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Towards Fractal Approach in Healthcare Information Systems: A Review

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***Abstract*— Recently, traditional information systems need adaption capabilities in order to overcome modifications and maintains of external environment. For that, researchers proposed many solutions from the Fractal method to improve the flexibility and quick adaptive of the system. Computer Information System, as widely used systems, needs modifications and adaptations to real changes. The most important action is to circulate and updating new data and information among the hosts in agent-based information systems. This paper presents the review of using features of fractal method to solve many problems in different fields. The paper is also suggesting employing fractal features for improving the flexibility and adaption of Healthcare Information System (HIS).**

***Keywords*— Flexibility and adaptability, fractal method, healthcare information system, information system.**

I. INTRODUCTION

Information System applications become a great part in many fields [1]. Business information systems can be consisting of independent units, where each unit acts as an information system, has an autonomy of system process activities [2]. Recently, the structure of the business information system needs adaption capabilities in order to overcome modifications and maintains of external environment [3]. These modifications could be happened in system data structure, functional procedures, access rights, information, etc. [4]. The Healthcare Information Systems (HISs) are like business information systems as both need operations' cooperation between their units [5]. Traditional HISs have been developed as warehouses in order to share patients' information between its units [6]. For that, these systems need very flexible structure and cooperative units in order for each unit that represents a sub system, like a hospital, can change and exchange information and structures based on external environment requirements [7]. The cooperation between healthcare units has been done by many methods, such as distributed artificial intelligence and multi-agent systems [8]. However, these methods have its boundaries of capability to react to any system changes, especially in the circulation and updating new data and information [3]. In order to achieve a concrete cooperation, a fractal approach [9] has been proposed by many researchers in different areas [4].

This paper reviews the applications that used Fractal features to build a flexible and cooperative model. The paper studies these features to investigate the possibility of adapting them in building the HIS. The aim of this adaption is to make the units of HIS more adaptive, flexible, and cooperative between these units, which represent each unit as a fractal. Satisfying such capabilities will make HIS more flexible to any changes required due to internal and / or external environments.

II. BACKGROUND

The fractal system is an open and distributed system aims to increase system flexibility [9], [10] consisting of decentralized and autonomous units known as fractals [11]. The mechanism action of the fractal system entities is bottom-up [9], where higher level fractals assume only those liabilities which cannot be realized by lower level fractals. The fractal function in a system can achieve collaboration and coordination process between its units to fulfil the goals of the system [12]. Therefore, the structure of the fractal system could be considered more flexible than conventional systems. The comparison between fractal systems and conventional systems are shown in Table 1 [13].

A model can perform fractal only through existing of main features, such as self-similarity, self-organization, goal-orientation, dynamics and vitality, and navigation; thus, [12]

have proposed graphical form of those features, as shown in Fig. 1.

Self-similarity feature means that all units in the fractal system have same structure or goals[9, 11]. These units contain a set of similar components and properties [14], and shares a set of objectives and vision [15] in order to investigate flexibility structure [3].

In addition to the self-similarity feature, self-organization has used as another important feature [9]. This feature means freedom for fractals in the organization and implementation functions, which means doesn't need the external intervention to reorganize itself [10]. Fractal units may choose their own methods of problem solving including self-optimization that leads process enhancements [12], [15].

In order to investigate dynamically system, dynamics and vitality feature has used in the fractal system [9]. This feature means that the fractals can be able to adapt to the changes on the environment without any challenges to the formal structure of the organization [12], [15].

In order to support cooperation between fractals, the navigation feature has been devised [12]. It means that fractals are networked via an efficient information and communication system [9].

Goal coordination operation is one of the important features of the fractal system. This feature means that system goals arise from the goals of the individual fractals [9]. It is used to satisfactory all members in the system by a goal consistency process between participating fractals. It is supported by an inheritance mechanism [16]. For that, fractal processes can exchange information and motivate each other in the system to make the service process better achieved [17]. The aim of this feature is acquisition of new knowledge by propagating information between system units [18]. Fig. 2 shows a conceptual structure of fractal manufacturing system [16].

To some extent, the fractal approach has tested in adaptive mathematics environment, image analysis [19], manufacturing environment [13], [20], [21], enterprise development [22], software development [23], and information system development and other areas [4].

TABLE 1

DIFFERENCES BETWEEN FRACTAL AND HIERARCHICAL SYSTEM STRUCTURE

	Hierarchical structure	**Fractal structure**
Hierarchy	Structured once only, at a specific point in time	Subject to a constant process of change (dynamic structuring)
Component relationship	Administrative higher unit and passive lower units	Coordinative higher fractal and active lower fractals
Job processing	Work according to specified Objectives	Work through the goal-formation process
Unit function	Controllers at the same level in the hierarchy have similar functions	Every fractals have same functional Modules
Adaptability	Suitable for a stable environment	Suitable for a turbulent environment
Flexibility	Not flexible	Flexible

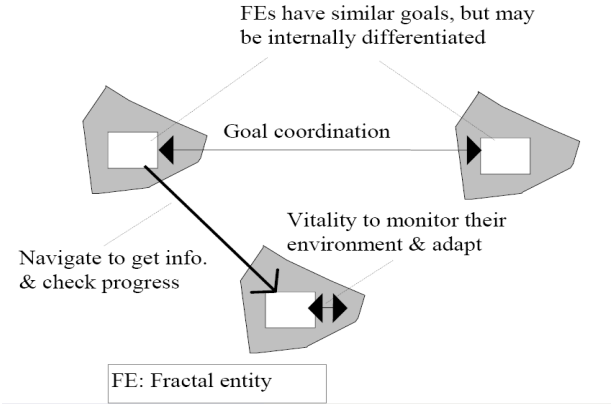

Fig. 1 Operation of fractal entities

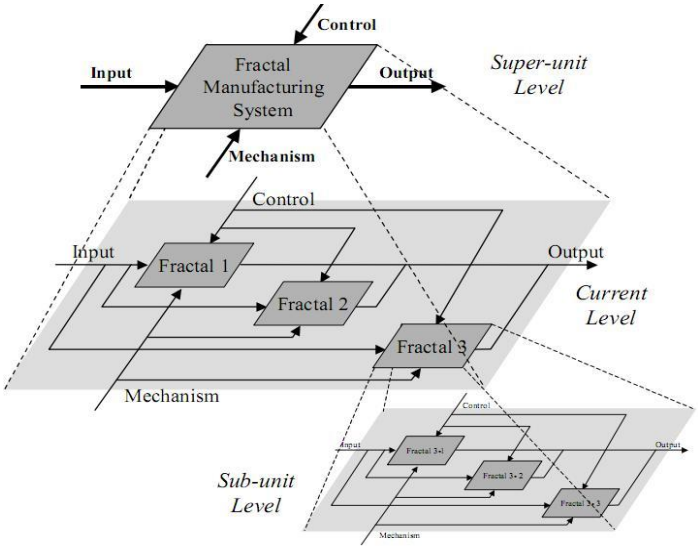

Fig. 2 Conceptual structure of fractal manufacturing system

III. A REVIEW ON FRACTAL IMPLEMENTATIONS

A. Fractal Implementation in Different Fields

In general, the fractal approach has been used to solve system lack of flexibility to react to external and/or internal changes [10]. Therefore, this approach has used to model complex system in order to reduce the complexity structure by increasing flexible, expandable and easing optimized [21]. However, the previous investigations have depended on well establish of rules for system units' structure.

Hence, agent-based system has many features, such as autonomy, cooperation, re-activity and pro-activity, and adaptation and decentralization [24]. The concept of agent is a part of software and/or hardware that possesses autonomy and intelligence, and capability of communications and cooperation with other agents in order to accomplish functions [25]. Therefore, The multi-agent system is suitable to the distributed systems, especially in the fractal systems [24]. Consequently, Ryu defines a fractal system is "set of self-similar agents whose goal can be achieved through cooperation, and coordination, and it can reorganize the configuration of the fractal system to a more efficient and effective one" [13].

Ryu and et al have proposed fractal model by using multi-agent technique, where each unit in a manufacturing system represent as a fractal (agent). Each fractal unit consists of five modules (observer, analyser, organizer, resolver and reporter). These modules work, act as an agent, together in order to form fractal action at different system levels. The main goal of the previous research is to increase the flexibility and adaptation of control systems in the manufacturing environment for meeting dynamically changing customer requirements [26]. Later, the same researchers have used fractal model in the supply chain management of e-business companies [16]. However, the implementation and testing this model in the real-system is complex and need more researches.

Also, in a business environment, Canavesio and et al have suggested a fractal model to establish small and medium enterprises network and to achieve flexible project management system. This model refers that each project management unit can be represented as a fractal; thus, each unit has self-organization, self-learning and goal-driven entity. The collaboration between those different expertise units is mapped to achieve a concrete system goal. The fractal management unit depicted as an agent that has six modules, such as monitor, analyser, reporter, planner, executor, and knowledge base. The goal of this model is to achieve a higher degree of flexibility of connection between system units [11]. However, this model could be applied in any environment that has fractal features with different modules and processes.

In addition, Yuanping and et al have proposed a model of service integration based on fractal approach to improve the cooperation among different staff in easy and speed ways. This model proposed to manage and integrating the service processes in the service companies to satisfy the customer's demands [17]. However, the previous research doesn't mention any strategies and functions of each module. It is just viewed the structure of each fractal unit and the coordination method of information transmission between fractals.

The competences of any enterprise have been modelled based on fractal approach by Xiuquan and others. The goal of this model is to improve enterprise competence in an efficient way of acquisition and creation new knowledge. This model made to facilitate the operation of determined the competences of each enterprise [18]. However, the above work is described the competence modelling based on fractal mathematically for acquisition and creation new knowledge without any practical evidence.

Moreover, the fractal approach has been used to decrease the difficulty of tracking and control processes of any enterprise. The researchers have used fractal mobile agent to represent the tracking and control process at each level of the structure of the workflow. Each fractal mobile agent has same structure of work in order to transfer a specific type of information to other agents. In this way, the complexity of tracking and control process is to be divided into several sub-processes, thus the difficulty of inter-enterprise quality tracking and control is decreased [22]. However, the previously discussed research remains need more researches to implement it in the real system.

Another, to improve the manager performance in any organization, business process activities have been modelled as business fractals by Rensburg. The business fractals are divided into two dimensions; static and dynamic. The static are pattern and content. The pattern is a shape has content unit that has data, information and knowledge about business system information. The dynamic are memory and volatility. The memory is information that always in update depends on the activities. The volatility defines the behaviour of the fractal. This model tried to improve the knowledge of manager for understanding and studying the business process to increase the performance of the organization [27]. However, the researchers focused only on the self-similarity fractal feature by representing each business process as pattern (fractal) that can be divided into small similar parts.

To increase the flexibility of a business process in organizational operation and development, a fractal enterprise approach has been proposed by Stecjuka and et al. This approach allows select the best practices of a business process, such as an annual report of scientific activities of institutions in University, among fractals. These fractals organized in a hierarchical structure as university, faculty, institute, and department. The best practices are propagated to all fractals at the same level and leveraging of those practices to higher organizational levels by appropriate information system design [28]. However, the previously discussed research is proposed the fractal approach in University environment in general, where each unit is free to develop their own processes and supporting system.

On the other hand, Flexible approach can solve problems caused by changes, such as the changes in universities and changes in the domestic high education system, Binsztok and Leja have proposed that university as a fractal organization of knowledge. They used fractal model in the university environment to improve the members' qualifications by sharing a good knowledge in a fast way [29]. However, the researchers are adapted the fractal approach in the university environment in a general in order to investigate efficient fractal university.

Finally, the fractal system [9] has used as a model in many systems in order to solve management and control process activities problems because such system is flexible in structure, and it consists of decentralized units that arranged in abstract levels [16]. Each unit has same structure and function, and has autonomy to execute its activities in the system [14]. The cooperation between those units is the main advantage of the fractal system [12]. This cooperation is through the exchange of information between system units [22]. However, many researchers have used fractal approach in manufacturing system environments and a few have used this approach in the information system domains [4].

B. Fractal Approach in Information Systems

The information system environment continuously needs changes and updates in structure and information depending on requirements [4]. The information systems can be consisting of decentralized and autonomous process units [2]. These units are computer units and human interfaces. They can retrieve and update data to provide knowledge and information as per requirements [4]. On the other hand, Warnecke expected that information system studies will adapt fractal approach in their researches. He thought that components of an information system could be functioned as fractal units in order to make a flexible vitality system [9]. For

that, the fractal system concept has been used in some systems to achieve flexible system structure and easy to manage and control system process activities [11], [16], [17], [22], [30].

The use of fractal approach in any information system domain offers an opportunity to design a more flexible system structure [31]. This system could be adapted quickly to system requirements by using decentralized and autonomous organizational fractal units [11]. Each fractal unit has its own knowledge base and cooperation tools with other fractals [2, 32]. The main work of information system units is processing knowledge, information, and data. Each unit can produce information (services) to other units in order to achieve system goals [4] and provide concrete collaboration as a fractal approach [12]. The connection way and interaction between those units, as agents, keeps continuance to the system, because it depends on the ways of disseminate information between its units (agents) [31].

The important benefit of the fractal system is maximizing information flows and stores between fractal units [13] as shown in Fig. 3 [17]. The information flows and stores are done in many ways, such as information flows inside the fractal itself, information flows between the same level fractals, information flows between different level fractals, and information flows between fractal entities and external environment [12].

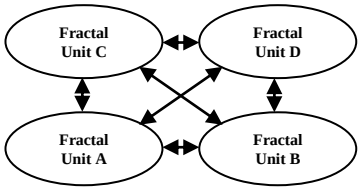

Fig. 3 Method of information transmission between fractal units

The information flows between fractal and external environment are used for increasing the collaboration characteristic between fractals. The style of this collaboration is used depending on the six specific levels of the work environment: culture, strategic, socio-informal, financial, informational, and technological [12]. The general model of collaboration in any system is illustrated in Fig. 4 [33].

In 2008, Kirikova has extracted some guidelines for adapting fractal approach to develop information systems. These guidelines are summarized in Table 2. He has mentioned that the important features of adapting any system as a fractal are self-similarity, self-organization, goal-orientation, and dynamics and vitality [4]. However, the researcher is pulling the fractal approach in an information system domain in general with weak evidences of practices.

In order to strengthen the evidences, Kirikova has used fractal approach in an information system to achieve flexibility of information architecture. The previously discussed research was focused on the educational institution units at a university. The structure of these units is same and organized in different scale as a fractal structure from bottom-up, like department, institute, faculty, and then university as a top unit [28]. In this structure, the high level acquires information from low level. Fractal features were used in the previous work in order to develop fractal information system. It was used self-similarity as each unit has similar knowledge structure. Self-organization was used to represent software procedures in each unit. Moreover, dynamics and vitality feature was used to monitor any change happens in the fractal entity. This change means changing the tacit knowledge to the explicitly knowledge and propagating this change to all other fractals, especially in the information architecture. Tacit knowledge is achieved by internal individual processes and stored in human beings, while explicitly knowledge is stored in the computer device, such as databases [33]. The purpose of the previously discussed research is to ensure integrity of the information from losing when any system change happens [3]. However, the researcher discusses a fractal approach in general for propagating information between fractals at different levels. Otherwise, the details of collaboration between system units at same level and external environment didn't mention.

In other viewpoints, the main goal of cooperation environment in any system is to enhance the members' skills, because individual work often doesn't have enough experience to satisfy all requirements [34]. Then, Stecjuka and et al have proposed a fractal model to select the best practices, such as an annual report of scientific activities of institutions in university, and propagating these practices between fractal units in the same level. This kind of cooperation between fractal units has been used in order to improve the skills of operation by acquiring new knowledge [28]. However, the previously discussed research is focused on some fractal features and needs more researches in order to investigate integrated fractal information system.

In the HISs, a hospital information system can be considered as a fractal system if it has autonomous units connected through the self-organization and self-similarity feature [14], [31].

To this end, integrated fractal information system is a system that has fractal features, such as self-similarity, self-organization, goal-orientation, navigation, and dynamics and vitality [9], [12]. This system consists of decentralized and individual fractal units [9]. Each fractal unit can be represented as an agent [26]. The cooperation between those agents is an important action in the fractal information system in order to get a whole system goal [12] and improving operations [28]. However, depending on the current literature and previous studies, only few researchers have used the fractal approach in information system domains. These researches used fractal approach only within the enterprise and university environments [3] and still they are in early stages. In addition, it has been found that there is rarely researches used the fractal approach in the healthcare environment. Therefore, this work presents the use of fractal features in the HIS. The use of fractal approach will lead to a structure that is more flexible and adaptable to any system changes as well as improve the collaboration between system units.

	Same Time	**Different Time**
Same Place	Face-to-face collaboration (Synchronous)	Asynchronous Collaboration
Different Place	Distributed Synchronous Collaboration	Distributed Asynchronous Collaboration

Fig. 4 Collaboration of working model

TABLE 2

SOME GUIDELINES FOR USING FRACTAL APPROACH IN IS ENVIRONMENT

No.	Guideline
1.	The fractals of IS should correspond to the fractals in its environment, therefore fractal properties of the IS environment should be analysed in terms of common and individual properties of business units, feedback mechanisms and mental models exposed by requirement holders.
2.	A bottom up approach may be used in identification and design of IS fractals.
3.	Once the potential fractal structure at some dimension is discovered the knowledge, information and data feed forward and feedback links must be identified so that lower level fractals could be nourished by information emerging in larger granularity fractals, and larger fractals would receive all information needed for the overall management of the business system. In other words forward and backward knowledge chains in the fractal IS should be introduced to ensure knowledge and information circulation in the system.
4.	In IS design process the following principles relevant in adaptive complex systems should be applied: • Maximize the relationships between enterprise members and the outside • Foster relationships between areas of people within the design process • Maximize the information flow • Promote heterogeneous participation and its balance in design decision making.
5.	At a conceptual level, introduce IS routines that can identify the need for restructuring the system in terms of procedural/service subsystems, data structures, and communication patterns.

IV. FRACTAL NATURE IN HIS ENVIRONMENT

The structure of the healthcare organizations in many countries is distributed. These organizations contain individual centres that supported by autonomous information systems, such as hospitals [35]. Healthcare Information Systems (HIS) were presented into hospitals since three decades ago. It helps physicians, nurses, and administrative staff in their works [36]. Then, these HISs have been rearranged for different departments and services of the healthcare organizations. They are organized in the hierarchical structure in order to achieve a cooperation environment. The data flow in such structure is bottom-up. This flow starts to aggregate data from autonomous units, such as laboratory tests, general practitioner, and ambulatory, etc. at a hospital level; then, accumulate these data from different hospitals at a state level to support central government level [35]. However, this strategy of work has been done as warehouses in order to share patients' information between system units [6]. Traditionally, the HISs have been focused only on the disease that contains patient data within a limited range of functions, such as laboratory tests. Recently, the collaboration approach among healthcare units becomes an important issue in order to create multi-expert care teams [37].

On the other hand, the fractal approach has been used by many researchers in modelling many systems at different areas in order to achieve flexible structure and concrete collaboration between system units [2], [32]. As many examples depicted in the previous sections, cooperation feature of fractal method leads to enhance the members' skills. Moreover, new system requirements will emerge in the collaboration healthcare environment over time [37]. These requirements need to maximize information sharing among participations, such as physicians, for providing information in an appropriate and timely way. However, current HISs are weak in information circulation process between system units at a time [6].

The features of the fractal approach have been successfully used to increase flexibility of a system and rapidly adaption to environmental changes in many fields. Therefore, in this work, we propose a conceptual framework for integrated cooperative HIS based on fractal approach, as shown in Fig. 5.

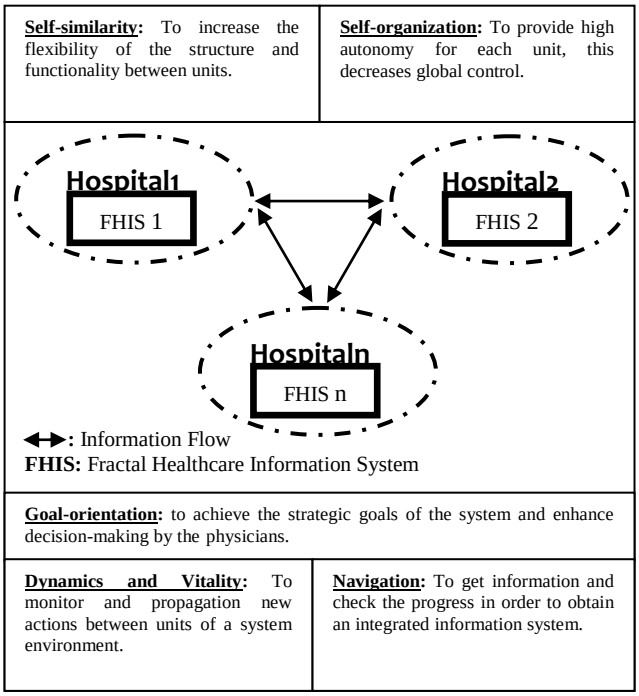

Fig. 5 Fractal features in HIS

V. CONCLUSIONS

The communication and coordination between units in any distributed system is an important issue in order to circulate and updating information between these units in a quick fashion. The features of fractal method can provide suitable flexibilities and collaborations between the units in most distributed systems. Therefore, the fractal approach has been used by many researches in order to get concrete cooperation environment. Identification features of this approach in any system leads to make this system more flexible and quick adaptive to any environmental changes. The HIS, as any distributed system, would be more flexible with inspiring the features of fractal method. Depending on the current literatures and previous works, this work deploying fractal features to healthcare information system. The units of this system have modules. The details in-depth of these modules delayed for further researches. This new method of inspiring fractal approach in the HIS environment is in itself worthy of scientific interest.

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