people who have been employed for a longer period of time [31]. Research shows that Occupational depression affects people who are often perfectionists and are extremely involved in work. Job burnout is a disease and this chronic fatigue should not be confused with short-term fatigue because the fatigue caused by continuous work gradually disappears with rest. In general, job burnout is related to psychological pressures. Psychological pressures occur when between The demands of the environment are incompatible with the individual's abilities, and the continuation of this situation leads to job burnout [33]. In general, it can be said that job burnout is the result of constant mental pressure, the result of which is the decrease in the quality of services created by the individual. A job is a state of physical, emotional and mental fatigue that occurs due to constant and repeated pressure caused by intensive and long-term contact with physical or human factors. but today it has become clear that this problem is common in all organizations, so that when a person feels unable to do work due to various pressures, the continuation of this situation causes him to burn out, organizations openly and secretly spend a lot of money due to the existence of burnout in employees, which sometimes leads to the resignation of employees who have spent a lot of money on their training and preparation. Considering the relationship between the health of employees and the efficiency of the organization, and the fact that a significant percentage of employees in the organization It is necessary for researchers, psychologists and managers to pay attention to this syndrome [31,32,33]. In this research, with the help of mathematical information including effective formulas and definitions and theorems, the mathematical model related to the effective factors of auditors' job stress will be built with the help of fractional calculators, and the chaotic nature of the model is presented, and that its order is of fractional order and the need has control, it is discussed. Then the presented nonlinear fractional order chaotic model is optimally controlled. Finally, the presented method is presented with the help of an applicable and dynamic model in the form of a simulation done with the help of MATLAB software.

2- Theoretical foundations and research background

2-1- Factors affecting auditors' job stress

Stress is the adverse reaction of employees against excessive pressures that are imposed on them during work. According to the World Health Organization, stress in the workplace is especially common in situations where employees are asked to do things beyond their knowledge, abilities, and skills. Excessive stress affects the concentration of employees and makes it difficult to make decisions. and reduces self-confidence. Stress can weaken the achievement of goals for both individuals and organizations, so managing stress in the workplace is very important [13]. That sentence can be bad working conditions, very high volume of work (high workload), doing work in shifts, long working hours, role conflict, weak communication between colleagues and managers and lower level employees, existence of risk factors and harmful factors and also He pointed out the lack of attention to the employees. The clear answers and reactions that people give indicate the presence of stress in them. These manifestations may be headache, sleep disorder, difficulty in concentrating, bad mood, bad mood, stomach upset and dissatisfaction. Other manifestations or factors indicating the existence of occupational stress in a person include muscle cramps, feeling of pressure and tightness in the chest, high blood pressure, sexual problems, arguing, annoying and making others uncomfortable [14,15]. The evidence shows that the type of job plays an important role in the stress of employees. Job changes such as organizational changes, salary and promotion are jobs that put pressure on people and make them feel confused, worried, confused and anxious. do Stress has been costly both for the people who suffer from it and for the institutions and production units, its symptoms are in the form of mental and physical fatigue, irritability, irritability, anxiety, increased blood pressure, lack of self-confidence and satisfaction. Work and lack of work motivation appear and cause a decrease in productivity. Several studies have been done to investigate occupational stress and related factors. In these studies, factors such as individual's job, role conflict and role ambiguity, individual's organizational role, professional development flow, professional relationships, organizational structure and atmosphere have been considered [16,17]. Auditing is actually one of the most stressful jobs. In this job, in addition to the general stress factors that exist in other jobs, the need to pay close attention to monetary and financial figures, the large amount of work, and the frequent use of new financial accounting methods, the amount of stress that the employees of this job the job they experience multiplies. In this case, Jirapa states that one of the reasons for job burnout among accountants is the existence of severe job stress, and this job stress has a negative effect on the performance of work duties and the physical and mental conditions of accountants. Accounting is one of the most stressful jobs, and even in the busy seasons, the blood cholesterol level of these people increases significantly, and after the busy periods, the blood cholesterol level returns to normal levels. Ether's work environment has a lot of stress in them, so accountants who worked in large international companies were more stressed than accountants who worked in local and small companies [18,19]. Organizational climate can be one of the factors that reduce or increase the stress of employees. If you can improve the way of life in the organization, you can prevent the occurrence of stress. The main source of the organizational climate is the perception of the organization's people, and because people are unique beings and differ from each other in terms of their temperament and personal characteristics, their perception is different from the organizational climate, and this point is important for the officials. In order to know the reflection of their activities, they should evaluate the feedback that the employees show so that they can direct the activities of the organization in the direction of their findings [20]. Regarding role responsibility, which is known as the third stressful factor, there are also different definitions, such as the feeling of responsibility in doing the work and performance of the subordinates, and the feeling of discomfort from their inefficiency, and the feeling of pressure caused by working with angry and difficult colleagues. Other mechanisms and definitions, such as a person's feeling of responsibility for the efficiency and well-being of others in the work environment. The scope of the role, according to the definition, is the feeling of doubt and doubt in fulfilling the conflicting demands of the superior and conflict with him, and the lack of clarity about the limits of authority and the number of people that the person is ordered to. Doing their work is another factor that causes stress in auditors. This dimension of role, which has been known in various researches as a stress-creating factor in accountants, indicates the contradictions of a person in terms of work conscience and the role that is expected of him. Also, the dimension of role inadequacy actually indicates that there is no proportion between the skills, education, and educational and experimental characteristics of the individual with what the job expects from the individual, and the individual is distrustful of his future employment [21,22]. Another important stressful factor caused by playing a role, from which very different results have been obtained in different researches, is the ambiguity or conflict in the role. how to spend oneself and the uncertainty of how it is evaluated. Role ambiguity is related to a person's awareness of the priorities and expectations of the work environment and evaluation criteria. Ambiguity in the role arises when a person does not have enough information about the work he is doing, and role conflict occurs when a person in the environment His work is faced with tasks and requests that he is not interested in. Ambiguity in the role arises when a person does not have information about the requirements and needs of his role and how to fulfill these needs and requirements, as well as about the existing educational processes that will ensure him to perform his role successfully [22,23].]. Occupational stress is one of the most common diseases of today's era, which causes a lot of expenses for both the people who suffer from it and the audit institutes, and its complications are in the form of mental and physical fatigue, irritability, irritability, high blood pressure, Decreased self-confidence, job dissatisfaction and lack of motivation appear in work and reduce productivity. Auditing is also considered a high-stress job and its concerns in a high-stress environment have a negative effect on the way work is performed [24]. Occupational stress originates from many problems in the work environment, continuous changes out of control, constant relocations, long working hours and irregular working hours. Auditors are exposed to stress because of the massive amount of work they have to do and the limited time allotted to them. In addition to these, auditors are always under pressure from the complex demands of supervisors, investors, and owners [24, 25]. The auditor's rush to complete the work process early reduces the quality of the audit and makes the auditors use less methods. The provider encourages audit quality [26,27]. Persellin (2015) concluded that auditors, on average, spend more hours per week than the standard time, and in busy seasons, 20 hours more than this threshold, which leads to a decrease in the quality of their work. When a person faces excessive work demands during his working days or hours, he is more exposed to tension and stress. For example, tension may be caused by time interference between family and work responsibilities, or may arise from implicit pressures related to unreported and allocated time for audit work [3]. Another type of stress occurs when the behavior of people within the organization is ambiguous. They call role ambiguity when employees face different expectations in front of common issues. Demands related to agreement with laws and other challenges related to hiring or extending the successful employee's contract has also been added to the above problems. Also, work pressures originating from busy seasons, retaining employers, planning to select a replacement audit employee, and finding and maintaining reliable personnel are among the important factors in the field of stress [4]. The most destructive result of stress on the performance of auditors is the unfavorable quality of the work done (audit report prepared). Therefore, behavioral factors such as stress have a significant effect on auditors' job performance. In the audit work, concerns such as inherent or applied limitations of the business owner in the scope of maturity and psychological pressure for convincing evidence are in the way of the auditor [28,29,30]. Wal (2013) believes that the balance factor in audit pricing can be the reason for the auditor to abandon the implementation of necessary content tests, which is considered a type of behavior that reduces the quality of the audit, and on the other hand, maintaining the quality of work at a high level, the necessity of implementing It includes all auditing methods that affect the economic benefits of auditing [6].

2-2- Factors affecting auditor burnout

Job burnout is a stressful situation with symptoms such as: mental exhaustion and physical fatigue, withdrawal from work, reduced efficiency, reduced energy, increased irritability and reduced sleep and focus on issues that can happen regardless of the type of job. . Fatigue is the result of chronic exposure to stressful factors. Continuity of presence in the face of stressful factors deprives people of their power to deal with resources and produces ineffective results. Job burnout is a mental reaction that people show when they are faced with job stress. In general, stressful factors such as workload, busy working seasons, pressures from employers, competitive position of companies, first audit, pressures related to limited time, job and work ambiguities, etc., have been effective in arousing auditors' stress [34,35].]. Job burnout is associated with pressure, loss of role, and poor job performance, and its cause is brought up in three organizational, interpersonal, and intrapersonal aspects [36,37]. The correction of role ambiguity refers to the lack of clarity of goals, responsibilities, and limitations and is related to factors such as the complexity of tasks, technology, and rapid and continuous change in the organization. In other words, role ambiguity occurs when the expectations in the work environment It may be unclear from a person and it may be due to lack of expectation, lack of familiarity with how to do the work, or lack of knowledge of its results. Therefore, when employees cannot anticipate in their jobs, they are confused [37]. Role conflict occurs when conflicting and inconsistent demands or demands are placed on individuals. For example, when a person is in this situation when he is given orders outside of his professional responsibility and territory, or when a person's moral values are in conflict with managers and supervisors, many researchers believe that being a peer of job expectation Initial and subsequent job experiences largely determine employees' reactions to their jobs. Theoretical discussions of job burnout emphasize that the prevalence of expectations and reality is a major factor in the experience of psychological stress. Many researchers believe that the matching of initial job expectations and subsequent job experiences largely determines employees' reactions to their jobs. Theoretical discussions of job burnout emphasize that the prevalence of expectations and reality is a major factor in the experience of psychological stress. Work density includes quantitative and qualitative components. Quantitative workload components include excessive demands that have little time to handle them, and qualitative workload is related to job complexity [38,39]. Various researches that have been conducted on the role of support in psychological stress and job burnout have identified social support as a source of help for people to deal with psychological stress and job burnout. Social support facilitates the adaptive behaviors of the individual, which of course The social nature of the person returns [39]. The lack of preparation for obtaining a job as an intra-individual variable has a decisive role in the process of job burnout. People who have not received the necessary training to get a job are more prepared to suffer from job burnout. Personality characteristics of people can act as a basis for job burnout, for example, people who have high self-esteem are resistant and active in facing problems and dangerous situations, while people with low self-esteem try to avoid the situation. Avoid in this way. The factors that cause job burnout among employees are: People's unfamiliarity with the organization's goals or objectives, or that these goals are not understandable to them. The policies that the management of the organization establishes in different dimensions of work life are applied in practice. Leadership and management practices at the frontline leadership levels (or the leadership style of unit supervisors) in the organization. Hard and inflexible rules, regulations and bylaws in the organization. Unhealthy communication networks in the organization and the lack of effective two-way and bottom-up communication in the organization. Non-interference of the management of the organization in the affairs of employees (welfare, treatment, recreation, etc.). Relative or complete neglect of managers in the field of taking advantage of all potential abilities and talents of people in performing job duties. Ambiguity of the individual's role in the process of producing goods and services provided by the organization. Dissatisfaction of people with their job, unit or organization at their place of work with their low level of satisfaction with their job. Lack of necessary facilities for growth and advancement by promoting people in the organization. Constant exposure of people in situations where it is necessary to do a lot of work in a limited time. Giving people more responsibilities than their capacity and fear of not being able to carry out these responsibilities. Engaging in feelings of role conflict, in which a person is assigned roles that are in conflict with each other (for example, a supervisor is asked to push subordinates to work harder, and at the same time, they expect him to be friendly with them). Inconsistency between the amount of salary and benefits and the amount of work that the person is expected to do in the organization. The inappropriateness of the job performance evaluation system of the organization's people and replacing the relationship with the rule. Lack of suitable and effective training facilities for the employees of the organization and until they are familiar with their job duties. Applying nonscientific methods to recruit, test and select people and assigning jobs to people who do not have the necessary qualifications to hold these jobs [40,41,42]. The complete and accurate unfamiliarity of people with their job duties from the very beginning of entering the organization, in general, some researchers are of the opinion that high expectations in the work environment cause job pressures and ultimately cause job burnout in the long run. . On the other hand, some other researchers believe that external factors such as low income can provide the basis for job burnout. Some other researchers have also considered organizational support and management system, while others Job promotion opportunities and its impact on reducing job burnout are emphasized [35,43]. In a research, Hao (2022) analyzed the effect of role stress on reducing audit quality. The results of the research showed that role conflict does not have a significant effect on reducing audit quality, but role overload has a significant effect on reducing audit quality [2]. . Winoto and Harindahyani (2021) in a research entitled the effect of auditors' work stress on audit quality concluded that auditing is associated with high stress and excessive work. In their research, they found that auditors' work stress significantly and negatively affects audit quality [7]. Smith and Emerson (2017) showed that there is a negative and significant relationship between burnout and auditors' performance [4]. Wiryathi (2014) investigated the effect of job stressors, including role ambiguity and role conflict, on auditors' job performance through the intervening variable of emotional intelligence. They concluded that there is a negative relationship between job stress and auditor performance. Utami and Nahartyo (2013) evaluated the relationship between role conflict, role ambiguity and role overload on auditors' burnout. The findings showed that role conflict and high workload have a positive relationship with job burnout; But role ambiguity does not have a significant relationship with job burnout. Yan and Xie (2016) showed in a research that there is an inverse relationship between work stress and audit quality in new customer reviews. Almer, E., & Kaplan, S. (2002) investigated the impact of resilience on the auditor's job stress model and found that auditors with resilient audit programs experienced more job satisfaction, and on the other hand, job conflicts, burnout emotional, personality deterioration and unwillingness to do less work.

2-2-chaos theory

The main foundation of chaos theory is the idea that order and chaos are not always opposites. Chaotic systems are a fascinating combination of order and chaos. When we look at them from the outside, they behave unpredictably and show disorder, but inside these systems we see a set of deterministic equations that work with order. Chaos is a name that is often applied to a non-linear dynamic. This expression is used to explain the complex behavior of so-called simple, linear and well-behaved systems. Chaotic behavior appears irregular and often random, similar to the behavior of a system strongly affected by random external noise. The mathematical definition of chaos is the unpredictable long-term behavior of a deterministic dynamical system due to sensitivity to initial conditions (commonly known as the butterfly effect). Chaos theory is defined as the qualitative study of transient, unstable behavior in deterministic nonlinear dynamical systems [54,55] Chaos occurs in very simple systems that are often free of noise. In fact, these systems are essentially deterministic; That is, with accurate knowledge about the initial conditions of the system, its future behavior can be predicted. As a result, chaos may be defined as a bounded, non-periodic (non-periodic) and noisy oscillation. In other words, a deterministic system behaves randomly, even if it has no random inputs. In unstable nonlinear systems, there are various strange effects including sub harmonic, quasi-periodic oscillations and chaotic behavior [45,46]. Some of the systems that are deterministic and have chaotic behavior are: atmospheric systems, solar system, geological plates, turbulence flow, population growth, power electronic circuits, etc. But chaos exists in many other fields such as biology, computer science, economics, engineering, finance, mathematics, meteorology, philosophy, physics, politics, psychology, stock market and robotics, etc. Chaos theory has fascinated scientists and engineers for two reasons. Chaos theory provides theoretical and experimental tools to categorize and understand complex behavior where other theories do not work. Chaos is universal; That is, it is used in mechanical oscillators, electrical circuits, chemical reactions, optical systems, nerve cells, lasers, etc. If a dynamic system exhibits chaotic behavior, it will be nonlinear. A key element to understanding chaos is the concept of non-linearity. Nonlinear dynamics studies systems in which the equations are nonlinear. All real systems are nonlinear, at least to some extent [49]. Some sudden and dramatic changes in nonlinear systems may produce complex behavior called chaos. The word chaotic and chaotic is used to describe the temporal behavior of a system whose behavior is aperiodic (never repeating perfectly) and is "apparently" random or noisy. Behind this chaotic randomness, there is an order determined by the system's equations. In fact, many chaotic systems are quite deterministic. Determining whether a physical system or process is random or chaotic from data is a difficult task, because in practice no time series consists of "pure signal". There is always some kind of annoying noise, even if it is a rounding error. Therefore, any real time series will have some randomness, even if it is mostly deterministic. Mathematicians have come up with other ways to quantify the description of chaotic systems. These methods include: absorbing fractal dimension, Lyapunov plots, recurrent diagrams, Poincaré maps, branching or bifurcation diagrams and transfer operator[51]. As you know, decision-making is one of the important tasks of management, nowadays there are phenomena characterized by complexity, uncertainty and uncertainty, disorder and turbulence, which have received a lot of attention. Chaos or disorder helps us to investigate and study complex systems, and by considering the principles of certainty and probability together, it provides a realistic solution to today's problems. The major effects of chaos theory in management on decision-making are that, in today's chaotic world, instead of focusing on long-term decision-making, short-term and flexible decision-making should be considered. Contingent and flexible planning as a part of the decision-making process of any organization should take great importance [52]. Intuitive and innovative approaches should be given more value and importance than rational decision making. The creation of temporary structures and systems should be more important. Reforming the cultures of organizations to attract new values and standards and appropriate to the world full of chaos should be considered. One should look for order in the depths of chaos and disorder. An important point that you should keep in mind when discussing chaos theory is that chaos theory does not claim that organizations are disordered and chaotic, but it claims that what seems chaotic to us has order at a higher level. And it is a model[54,55]. The best way to solve temporary problems at the lower levels of the organization is to give the people closest to the problem the authority to do whatever they think is necessary in the particular situation. After all, change is what makes life interesting. It is an issue that requires thinking; And it is inevitable. Chaos theory in management is a way to deal with these dynamics [53].

2-3-genetic algorithm

Genetic algorithms are search algorithms based on the concepts of natural selection and genetics of living organisms. Phenomenological genetic algorithms have come to simulate some of the processes observed in natural evolution through computer algorithms. Processes that are formed based on performing operations on chromosomes (organic systems for coding the genetic structure of living organisms). As mentioned before, genetic algorithms are under the search algorithms. However, they have very fundamental differences with other search algorithms [57]. Instead of dealing directly with the values of the problem parameters, genetic algorithms work with a coded representation of the set of problem parameters and search a population of points in a search space to find solutions to the problem. Also, they optimize the objective function of the problem without knowing the gradient information related to the objective function of the problem. In genetic algorithms, probabilistic mechanisms are used to transition from one state in the problem space to another; while in conventional search algorithms, gradient information related to the objective function of the problem is used for such work. Such an important feature in genetic algorithms has made them universal search algorithms. Also, genetic algorithms are used to search irregular search spaces. In general, genetic algorithms are used to solve problems in applications such as function optimization, parameter estimation, and machine learning [58,59].

2-4- particle swarm optimization algorithm

The particle swarm optimization algorithm or PSO algorithm is a meta-heuristic algorithm that is suitable for the optimization of non-linear continuous functions. The particle swarm optimization algorithm or PSO algorithm is inspired and branched from the concept of particle intelligence (which usually exists in groups of animals such as herds and packs of animals). In order to clarify the overall mechanism of the particle swarm optimization algorithm and other algorithms that are inspired by the group behavior of animals, explanations about the group (herd) behavior of animals are provided. These explanations can help to understand how to build the particle swarm optimization algorithm (and other algorithms with a similar approach) to solve complex mathematical problems [56]. They have to find a place to land. In this case, defining where all the birds should land is a complicated issue. Because the answer to this problem depends on various issues, i.e. maximizing available food resources and minimizing the risk of predators at the landing site. In this situation, the observer can see the movement of the birds in the form of dancing.[47] The birds move simultaneously at a point in time so that the best place to land is determined and all the flocks (groups) land at the same time.) or the flock of birds, have the possibility to share information with each other. If the birds do not have the possibility to share information with each other in their groups, each bird from the group (flock) will land at a different place (point) and at a different time. Research conducted since 1990 on bird behavior indicates that all birds in a flock (group | flock) that are looking for a good landing spot are able to choose the best landing spot when that spot is marked by one of the birds. Swarm members found, alerted. Using this knowledge, each member of this crowd balances their personal and crowd knowledge experience, which is known as social knowledge. are survival conditions that will exist at one point for survival[60]. Among these cases, the maximum food resources and the minimum risk of predators, which were mentioned earlier? The problem of finding the best landing point is an optimization problem. The group, swarm or herd must determine the best landing point, for example latitude and longitude, in order to maximize the survival conditions of its members [47,48]. To do this, each bird searches for a suitable landing point while flying and evaluates different points in terms of various survival criteria to find the best area for landing, and this is done until the best area for landing, Be identified by the whole crowd. Kennedy and Eberhart were inspired by the collective behavior of birds; A behavior that ensured significant survival advantages for birds as they searched for a safe landing spot. Accordingly, they presented an algorithm called particle swarm optimization algorithm. The PSO algorithm can imitate a behavior such as what was said for the flock of birds [50].

2-5-optimal control

The design of classical control systems is often a trial and error process that is repeated until the optimal closed-loop characteristics, such as: appropriate lift percentage, appropriate rise and fall time, and Get the right bandwidth. This design method is not suitable for complex multivariable systems. For example, consider the attitude control design of a satellite. In the design of the system, issues such as fuel consumption should be taken into account, while it is not possible to consider it in classical control. An alternative method to solve the above problem is the use of optimal control theory, whose applications are expanding today with the advancement of digital computers [44]. The theory of optimal control, which plays a very important role in the design of modern controllers, is used with the goals of maximizing the performance of a system at the same time as minimizing the cost of the system, both in terms of energy consumption and economy. In other words, the objective of optimal control is to determine the control signals in such a way that in addition to meeting the constraints governing the plant, a criterion function is also minimized. The benchmark function can be fuel consumption, tracking error, or process cost. The problem of optimal control is the problem of finding a control law for the given system in such a way that a certain optimality criterion is achieved. A control problem has a cost function, which is a function of the state and control variables. An optimal control is a set of differential equations that describe the trajectories of the control variables that optimize the objective function. Optimal control can be obtained from Pontriagin's maximum principle [45,60].

2-1-1-Research hypotheses

Hypothesis 1: With the mathematical modeling of the non-linear fractional order chaotic system of factors affecting auditors' job stress, the chaos in the model can be determined in the best possible way.

Hypothesis 2: Using the methods of genetic algorithm and particle swarm optimization algorithm improves the optimal control of the chaotic model of factors affecting auditors' job stress.

Hypothesis 3: The use of genetic algorithm techniques and particle swarm optimization algorithm leads to error reduction and increased accuracy and reliability.

3- Research methodology

This research is based on research methods, quantitative, descriptive, analytical and scientific. In terms of purpose, it is considered as applied research. And also in terms of nature, it is post-event. The proposed method of this research consists of several different steps. In other words, for the mathematical modeling of the nonlinear fractional order chaotic system and the optimal control of the factors affecting the stress and burnout of auditors, first a modeling approach of the type of differential equations is required. In fact, differential equations with fractional derivatives are used for modeling purposes, and various algorithms have been developed for modeling and optimal control. Algorithms that can help in implementing and simulating mathematical models are genetic algorithm and particle swarm optimization algorithm. In the presented method, the work is started with the initial definitions of mathematical models of the type of differential equations with Caputo's fractional derivatives and it is tried to discover the cases that were not known before and make rules for them. In fact, in the presented method, first, with the help of mathematical knowledge, the necessary mathematical information for modeling and so on is extracted. In the next step, after extracting effective formulas and definitions and theorems, the mathematical model related to the factors affecting the stress and job burnout of auditors will be built with the help of fractional calculators, and it will be shown that the presented model has chaos, its order is from order It is a deficit and needs to be controlled. In the next step, prerequisites and optimal control concepts are presented. Then the presented nonlinear fractional order chaotic model should be optimally controlled. Finally, the presented method is done with the help of an applicable and dynamic model in the form of a simulation done with the help of standard software, so that with the lowest possible cost before implementing and implementing the presented method, corrections are made according to different scenarios in order to improve performance. be done. The software used to implement the modeling process and its optimal control is MATLAB software. Finally, simulation will be done using genetic algorithm and particle swarm optimization algorithm in MATLAB software. Considering that this research deals with providing mathematical model and its optimal control. Therefore, the method of gathering information in this research is to use the information available in sources, articles, books and other research related to mathematical and engineering sciences in a general and detailed way, so there is no need to use the information of stock companies. The collection tools in this research are databases (including websites, blogs and scientific associations of faculties of mathematical and technical sciences, engineering and humanities), computer networks and the Internet to provide resources and mathematical concepts and optimal engineering control from universities. It is used inside and outside.

3-1- Research variables

In this research, the dependent variable is the application of the genetic algorithm and the particle swarm optimization algorithm in providing mathematical models of the non-linear fractional order chaotic system, the factors affecting the stress and burnout of auditors and the independent variables, which are prepared based on the questions raised to conduct the research. Have been, are:

1. The lack of optimal control of chaotic system models of factors affecting stress and burnout of auditors
2. Doubts in reducing the error of chaotic models of the system of effective factors on stress and burnout of auditors
3. Determining the degree of improvement in the accuracy and reliability of control of chaotic models with genetic algorithm and particle swarm optimization algorithm

3.2. Riemann-Liouville Integral and Caputo fractional derivative

Suppose that $n > 0$ and fare continuous segments on the interval (α, ∞) and are integrable on any finite sub-interval(α, ∞). Then, the fractional Riemann-Liouville Integral *f* for *t*>*a* of order *n* is defined as

$$ {}_aD_t^{-n} f(t) = \frac{1}{\Gamma(n)} \int_\alpha^t (t-T)^{n-1} f(T)dT, \tag{1}$$

which can also be displayed with the symbols I_a^n orJ_a^n . In addition, if *f* is continuous on $[a, t]$, then $\lim_{n\to\alpha} D_t^{-n} f(t) = f(t)$. Furthermore, the following equation can be true:

$$ {}_aD_t^{0} f(t) = f(t). \tag{2}$$

When $n - m \in N$, the definition of (1-1) is compatible$-m$ with -fold integral as follows:

$$ {}_aD_t^{-m} f(t) = \int_\alpha^t dT_1 \int_\alpha^{T_1} dT_2 \dots \int_\alpha^{T_{m-1}} f(T_m)dT_m $$
$$ = \frac{1}{(m-1)!} \int_\alpha^t (t-T)^{m-1} f(T)dT, \quad m \in N. \tag{3}$$

Regarding $m \geq 0$ and $v > -1$, the integral from the defined real order in Equation (1) has the following properties:

$$ I.{}_\alpha D_t^{-n}(t-\alpha)^v = \frac{\Gamma(v+1)}{\Gamma(n+v+1)}(t-\alpha)^{n+v}, $$
$$ II.{}_\alpha D_t^{-n} k = \frac{k}{\Gamma(n+1)}(t-\alpha)^n, $$

If $f(t)$ for $t \geq a$ is continuous, then:

$$ III.{}_\alpha D_t^{-n}({}_\alpha D_t^{-m} f(t)) = {}_\alpha D_t^{-m}({}_\alpha D_t^{-n} f(t)) = {}_\alpha D_t^{-n-m} f(t). $$

Caputo defined a derivative operator in 1976 that differs from previous derivatives in terms of characteristics. The symbol of this operator is as ${}_aD_*^n$ and is defined as:

$$ {}_aD_*^n f(t) = \frac{1}{\Gamma(m-n)} \int_\alpha^t (t-T)^{m-n-1} f^{(m)}(T)dT \qquad (m-1 < n \leq m) \tag{4}$$
$$= \alpha D_t^{-(m-n)} f^{(m)}(t),$$

On the conditions that $n \to m$ are exercised on the f function, then the Caputo derivative transforms to the m[th] order derivative of the f(t) function. Suppose that $0 \leq m-1 < n < m$ and function f(t) have m+1 continuous bounded derivative in the interval$[a,t]$, then by partial integration for each $t > a$ per $m = 1,2,\ldots$, we have:

$$\lim_{n\to m} {}_\alpha D_*^n f(t) = \lim_{n\to m} \left(\frac{f^{(m)}(\alpha)(t-\alpha)^{m-n}}{\Gamma(m-n+1)} \int_\alpha^t (t-T)^{m-n} f^{(m+1)}(T)dT\right)$$
$$(5) = f^{(m)}(\alpha) + \int_\alpha^t f^{(m+1)}(T)dT = f^{(m)}(t).$$

3-2-1- Chaotic fractional-order systems

The parameters and conditions for which the fractional-order system could have chaotic behavior are both investigated in this article [13]. In this section, two relevant theorem for fractional-order systems are stated [8,10,14]. The theorem is about proportional fractional-order systems.

Theorem 3-2-2- *Consider the autonomous system*

$$\frac{d^\alpha x}{dt^\alpha} = Ax, \quad x(0) = x_0. \tag{6}$$

i) *Suppose* $0 < \alpha < 1$ *and* $x \in \mathbb{R}^{n\times n}$ *, then, matrix A* $\in \mathbb{R}^{n\times n}$ *is asymptotically stable if and only if* $|arg(\lambda)| > \frac{\alpha\pi}{2}$ *is valid. In this equation,* λ *is the eigenvalue of matrixA In addition, this matrix is stable if and only if* $|arg(\lambda)| \geq \frac{\alpha\pi}{2}$.

ii) *The equilibrium point in fractional-order systems is calculated by the following system of ODEs [16]:*

$$\frac{d^\alpha x}{dt^\alpha} = f(x), \tag{7}$$
$$f(x) = 0, \tag{8}$$

for $0 < \alpha < 1$ *and* $x \in \mathbb{R}^{n\times n}$. *The equilibrium point achieved by the solution of the system is asymptotically stable if the calculated eigenvalue* λ *related to the Jacobian matrix* $J = \frac{df}{dt}$ *satisfies the following equation in equilibrium point [8,9]:*

$$. \qquad (9)|arg(\lambda)| > \frac{\alpha\pi}{2}$$

Proof: See [8,10] for the proof.

Theorem 3-2-3- *The n-dimensional dynamic fractional-order system could be specified as follows [17]:*

$$\begin{aligned}
\frac{d^{\alpha_1}x_1}{dt^{\alpha_1}} &= a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n,\\
\frac{d^{\alpha_2}x_2}{dt^{\alpha_2}} &= a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n,\\
&\vdots\\
\frac{d^{\alpha_n}x_n}{dt^{\alpha_n}} &= a_{n1}x_1 + a_{n2}x_2 + \cdots + a_{nn}x_n.
\end{aligned} \tag{10}$$

In the system above, α_i*'s are between 0 and 1. It is assumed that M is the least common multiple of* u_i *that is expressed as* $\alpha = \frac{v_i}{u_i}$. *Here* $(u_i, v_i) = 1$ *and* $u_i, v_i \in \mathbb{Z}^+$ *for* $i = 1,2,3,\ldots,n$. *Finally* $\Delta(\lambda)$ *Is described as below [18]:*

$$\Delta(\lambda) = \begin{pmatrix} \lambda^{M\alpha_1} - a_{11} & -a_{12} & \cdots & -a_{1n} \\ -a_{21} & \lambda^{M\alpha_2} - a_{22} & \cdots & -a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ -a_{n1} & -a_{n2} & \cdots & \lambda^{M\alpha_n} - a_{nn} \end{pmatrix}. \quad (11)$$

The system response described in (10) is asymptotically stable if all roots (λ) of equation $det(\Delta(\lambda) = 0)$ satisfy the condition:

$$|arg(\lambda)| > \frac{\alpha\pi}{2}.$$

Denoting the matrix $\Delta(s)$ is the characteristic matrix, and $det(\Delta(s))$ is the polynomial characteristic of the system (10).

Proof: See [8,10] for the proof.

Definition 3-2-4- Consider the fractional-order system [20]:

$$\frac{d^{\alpha_i}x_i}{dt^{\alpha_i}} = f_i(x_1, x_2, x_3, \dots, x_1), \quad i = 1,2,3, \dots, n, \quad (12)$$

where all α_i coefficients have values between 0 and 1. The equilibrium point of the system (12) is acquired with solution of the following equations [19,21]:

$$f_i(x_1, x_2, x_3, \dots, x_1) = 0, \quad i = 1,2,3, \dots, n. \quad (13)$$

It is assumed that $x_1^* = (x_1^*, x_2^*, x_3^*, \dots, x_n^*)$ is the equilibrium point of the system(12) meaning$f_i(x_1^*, x_2^*, x_3^*, \dots, x_n^*) = 0$. Considering the values for *i*, the equation below is defined to evaluate the stability of equilibrium point [22]:

$$\varepsilon_i = x_i - x_i^*, \quad i = 1,2,3, \dots, n. \quad (14)$$

As the Caputo differentiation by a constant value is zero, we would conclude:

$$\frac{d^{\alpha_i}\varepsilon_i}{dt^{\alpha_i}} = f_i(x_1^* + \varepsilon_1, x_2^* + \varepsilon_2, \dots, x_n^* + \varepsilon_i), \quad i = 1,2,3, \dots, n. \quad (15)$$

If the second partial differentiation of function f_i around the equilibrium point x^* exists in the *n*-dimensional space of $\mathbb{R}^n$, the right-hand side of equation (15) could be rewritten as [22]:

$$f_i(x_1^* + \varepsilon_1, x_2^* + \varepsilon_2, \dots, x_n^* + \varepsilon_i) = f_i(x_1^*, x_2^*, \dots, x_n^*) + \left[\frac{\partial f_i}{\partial x_1}\bigg|_{x^*} \frac{\partial f_i}{\partial x_2}\bigg|_{x^*} \cdots \frac{\partial f_i}{\partial x_n}\bigg|_{x^*}\right]\varepsilon + \overline{f_i}(\varepsilon). \quad (16)$$

In the equation above, $\varepsilon = [\varepsilon_1, \varepsilon_2, \dots, \varepsilon_n]^T$, and $\overline{f_i}(\varepsilon)$ consist of the higher-order terms of Taylor expansion that is neglected. In addition, it is assumed that we have $f_i(x_1^*, x_2^*, \dots, x_n^*) = 0$, for$i = 1,2,3, \dots, n$. As a result, we could conclude:

$$f_i(x_1^* + \varepsilon_1, x_2^* + \varepsilon_2, \dots, x_n^* + \varepsilon_i) \approx \left[\frac{\partial f_i}{\partial x_1}\bigg|_{x^*} \frac{\partial f_i}{\partial x_2}\bigg|_{x^*} \cdots \frac{\partial f_i}{\partial x_n}\bigg|_{x^*}\right]\varepsilon + \overline{f_i}(\varepsilon). \quad (17)$$

Furthermore, we could assume the following equation:

$$\begin{pmatrix} \frac{d^{\alpha_1}x_1}{dt^{\alpha_1}} \\ \frac{d^{\alpha_2}x_2}{dt^{\alpha_2}} \\ \vdots \\ \frac{d^{\alpha_n}x_n}{dt^{\alpha_n}} \end{pmatrix} = J\varepsilon, \quad (18)$$

where we have $f = [f_1, f_2, \dots, f_n]^TandJ = \frac{\partial f}{\partial x}\Big|_{x^*}$.

It is assumed that *M* is the least common multiple of α_i that is defined as$\alpha_i = \frac{v_i}{u_i}$,$(u_i, v_i) = 1$, and $u_i, v_i \in \mathbb{Z}^+$for $i = 1,2,3, \dots, n$. According to Theorem (1.3.1), if $|arg(\lambda)| > \frac{\alpha\pi}{2}$ for all λ calculated by the equation below, the equilibrium point $x = x^*$ of the system (12) is asymptotically stable [10,17]:

$$det(diag([\lambda^{M\alpha_1}\ \ \lambda^{M\alpha_2}\ \ ...\ \ \lambda^{M\alpha_n}]) - J) = 0, \tag{19}$$

It should be noted that $diag([m_1\ \ m_2\ \ ...\ \ m_n])$ is represented by a square $n \times n$ matrix as below:

$$diag([m_1\ \ m_2\ \ ...\ \ m_n]) = \begin{pmatrix} m_1 & 0 & \cdots & 0 \\ 0 & m_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & ... & m_n \end{pmatrix}. \tag{20}$$

3-2-5- The required conditions for the presence of chaos in fractional-order system

The saddle point is an equilibrium point in a three-dimensional integer-order system with at least one eigenvalue at the stable region (the left-hand part of the imaginary axis) and at least one eigenvalue in the unstable area (the right-hand part the imaginary axis) [23,24]. This saddle point is called saddle point of kind one if one of the eigenvalues is unstable and the others are stable, and if one eigenvalue is stable while two others are unstable [15,23], the saddle point is of kind two. The chaotic behavior in a chaotic system is demonstrated around a saddle point of kind two. The chaotic behavior could also be observed around a saddle point of the second kind in a three dimensional fractional-order system, just as the three-dimensional integer order one [25]. It is considered that the chaotic three-dimensional system of the form $\dot{x} = f(x)$ have chaotic attractors. It is also assumed that Ω is a set of equilibrium points of the system surrounded by a twisting [15]. On the other hand, both system $D^\alpha x = f(x)$ with defined $D^\alpha \equiv \left(\frac{d^{\alpha_1}}{dt^{\alpha_1}}, \frac{d^{\alpha_2}}{dt^{\alpha_2}}, \frac{d^{\alpha_3}}{dt^{\alpha_3}}\right)$ and $\dot{x} = f(x)$ have equal equilibrium points [15]. Therefore, the required condition for a fractional-order system of $D^\alpha x = f(x)$ to have chaotic attractor is stated as the following equation [26]:

$$\left(\frac{\pi}{2M}\right) - min|arg(\lambda_i)| \geq 0, \tag{21}$$

where λ_i are the roots of the equation below:

$$det([\lambda^{M\alpha_1}\ \ \lambda^{M\alpha_2}\ \ ...\ \ \lambda^{M\alpha_n}]) - \left.\frac{\partial f}{\partial x}\right|_{x-x^*} = 0, \quad \forall x^* \in \Omega. \tag{22}$$

The system's behavior around this point cannot tend to a chaotic attractor if the system has a stable equilibrium point, and the initial conditions related to the system do not lie inside the attracting region [17]. In other words, the system cannot have a chaotic behavior for any initial condition, and some of the initial conditions do not actually represent chaotic behavior. In general, there is not a specific mathematical relation to the present attracting region. The condition of being chaotic for the fractional-order system of (12) could be stated as follows (by assumption $\alpha_1 = \alpha_2 = \alpha_3 = \alpha$. See [8,22,60] for more details):

$$\alpha \geq \frac{2}{\pi} min|arg(\lambda_i)|, \tag{23}$$

where λ_i are the eigenvalues of the Jacobin matrix defined by $\left.\frac{\partial f}{\partial x}\right|_{x-x^*} = 0$ for every $x^* \in \Omega$. The relation (23) states the necessary condition for chaos to occur in a fractional-order system [8,10]. This relation could be used to acquire the minimum order of the system for which the chaotic behavior could occur.

3-2-5-Characteristics of research models

3-2-5-1- Modeling the factors affecting auditors' job stress

In general, systems modeling methods are a practical way to better understand and avoid wasting time and money. To understand the behavior of the model, researchers have proposed various models. In the models, they tried to find equations to express the variables and factors affecting them. These equations are presented considering various factors. In this research, the mathematical model of factors affecting auditors' job stress is presented in the following differential equation system; we examine the issue of optimal control of factors affecting auditors' job stress. So we will have:

$$x' = a_1 - a_2xy - a_3x - a_4z,$$
$$y' = a_5xy - a_6yz - a_7xz, \tag{24}$$
$$z' = a_8xz + a_9y,$$

Where x(t) organizational stressors (reward, organizational structure and supervision style), y(t) individual stressors (time pressure, role ambiguity, role conflict), z(t) environmental stressors (long hours) Work shows the lack of job security, working in hours other than the usual hours of the day. In the above relationships, x' is the derivative of the variable x(t) in relation to t, y' is the derivative of the variable y(t) in relation to t, z' is the derivative of the variable z(t) in relation to t. in the above model are defined in the following table. In table (1) the definitions and values of the parameters of the model of the factors affecting auditors' job stress are presented.

Table (1) definitions and parameter values of the factors affecting auditors' job stress model

parameter	Definition	Value
a_1	reward	11
a_2	Organizational Structure	0.03
a_3	Monitoring style	0.05
a_4	time pressure	0.008
a_5	Role ambiguity	0.42
a_6	role conflict	0.002
a_7	Long working hours	0.06
a_8	Lack of job security	0.74
a_9	Working at hours other than the usual hours of the day	0.001

We want to control the non-linear fractional order model of factors affecting auditors' job stress. Therefore, we consider a chaotic model with nonlinear fractional order derivatives based on the stability theorem related to fractional order systems. Because modeling a system with fractional derivatives can show the behavior of the system better than normal derivatives. To find the lowest fractional order for the system to be in the chaos region, we put:

$$\alpha \geq \frac{2}{\pi} min|\arg(\lambda_i)|, \tag{25}$$

where for the parameters presented in Table 1, the order of the system is considered as [0.99, 0.99, 1], because for these parameters and the specified order, the relation (25) is used. Based on the specified order, we show the chaotic system related to the research model with the nonlinear fractional order differential equation as follows.

$$x'(t) = 11 - 0.03xy - 0.05x - 0.008z,$$
$$D_t^{0.99}y(t) = 0.42xy - 0.002yz - 0.06xz, \tag{26}$$
$$D_t^{0.99}z(t) = 0.74xz + 0.001y,$$

3-2-5-2- Modeling the factors affecting auditor burnout In the continuation of this research, the mathematical model of the factors affecting the job burnout of auditors is presented in the following differential equation system, we examine the issue of optimal control of the factors affecting the job burnout of auditors. So we will have:

$$x' = a_1 - a_2y - a_3y - a_4yz,$$
$$y' = a_5x - a_6yx - a_7z, \tag{27}$$
$$z' = a_8xy + a_9yz,$$

where x(t) organizational factors (job ambiguity, job expectations, role conflict and workload), y(t) interpersonal factors (competition, social support, insecurity), z(t) intrapersonal factors (unpreparedness for It shows job qualification, personality traits, level of education). In the above relationships, x' is the derivative of the variable x(t) in relation to t, y' is the derivative of the variable y(t) in relation to t, z' is the derivative of the variable z(t) in relation to t. in the above model are defined in the following table. In table (2) the definitions and values of the parameters of the model of the factors affecting the job burnout of auditors are presented.

Table (2) definitions and parameter values of the factors affecting auditor burnout model

parameter	Definition	Value
a_1	job ambiguity	9
a_2	Job expectations	0.004
a_3	Role conflict and workload	0.06
a_4	Competition	0.02
a_5	social support	0.34
a_6	Insecurity	0.03
a_7	Lack of preparation for employment	0.009
a_8	Personality characteristics	0.52
a_9	Level of education	0.004

The objective of the optimal control of the non-linear fractional order model is the factors affecting the burnout of auditors. Therefore, we consider a chaotic model with nonlinear fractional order derivatives based on the stability theorem related to fractional order systems. Because modeling a system with fractional derivatives can show the behavior of the system better than normal derivatives. To find the lowest fractional order for the system to be in the chaos region, we put:

$$\alpha \geq \frac{2}{\pi} min|\arg(\lambda_i)|, \tag{28}$$

where for the parameters presented in Table 2, the order of the system is considered as [0.96, 0.96, 1], because for these parameters and the specified order, the relation (28) is used. Based on the specified order, we show the chaotic system related to the research model with the nonlinear fractional order differential equation as follows.

$$\begin{aligned} x'(t) &= 9 - 0.004y - 0.06y - 0.02yz, \\ D_t^{0.96} y(t) &= 0.34x - 0.03yx - 0.009z, \\ D_t^{0.96} z(t) &= 0.52xy + 0.004yz, \end{aligned} \tag{29}$$

3-3- Optimum control of the model of factors influencing stress and burnout of auditors

First, it is necessary to determine the control objective for the optimal control of non-linear fractional order models of factors affecting auditors' stress and burnout. Here, our goal is to achieve the minimum amount of organizational stressors on auditors' stress and burnout. It is necessary to define a standard mathematical function based on the specified goal. It is possible to display the function with the following relation:

$$j = \int_0^{t_f} (x^2 + u^2) d. \tag{30}$$

The physical meaning of the proposed standard function is that by choosing the appropriate control variable, the amount of organizational stressors that affect auditors' stress and burnout will reach zero in the presented model. In other words, the main task of the control is to find the optimal control signal to minimize the standard function specified in (27). Now, the non-linear fractional order model of factors affecting auditors' job stress by considering the control variable in relation

(31) and the non-linear fractional order model of the effective factors of auditors' job burnout in relation (32) are considered as follows:

$$x'(t) = 11 - 0.03xy - 0.05x - 0.008z - u,$$
$$D_t^{0.99}y(t) = 0.42xy - 0.002yz - 0.06xz - 0.5u, \quad (31)$$
$$D_t^{0.99}z(t) = 0.74xz + 0.001y - 0.5u,$$

$$x'(t) = a_1 - a_2y - a_3y - a_4yz - u,$$
$$D_t^{0.96}y(t) = a_5x - a_6yx - a_7z - 0.5u, \quad (32)$$
$$D_t^{0.96}z(t) = a_8xy + a_9yz - 0.5u,$$

Since the system models and objective functions are specified, determining an optimal control method solves the problem. In this research, we use particle swarm optimization algorithm and genetic algorithm methods to solve the problem.

3. Results of the research

The results of each method are presented in the sequel.

3.1. Without control

In uncontrolled mode, in Fig. 1, the following results for three-mode variables are obtained that are not desirable:

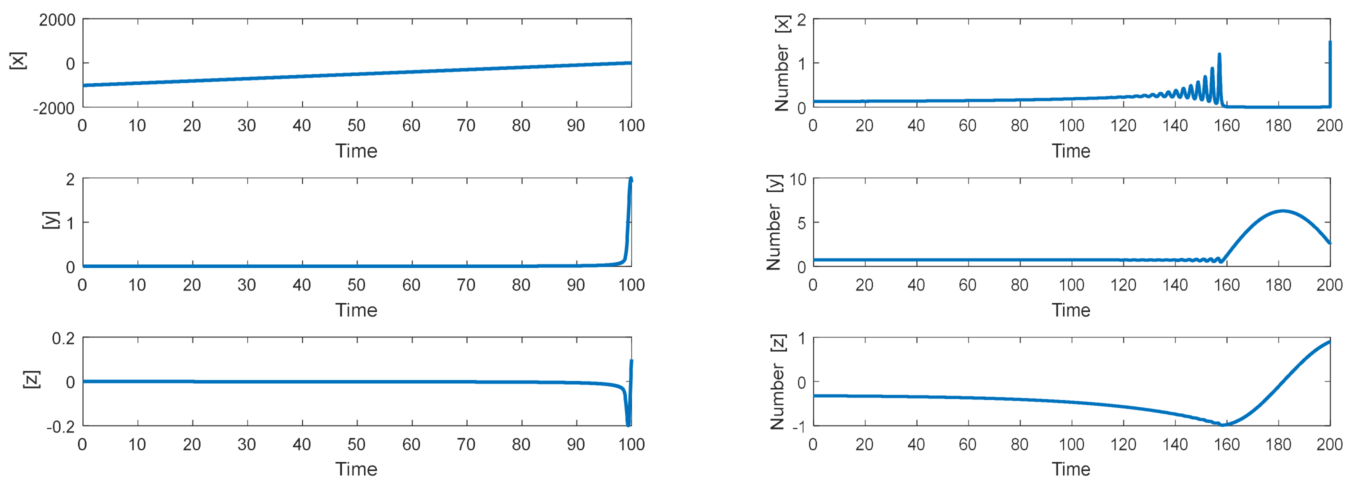

FIGURE B. THE RESULTS FOR THREE-STATE VARIABLES WITH [0.99,0.91,0.91] FOR FINANCIAL RISK

FIGURE A. THE RESULTS FOR THREE-STATE VARIABLES WITH SYSTEM ORDER AS [1,0.99,0.99] FOR LIQUIDITY RISK

Fig 1. Results for three-mode variables

3.2. Results of genetic algorithm method

First, According to the implementation of the control input, the following results are obtained. It is clear that the results are excellent as soon as the control input is applied (in Fig. 2, blue lines are for the uncontrolled method and red are for the controlled ones):

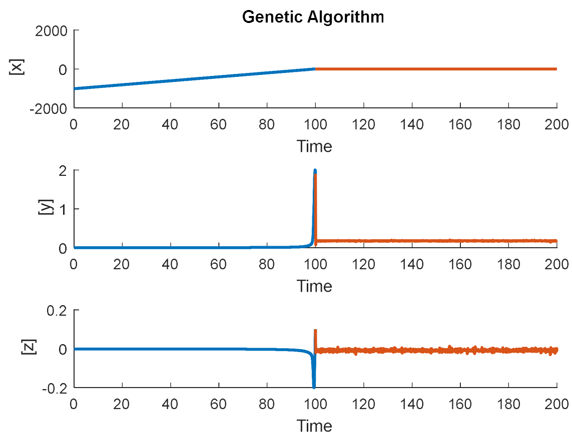

Figure B. Blue lines for uncontrolled method and red lines for controlled cases for order [1, 0.99, 0.99] for financial risk

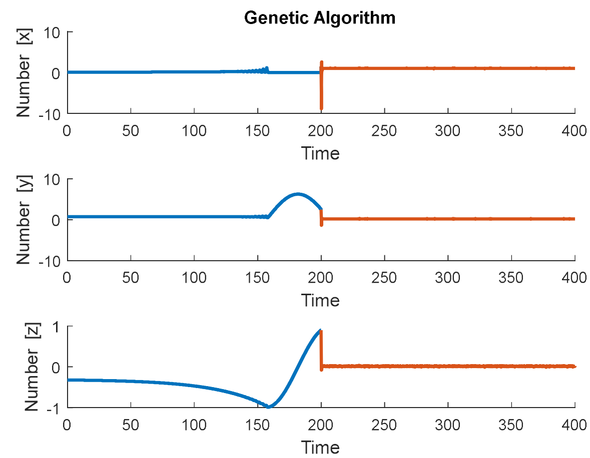

Figure A. Blue lines for uncontrolled method and red lines for controlled cases for order [1,0.99, 0.99] for Liquidity risk

Fig 2. Blue lines are for the uncontrolled method and red are for the controlled ones

Again, in Fig. 3, we examine the results when the controller is in use from the beginning. It is easy to see that the answers are excellent from the beginning.

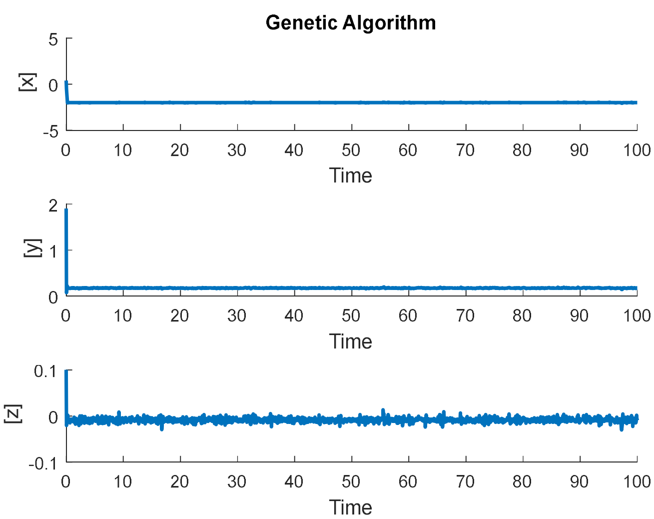

FIGURE B. THE RESULTS WHEN THE CONTROLLER IS IN USE FROM THE BEGINNING FOR THE ORDER OF THE SYSTEM AS [1, 0.99, 0.99] FOR FINANCIAL RISK

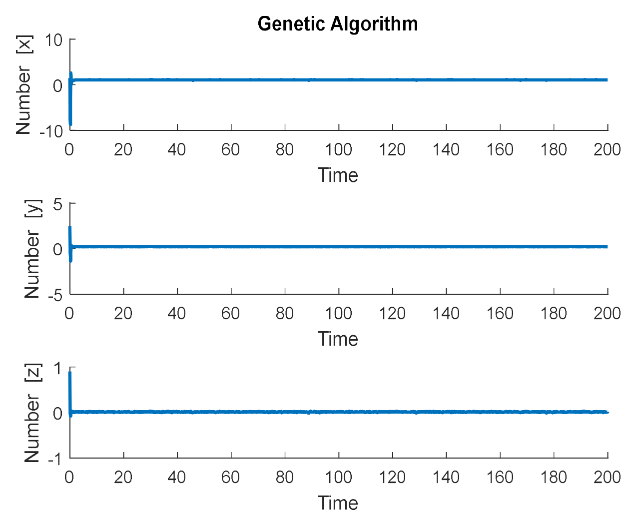

FIGURE A. THE RESULTS WHEN THE CONTROLLER IS IN USE FROM THE BEGINNING FOR THE ORDER OF THE SYSTEM AS [1, 0.99, 0.99] FOR LIQUIDITY RISK

Fig 3. The results when the controller is in use from the beginning

In Fig. 4, changes in control input are as follows:

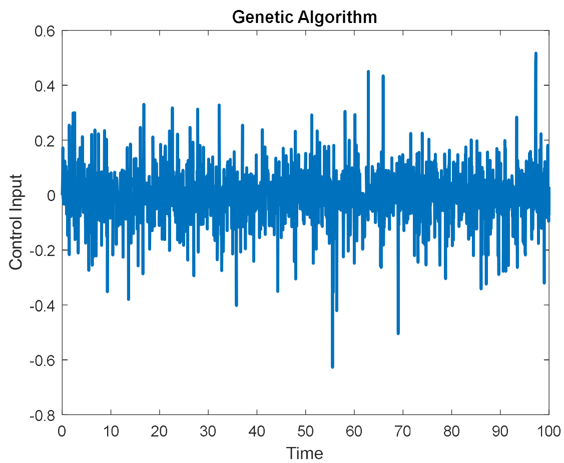

FIGURE B. CHANGES IN THE CONTROL INPUT FOR THE ORDER [1, 0.99, 0.99] FOR FINANCIAL RISK

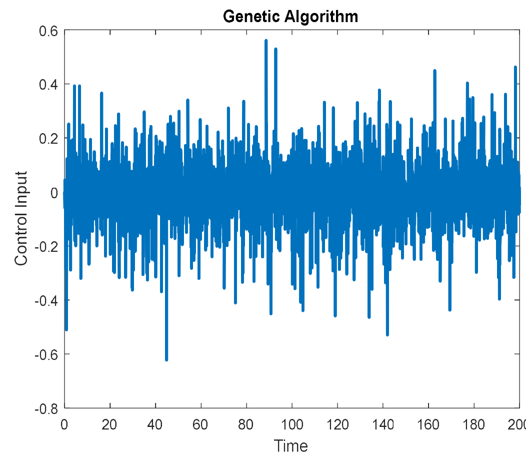

FIGURE A. CHANGES IN THE CONTROL INPUT FOR THE ORDER [1,0.99, ,0.99] FOR LIQUIDITY RISK

Fig 4. Changes in control input

Details about the values is available on request.
For this reason, in Fig.5 we draw a diagram for the approximation and error of the zero reference signals:

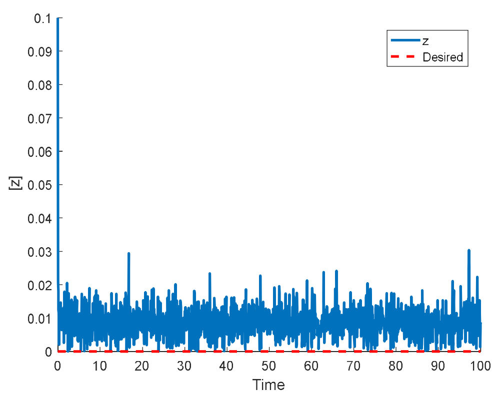

FIGURE B. APPROXIMATION DIAGRAM AND ERROR OF ZERO REFERENCE SIGNALS FOR THE ORDER [1, 0.99, 0.99] FOR FINANCIAL RISK

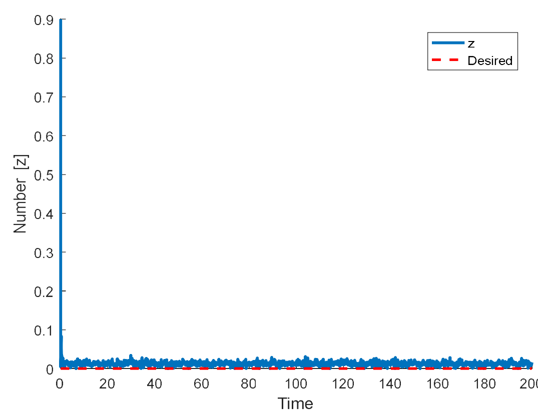

FIGURE A. APPROXIMATION DIAGRAM AND ERROR OF ZERO REFERENCE SIGNALS FOR THE ORDER [1,0.99, 0.99] FOR LIQUIDITY RISK

Fig 5. Diagram for the approximation and error of the zero reference signal

The MSE and RMSE specifications for error are on the MATLAB command page. We observe that their values are small. Consequently, the simulation is effective. It can be seen in Table 3.

Table 3.The MSE and RMSE specifications for error

System order	MSE	RMSE
[1, 0.99, 0.99] for financial risk	9.4931e-05	0.0097432
[1, 0.99, 0.99] for liquidity risk	0.00039219	0.019804

3.3. Results of particle swarm optimization algorithm

We also repeated all the above steps for this method and observed that it is very successful. Moreover, in Figs. 6, 7, 8 and 9 its results are very close to the genetic algorithm method.

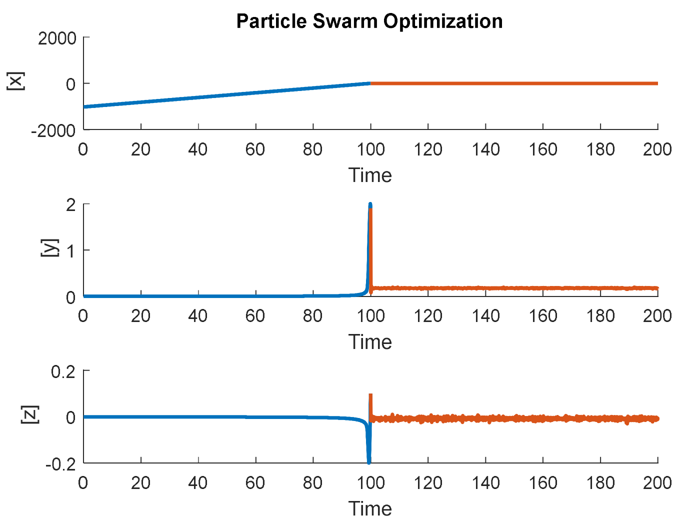

FIGURE B. BLUE LINES FOR UNCONTROLLED METHOD AND RED LINES FOR CONTROLLED CASES, ORDER [1, 0.99, 0.99] FOR FINANCIAL RISK

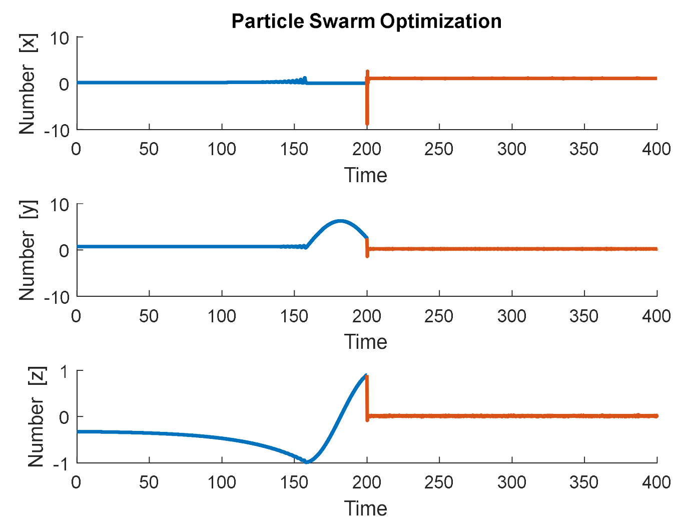

FIGURE A. BLUE LINES FOR UNCONTROLLED METHOD AND RED LINES FOR CONTROLLED CASES, ORDER [1,0.99, 0.99] FOR LIQUIDITY RISK

Fig 6. Blue lines are for the uncontrolled method and red are for the controlled ones

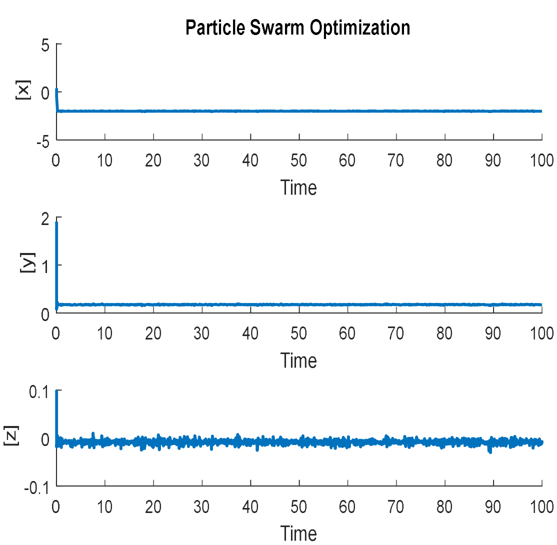

FIGURE B. RESULTS WHEN THE CONTROLLER IS IN USE FROM THE BEGINNING FOR ORDER [1, 0.99, 0.99] FOR FINANCIAL RISK

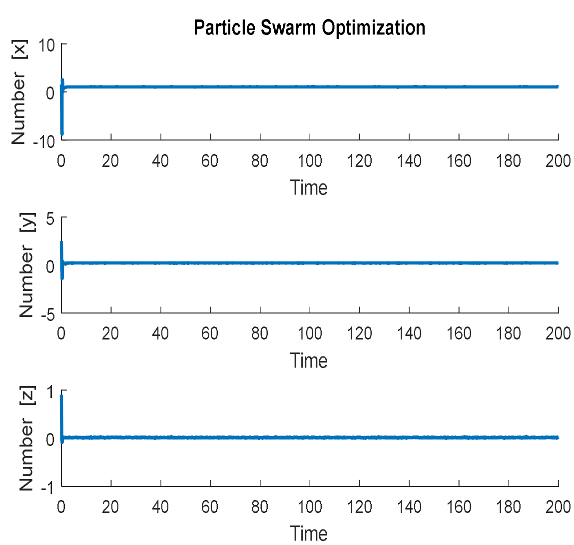

FIGURE A. RESULTS WHEN THE CONTROLLER IS IN USE FROM THE BEGINNING FOR ORDER [1,0.99,0.99] FOR LIQUIDITY RISK

Fig 7. The results when the controller is in use from the beginning

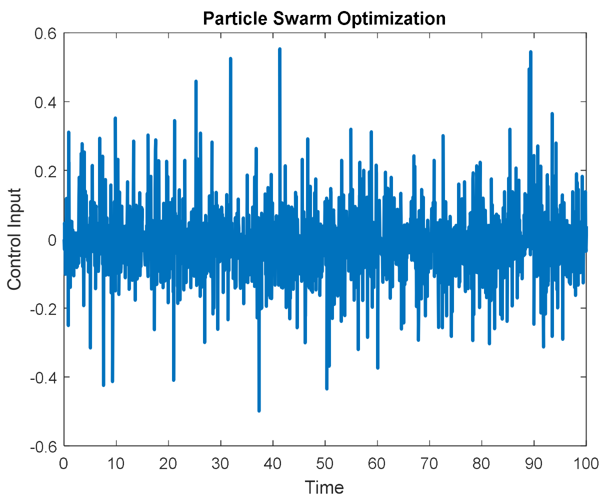

FIGURE B. CHANGES IN THE CONTROL INPUT FOR THE ORDER OF THE SYSTEM AS [1, 0.99, 0.99] FOR FINANCIAL RISK

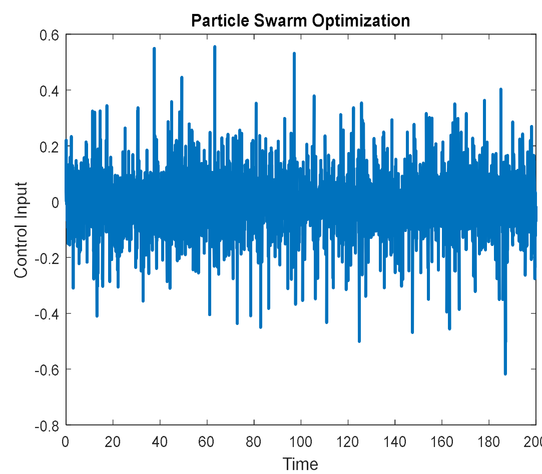

FIGURE A. CHANGES IN THE CONTROL INPUT FOR THE ORDER OF THE SYSTEM AS [1,0.99, 0.99] FOR LIQUIDITY RISK

Fig 8. Changes in control input

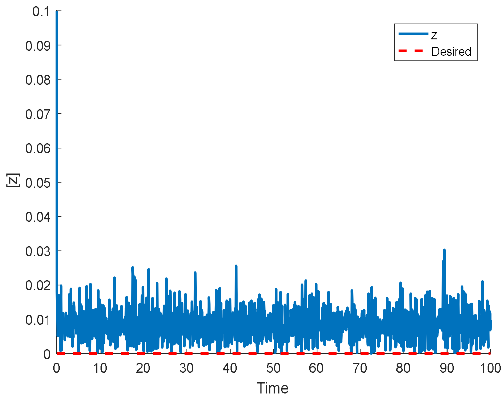

FIGURE B. APPROXIMATION DIAGRAM AND ERROR OF ZERO REFERENCE SIGNALS FOR ORDER [1, 0.99, 0.99] FOR FINANCIAL RISK

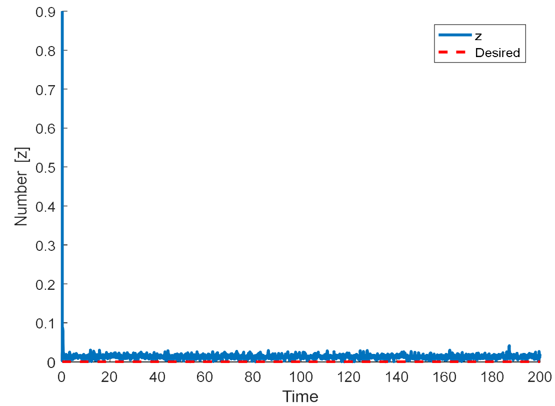

FIGURE A. APPROXIMATION DIAGRAM AND ERROR OF ZERO REFERENCE SIGNALS FOR ORDER [1,0.99, 0.99] FOR LIQUIDITY RISK

Fig 9. Diagram for the approximation and error of the zero reference signal

The MSE and RMSE specifications for error are on the MATLAB command page. We observe in Table 4 that their values are small. Consequently, the simulation is effective.

Table 4.The MSE and RMSE specifications for error

System order	MSE	RMSE
[1, 0.99, 0.99] for financial risk	9.4182e-05	0.0097048
[1, 0.99, 0.99] for liquidity risk	0.00039194	0.019797

5- Discussion and conclusion

The aim of the current research is to present the model and optimal control of the nonlinear fractional order chaotic system of factors affecting auditors' job stress using genetic algorithm and particle swarm optimization algorithm. Genetic algorithm and particle swarm optimization algorithm were used in MATLAB software to implement the model simulation process and its optimal control. The results of the research showed that with the mathematical modeling of the chaotic system of non-linear fractional order, the effective factors on auditors' job stress can be determined in the best possible way, the chaos in the model. The use of the proposed research method will improve the optimal control of the chaotic model of factors affecting auditors' job stress; reduce errors and increase accuracy and reliability. The results of the genetic algorithm method and the particle swarm optimization algorithm method show that this method is also very successful and excellent and the results of the two methods are very close to each other. The simulation results confirm the success of the control objectives according to the presented diagrams. The error values are very small, which indicates that the simulation is effective. The more auditors have the ability to endure challenging and stressful conditions, the more they have the ability to successfully adapt to threatening conditions and return to the initial balance, so the audit quality will increase. Correct control and management of complexities can improve work and personal interactions. On the other hand, the atmosphere in the company and more precisely the constructive organizational culture will facilitate the growth of the organization and face challenges. Lack of transparency and self-interest increases interpersonal tension and causes a negative attitude in the company. On the other hand, tailoring the work environment to the employee can improve individual and organizational productivity. Dealing with work-family conflict and strategies to deal with such conflicts play a vital role in improving the quality of auditors' work life. Adopting optimal educational approaches and using psychological empowerment techniques, including motivational measures, planning in order to enrich the meaning of assigned responsibilities, emotional support, correct understanding of auditors' attitudes and awareness of people's needs can reduce tension and empower the company day by day. Since in all organizations and institutions, large and small, the existence of a single accounting unit is necessary and unavoidable, and on the other hand, due to the nature of this job and the need for great accuracy and concentration in numbers and figures, there is a special type of stress in this group. It is caused by employees, which leads to the feeling of fatigue, disintegration, anxiety, memory loss, scattered thoughts... Therefore, it is up to all organizations and institutions to prevent the long-term effects of occupational stress on the employees of this profession, whose number is increasing in today's society, considering the needs of the society. Among the programs effective in reducing job stress that has been mentioned in most researches is the participation of employees in decision-making, which creates a good two-way relationship between supervisors and subordinates. In general, structures that give more decision-making power to their employees create less stress and strengthen the sense of autonomy, responsibility and sense of control in employees. Also, the following very simple and low-cost solutions are suggested to reduce auditors' job stress. Establishing regular meetings for employees and encouraging them to express problems and inadequacies in the work environment and take action to solve the problem. Training methods of dealing with or adapting to stress in the work environment, increasing the level of knowledge of employers and managers in the field of planning as best as possible to reduce stress factors in the work environment. Increasing ambiguity and conflict in the role, employees tend to look for other jobs and leave their jobs if the conditions are available due to job dissatisfaction and work-related discomforts and mental tensions. Improving performance is one of the positive consequences of reducing stress and burnout. Therefore, considering the importance of the role of stress and job burnout on the performance of auditors, it is suggested that by reducing job stressors in the work environment, it is possible to improve performance, improve quality, and finally increase the credibility of the auditing profession in the society. Managers should look for ways to reduce the burnout of auditors in order to improve their attrition and avoid imposing costs on the organization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work report in this paper.

References

[1] Almer, E., & Kaplan, S. (2002). The effects of flexible work arrangements on stressors, burnout, and behavioral job outcomes in public accounting. Behavioral Research in Accounting, 14(1), 1–34.

[2] Hao, J., P.Viet, G.Meng. (2022). Analysis of the Influence of Role Stress on Reduced Audit Quality.Jurnal Akuntansi, 23(2): 301-315.

[3] Persellin, J., Schmidt, J., & Wilkins, M. S. (2015). *Auditor perceptions of audit workloads, audit quality, and the auditing profession.* Available online at http://dx.doi.org/10. 2139/ssrn.2534492.

[4] Smith, K.J., & Emerson, D.J. (2017). An analysis of the relation between resilience and reduced audit quality within the role stress paradigm. Advances in Accounting, 37, 1-14.

[5] Utami, I., & Nahartyo, E. (2013). The Effect of Type a Personality on Auditor Burnout: Evidence from Indonesia. Global Journal of Business Research, 5(2), 89-102.

[6] Wal, C. K., May, T. G., Ye, T. S., Yuan, T. S., & Mun, Y.Y. (2013). The relationship between work stress and auditors' job performance, M. A. Thesis in Accounting, University Tunku Abdul Rahman.

[7] Winoto, C. O., & S.Harindahyani.(2021) the effect of auditor work stress on audit quality listed in Indonesian companieson audit quality listed in Indonesian companies. Journal of Economics, Business, & Accountancy Ventura: 23(3).

[8] Wiryathi, N. M., Rasmini, N. K., and M. G. Wirakusuma, (2014). "Influence of Role Stressors on Auditor's Burnout With Emotional IntelligenceAs Moderating Variables", E Journal Ekonomi Dan Bisnis Universitas Udayana, 5(3): 227-244.

[9] Yan, H., Xie, S. (2016). How does auditors' work stress affect audit quality? Empirical evidence from the Chinese stock market. China Journal of Accounting Research, 9(4), 305-319.

[10] Bedford, D. S., Spekle, R. F. & Widener, S. K. (2022). Budgeting and employee stress in times of crisis: Evidence from the Covid-19 pandemic. *Accounting, Organizations and Society*, 101, 101-123.

[11] Amiruddin, A. (2019). Mediating effect of work stress on the influence of time pressure, work–family conflict and role ambiguity on audit quality reduction behavior. *International Journal of Law and Management*, 61(2), 434-454.

[12] Asnawi, M. (2022). The quality of audit recommendation: The effect of role conflict, role ambiguity and work stress. Accounting, 8(3), 315-322.

[13] Awan, F. H., Dunnan, L., Jamil, K., Gul, R. F., Guangyu, Q., & Idrees, M. (2021). Impact of Role Conflict on Intention to leave Job with the moderating role of Job Embeddedness in banking sector employees. Frontiers in psychology, 48(6).

[14]Azzahra, S. (2021). The Influence of Role Ambiguity, Job Stress and Leadership on Job Satisfaction and Employee Turnover at PT. Bank BRI Syariah Samarinda Branch. Saudi Journal of Business and Management Studies, 6(1), 15-23.

[15] Greulich, B., Debus, M. E., Kleinmann, M., & König, C. J. (2021). Response Behavior in Work Stress Surveys: A Qualitative Study on Motivational and Cognitive Processes in Self-and Other-Reports. European Journal of Work and Organizational Psychology, 30(1), 40-57.

[16] Aditya, A. G., & M. G. Kusuma. 2019. The effect of tri hita karana culture in relationship between work stress and internal auditor performance. International research journal of management, IT and social sciences, 6(2): 72-78.

[17] Azad .(1994), time budget pressure and filtering of time practices in internal auditing, auditing, managerial auditing journal, vol.9 , no.6 , pp. 17-25.

[18] Larson, L., H. Meier, and P.Poznanski. 2004. Concepts and Consequences of

[19] Margahana, H. 2020. The Role of Organizational Citizenship Behavior(OCB) Towards Growth and Development of the Company. International Journal of Economics, Business and Accounting Research (IJEBAR), 4(2): 303-309.

[20] Jones, A., Norman, C., & Wier, B. (2010). Healthy lifestyle as a coping mechanism for role stress in public accounting. Behavioral Research in Accounting, 22, 21–41.

[21] Chen, J. C. and C. Silverthorne (2008). The Impact of locus of Control on Job Stress, Job Performance and Job Satisfaction in Taiwan. Leadership and Organization Development Journal, 29(7), 572-582.

[22] Choo, F. (1995). Auditors' Judgment Performance under Stress: A test of the predicted relationship by Three Theoretical Models. Journal of Accounting, Auditing and Finance, 10(3), 611-641.

[23] Cordes, C. L. and T. W. Dougherty (1993). A Review and an Integration of Research on Job Burnout. Academy of Management Review, 18(4), 621-656.
[24] Fisher, R. T. (2001). Role Stress, the Type A Behavior Pattern, and External Auditor Job Satisfaction and Performance. Behavioral Research in Accounting, 13(1), 143-170.
[25] Fletcher, B.C., Jones, F. (1993). A refutation of Karasek's demand-discretion model of occupational stress with a range of dependent measures. Journal of Organisational Behaviur, 14 (4), 319–330.
[26] Fogarty, T. J.; Singh, J.; Rhoads, G. K.; and R. K. Moore (2000). Antecedents and Consequences of Burnout in Accounting: Beyond the Role Stress Model. Behavioral Research in Accounting, 12(1), 31-67.
[27] MohdNor, M. N. (2011). Auditor Stress: Antecedents and Relationships to Audit Quality. M. A. Thesis in Accounting, Edith Cowan University, School of Accounting, Finance and Economics.
[28] Szabo, S. 2020. The Origins & Evolution of Stress Research: From Distress to Eustress. The FASEB Journal, 34(S1): 1-1.
[29] Terp, U., F.Hjärthag, & B.Bisholt. 2019. Effects of a cognitive behavioralbased stress management program on stress management competency, self-efficacy and self-esteem experienced by nursing students. Nurse Educator, 44(1): E1-E5.
[30] Michie, S. (2002). Causes and Management of Stress at Work. Occupational and Environmental Medicine, 59:67-72.
[31] AL Zahrani, A. (2011). The impact of organizational justice on job burnout: a study in private hospitals in Riyadh, Saudi Arabia, interdisciplinary. Journal of Contemporary Research in Business, 3 (6):627-637.
[32] Argentero, P., & Setti I. (200 8). Job perception, work conditions and burnout in emergency workers. Giornale italiano di medicina del lavoro ed ergonomia, 30 (1): 64-70.
[33] Ashtari, Z., Frhady, Y., Khodaee, MR. (2009). Relationship between Job Burnout and Work Performance in a Sample of Iranian Mental Health Staff. African Journal of Psychiatry, 2: 71-74.
[34] Almer, E. D. and S. E. Kaplan (2002). "The Effects of Flexible Work Arrangements on Stressors, Burnout, and Behavioral Job Outcomes in Public Accounting", *Behavioral Research in Accounting,* Vol. 14, No. 1, pp. 1-34.
[35] Fogarty, T. J.; Singh, J.; Rhoads, G. K.; and R. K. Moore (2000). "Antecedents and Consequences of Burnout in Accounting: Beyond the Role Stress Model", *Behavioral Research in Accounting,* Vol. 12, No. 1, pp. 31-67.
[36] Cordes, C. L. and T. W. Dougherty (1993). "A Review and an Integration of Research on Job Burnout", *Academy of Management Review,* Vol. 18, No. 4, pp. 621-656.
[37] Babakas, E., Yavas, U., & Ashill, N.J. (2009). The role of customer orientation as a moderator of the job demand- burnout-performance relationship: A surface-level trait perspective. Journal of Retailing, 85(4): 480-492.
[38] Best, R.G., Stapleton, L.M., & Downey, R.G. (2005). Core self-evaluations and job burnout: The test of alternative models. Journal of Occupational Health Psychology, 10: 441–451.
[39] Bianchi, R., Schonfeld, I.S., & Laurent, E. (2015). Burnout–depression overlap: A review. Clinical Psychology Review, 36: 28-41.
[40] Chang, E., Hancock, K. (2003). Role stress and role ambiguity in new nursing graduates in Australia, Nursing &Health sciences; 5(2):155-165.
[41] Ghavidel, F., Fallahi-Khoshknab M., Molavynejad Sh., & Zarea. (2019). The role of organizational factors in nurse burnout: Experiences from Iranian nurses working in psychiatric wards. J Family Med Prim Care. 8:3893-9.

[42] Erebak, S., & Turgut, T. (2021). Anxiety about the speed of technological development: Effects on job insecurity, time estimation, and automation level preference. The Journal of High Technology Management Research, 32(2), 100419.
[43] Chong, V. K. and G. S. Monroe (2015). "The Impact of the Antecedents and Consequences of Job Burnout on Junior Accountants' Turnover Intentions: A Structural Equation Modelling Approach", *Accounting and Finance,* Vol. 55, No. 1, pp. 105-132.
[44] Mohammadi,S., & S. Reza Hejazi (2023) Lie symmetry, chaos optimal control in non-linear fractional-order diabetes mellitus, human immunodeficiency virus, migraine Parkinson's diseases models: using evolutionary algorithms, Computer Methods in Biomechanics and Biomedical Engineering, DOI: 10.1080/10255842.2023.2198628
[45] Mohammadi,S., & S. Reza Hejazi (2023) Presentation of the model and optimal control of non-linear fractional-order chaotic system of glucose–insulin, Computer Methods in Biomechanics and Biomedical Engineering, DOI: 10.1080/10255842.2023.2205979
[46] Ahmad Taher Azar, Sundarapandian Vaidyanathan, Adel Ouannas, Fractional-Order Control and Synchronization of Chaotic Systems, ISBN: 978-3-319-50249-6, 2017, Offers a snapshot of the latest research on fractional-order control and synchronization of chaotic systems.
[47] F.V. den Bergh, A.P. Engelbrecht, A study of particle swarm optimization particle trajectories, Inform. Sci. 176 (8) (2006) 937–971.
[48] T. Chao-Tang, Ching-Jong Liao, A particle swarm optimization algorithm for hybrid flow-shop scheduling with multiprocessor tasks, Int. J. Prod. Res. 46 (4655) (2008) 17–4670.
[49] Varsha Daftardar-Gejji, Sachin Bhalekar, Chaos in fractional ordered liu system, Comput. Math. Appl. 59 (3) (2010) 1117–1127.
[50] R. Eberhart, Y. Shi, Comparing inertia weights and constriction factors in particle swarm optimization, in: Proceedings of the 2000 Congress on Evolutionary Computation, Vol. 1, Washington, DC, 2000, pp. 84–88.
[51] Mohammad Reza Faieghi, Hadi Delavari, Chaos in fractional-order Genesio–Tesi system and its synchronization, Commun. Nonlinear Sci. Numer. Simul. 17 (2) (2012) 731–741.
[52] Xiao jun Liu, Ling Hong, Lixin Yang, Dafeng Tang, Bifurcations of a new fractional-order system with a one-scroll chaotic attractor, Discrete Dyn. Nat. Soc. 2019 (2019) 8341514, 15 pages.
[53] Xiaojun Liu, Ling Hong, Lixin Yang, Dafeng Tang, Bifurcations of a new fractional-order system with a one-scroll chaotic attractor, Discrete Dyn. Nat. Soc. (15) (2019).
[54] M. Shahiri, R. Ghaderi, A.N. Ranjbar, S.H. Hosseinnia, S. Momani, Chaotic fractional-order Coullet system: Synchronization and control approach, Commun. Nonlinear Sci. Numer. Simul. 15 (3) (2010) 665–674.
[55] Mohammad Shahzad, Chaos control in three dimensional cancer model by state space exact linearization based on Lie algebra, Mathematics 4 (2).
[56] Pires E.J. Solteiro Tenreiro Machado, J.A. Oliveira, P.B. de Moura, Particle swarm optimization with fractional evolution, in: Symposium on Fractional Signals and Systems Lisbon09, Lisbon, Portugal, November 4-6, 2009.
[57] A. Nouainia, F. Mejri & T. Aguili (2022) Analysis and optimization of electromagnetic leaks using genetic algorithms, Journal of Electromagnetic Waves and Applications, 36:17, 2519-2535.
[58] Ioli Gypa, Marcus Jansson, Krister Wolff & Rickard Bensow (2023) Propeller optimization by interactive genetic algorithms and machine learning, Ship Technology Research, 70:1, 56-71.

[59] Syed Yasir Abbas Naqvi & Zahid Iqbal (2023) To improve the performance of genetic algorithms by using a novel selection operator, Journal of Statistical Computation and Simulation, 93:17, 3067-3081.

[60] Mohammadi,S.,S.Reza Hejazi, Using particle swarm optimization and genetic algorithms for optimal control of nonlinear fractional-order chaotic system of cancer cells, Mathematics and Computers in Simulation, Volume 206,2023,Pages 538-560.