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New Evolutionary Approach to Business Process Model Optimization

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***Abstract*-In today competitive business world, organizations and enterprises need to manipulate their business processes. The real key to be successful in these organizations lies in proper business process design and management. Concentrating on business process optimization and improvement, enterprises can achieve reduced costs, increased quality of products, raised efficiency of products, adapting with requirement changes, and they will flourish in this competitive environment. Since more than one objective is involved in business process optimization, multi objective optimization can be used appropriately. In this paper we proposed an evolutionary approach to optimizing business process model. Proper effective operators to generate new models are suggested as well.**

***Index Terms*-Business process (BP), BP optimization, BP modeling, multi-objective optimization, Genetic algorithm**

I. Introduction

Doubtless, business process plays an important role in enterprise progress. Hence, process modeling is one of the most essential steps in advanced enterprises. In addition, generating application and information systems are strongly dependable on the business process modeling. Many attempts have been made on creating variety of process modeling techniques, different notations, methods and tools each of which views process modeling in particular way and contains its specific semantic concepts.

There exist different modeling approaches that undertake different aspects of a business process. Among those, few methods are able to analyze quantitatively and optimize a business process [5]. Modeling techniques can be divided in three different groups, mathematical models, business process languages and graphical languages that have been elaborated completely in [5]. On the basis of being graphical model and having been supported by a strong mathematical background, petri net is apt to be better option to be optimized. Business process analyzing has no value if it cannot help to improve or to optimize a business process. An ideal approach toward business process is, capturing a business process and providing appropriate tools to identify bottlenecks and to evaluate the performance and finally generate optimized business process based on specific objectives. However, the last part is usually overlooked if not completely disregarded. We are convinced to use efficiently this view, multi objective optimization, in the area of business process as it has been researched and analyzed in variety of computer science NP-Hard problems and it shows promising results. The rest of the paper is organized as follows. Section two provides some related works and methods.

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Section three describes some key concepts and contains business process modeling with petri net. Section four presents a new approach in business process optimization by genetic algorithm. Finally, section five concludes the paper.

II. Literature Review

There are different definitions of business process in business process literature that each one regards only a part of business process that correlated with analyzing, evaluating or modeling. Therefore, there is no commonly agreed definition. Some of definitions are too general that cannot consider all aspects of a business process [2] such as Harvey's definition which proposed in [3] "step by step rules specific to the resolution of a business problem". Another definition exists from Hammer et al [17] - "a business process is a set of processes that receive one or more inputs and generate a valuable output for customers," and recently in [18] a new definition has been described with this implication, a set of activities and resources if has been sequenced properly, can do a business transaction. Other definitions can be found in [10, 19, 20] as well.

According to Volkner and Warners in [4], since business process modeling organizes a process and analyzes current and alternative activities comprehensively and systematically, business process modeling is indispensible.

Zho and Chen in [8] proposed that business process optimization leads to reduced process completeness time and running costs, as well as increasing quality of products and customer satisfaction. With this outlook, quite literally an organization can acquire the competitiveness advantage which it was looking for.

Based on Moon and Seo in [9] the most attractive property of evolutionary algorithms is its flexibility in utilizing different objective functions with less mathematical requirements. In addition, Vetschera and Hofacker [6] have put in some effort to optimize a buesinss process with genetic algorithm, but as their method mainly depends on various mathematical formulas and has required a great deal restrictions, feasible solutions were hardly produced. However, Tiwari et al [13] and Vergdis et al [11] expanded this mathematical model and proposed a multi objective optimization algorithm that has been reported satisfactory results which opened promising researches as future works. Afterwards, Tian et al in [12] suggests four types of evaluation criteria including execution time, cost, throughput and queue length by analyzing and examining different optimizing parameters based on static and dynamic configuration. Valiris claimed that most of business process reengineering methods lack a formal confirmation that makes us ensure the generated model is the most suitable one for business process [7]. Therefore, need to a systematic approach that software redesign can have an appropriate model with following some steps, convinced researchers to propose new methods to find optimized business process models. There were some prior approaches in order to set up business process redesign projects, but, developing a design and generating an optimized design was largely left to the designer intuition [15]. Thus, regardless of the approach that has been opted to design a business process couldn't be the best one. At least we couldn't have an absolute certainty on the generated design.

In this paper by using petri net and on the contrary with [21] which has just only considered two parameters , time and cost , a vector of criteria such as time , cost , quality of products and queue length has been taken into account. After modeling a business process, a mathematical structure for its optimizing is provided and then by utilizing evolutionary algorithm an optimized design is created. The process of modeling by using petri net will be detailed in the subsequent section.

III. Business process modeling with petri net

There is no doubt over the role of business process in business environment; therefore, business process modeling is one of the most important steps in business process development. In the organization's viewpoint, there exist different objectives for business process modeling- Modeling to documentation, running, etc. However, the output was constantly a business process model in a certain form regardless of the objectives [1]. For instance, some of the extensively used modeling approaches are BPEL4WS, BPMN, UML, EPDL, EPC, and WSDL. Among these, petri net has been used widely in the business process area. Based on using two simple notations, transition and place, petri net strongly supports the definition was proposed in [18].

Some of the least not the last important reasons that have been taken into account to use petri net in proposed algorithm are:

1- To preclude optimizing a business process model with some semantic error such as dead lock and live lock.
2- Petri net among graphical models methods, just by using two notations and also being intuitively graph oriented made it suitable to use in our new algorithmic optimizing approach.
3- Possessing a mathematical and graphical presentation which helps us in offering a formal mathematical presentation for optimization.
4- State-based diagram rather event –based diagram.
5- Many tools and analyzing techniques proposed beforehand to support it.

A petri net (PN) is a triplet of (P, T, φ) that P is a finite set of places and T is a finite set of transitions and φ is a mapping function $\varphi:(P \times T) \cup (T \times P) \rightarrow N$. A firing is a mapping from $\mu: P \rightarrow N$. In other words, μ allocates each token to a specific place in network. In visualized form, a PN is a direct and twofold diagram that is combined of two nodes, places (that is shown with circle and each black point represents a token) and transitions (that is represented by bars or boxes). Each Arc is connected from a transition to a place and vice versa, and an arc is interpreted as a $\varphi(p,t)$, $\varphi(t,p)$ that p and t are beginning and ending of an arc respectively.

Therefore, a PN design is represented as below:

Business process modeling structure

$$PD = \langle T, P, V \rangle \; \forall t \in T \quad \exists \quad v_i \propto t \qquad (1)$$

Where T is a set of n transitions $T=\{t_1,t_2, \dots , t_n\}$ that consists of two different types of silent and labeled transitions. P is a set of m places $P=\{p_1,p_2, \dots , p_m\}$. Besides, each transition t_i is assigned with a vector by K parameters $v_i=\{v_{i1},v_{i2},\dots,v_{ik}\}$ that contain evaluating parameters such as Time , Cost , quality of products and queue length and etc. Since some of these parameters depended on each other oppositely, such as time and cost, identifying optimized design is a difficult task, so that multi objective optimization instead of processing and considering one design at a time can properly analyze and process a set of candidate designs. Sets, I_i and $O_i \subseteq$ P are input and output of each transition respectively. As optimizing parameters haven't identical value, a weight vector $\omega = \{\omega_1, \omega_2, \omega_3, \dots, \omega_k\}$ assumed in business process models so that $\sum_{i=1}^{k} \omega_i = 1$. A sample process that shows itinerary process has been modeled by petri net in Fig. 1.

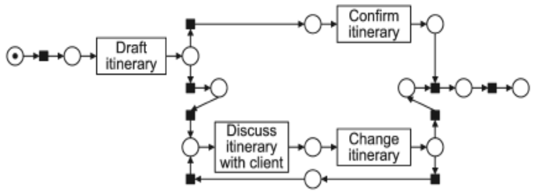

Fig. 1. Petri net model for an itinerary process

IV. Proposed algorithm

In most of optimization applications, evolutionary approaches outweigh the classic approaches which process a single solution in each step because of processing a population of solutions at each step. Evolutionary approaches are being used widely to solve scheduling problems, to find pareto and best solutions in science, business and engineering, etc. In area of optimizing business process design, it can take advantages of evolutionary methods. Hence, provided model by petri net with assigned vectors is captured as an input in this approach and an optimized model with some alternatives will be produced as results.

In this method, each chromosome represents a different design of a business process. Each of design's activity uses a set of alternative implementations. Due to this cause, genetic algorithm makes it possible to provide a best choice of activities sequences and proper implementations.

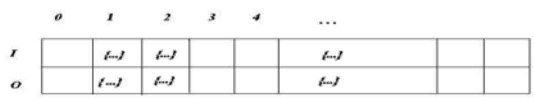

Fig. 2. Chromosome representation for a business process design

In other words, in a huge business process, there are many different implantations of each activity so that human designer will be confused within different order of implementations and activity sequences. Fig. 2 illustrates the structure of chromosome that has been used. In this model we used two dependable structures, a vector to represent the design and a matrix to exhibit the evaluation criteria. In design representation we used a vector with two rows (Fig. 2), the former contains input sets for each transition and the latter contains output set as well. Besides,

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the number of columns is equal to the number of transitions and since all these numbers can vary from a design to another, this aim just can be carried out with dynamic structures.

For instance, Fig. 2 can display a chromosome that is a part of a huge petri net which fifth entry in this structure represents in Fig. 3. This should note that we use an identical evaluation structure for a design, but a sample design can hold this evaluation structure with different size and values. For example, Fig. 4 illustrates a design with 5 transitions and 2 types of different evaluation parameters, time and cost. During the running genetic algorithm by applying different types of operations to manipulate chromosomes the number of transitions may increase or perhaps decrease. Hence, this structure has to be considered dynamically. In this paper, instead of using classical genetic algorithm operations, cross over and mutation, we proposed two novel operations, parallelization and merge operations respectively, that can be properly adaptable with this structure and method.

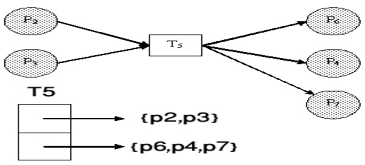

Fig. 3. Evaluation structure in a chromosome

	Time	Cost
T_0	3	70
T_2	5	60
T_3	:	:
T_4	:	:
T_5	:	:

Fig. 4. Forth element in a chromosome

a. Parallelization operation

First operation is parallelization. In some cases, dividing an enormous estimated high cost activity located in bottleneck, into some paralleled activities that all have same input and output, definitely leads to less running time and accelerates the whole process performance and efficiency. For example, after performing parallelization operator in Fig. 3, the structure will alter to the Fig. 5.

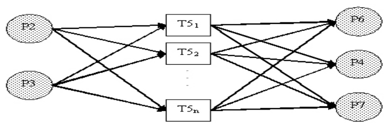

Fig. 5. Parallelization operator on Fig. 3.

In this operator with the number of produced transitions we add rows in evaluation structure and all its values will change based on the following expression (2). In addition, equal to the number of produced transitions we add columns in new structures – chromosome structure, and all input sets are changing similar to the transition T_5 in Fig. 5. Also the mentioned expression has to be achieved between paralleled transitions. Therefore

$$T_j . I_j = T_{j,1} . I_j = T_{j,2} . I_j = \ldots = T_{j,n} . I_j$$

Where I_j is the input of transition j and $T_{i,1} \ldots T_{j,n}$ are the generated transitions by applying parallelization operator. Moreover, the following equation should be satisfied in order that we keep the efficiency of produced transitions.

$$T_{i,p} \bullet V_i[Time, \ldots] = \lambda\, T_i \bullet V_i[Time, \ldots] \quad (2)$$

$$0 \prec \lambda \prec 1 ; \quad p \prec n$$

$$\lambda = \frac{T_{i,p} \bullet V_i[Time, \ldots]}{n}$$

That represents row i in parent chromosome structure has to be λ times of the same row in offspring. Due to the fact that, we're not allowing parallelizing each chosen transition, before starting optimization phase, we should have determined all the restriction and restrains regarding which transition might be parallelized. Because, in some cases, some of the activities in activity diagram are atomic and we're not allowing to parallelize or to perform any changes so that these activities have to be immutable in petri net models. We used two transition labels, silent and labeled transitions, to determine the difference between changeable and unchangeable transitions.

b. Merge operator

Second operator is merge operator. The main aim of this operator is to merge two or more activities, by doing which, helps to reduce the running time and also time required to complete the whole process. The process of firing tokens takes time, therefore by merging these transitions we can save time during this firing process. For example, in Fig. 6-b by combining two transitions T_1 and T_2 and creating T_{12}, practically, the intermediate place has been removed (Fig. 6-a).

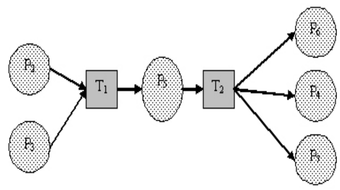

Fig. 6-a

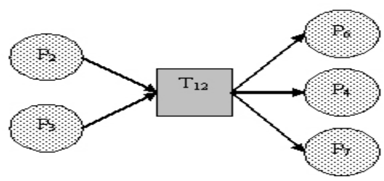

Fig. 6-b

Furthermore, the merge condition between transition i and j is $T_i \bullet O_i = T_j \bullet I_j \;\; i \neq j$

that illustrates the output of transition i has to be the input of transition j. In this case these both transition i and j are combinable.

c. Fitness function

After studying thoroughly different fitness functions, the subject that was neglected in previous researches in this area, to find optimized design in business processes such as: aggregating function, dominance relation, relaxed form of the domain relation and other approaches that you can find a list of them in [22]. We figure out that we'd rather use combination methods. Since each of these approaches was proper for a different class of optimization problems and complex nature of business process mathematical models impose us to find a combination approach to determine pareto solutions. In this approach each of the chromosomes represents a directed graph petri net model. Therefore, by calculating the critical path or longest path of the petri net within this graph, the total measure of this chromosome will

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be evaluated as well, so that for each of the transitions has been met in a specific path, the total value of the transition is measured as in (3),

$$C_{t_i} = \sum_{j=1}^{k} \omega_j \vartheta_{ij} \quad (3)$$

and if the $path_i$ consists of m transitions, then,

$$C\,(path_i) = \sum_{i=1}^{m} c_{t_i} \quad (4)$$

The aim of this fitness function is to find chromosomes which obtain lowest critical path in their petri net model.

After accomplishing superior chromosomes by using this combinational fitness function, next loop will start in genetic algorithm routine till the stop condition is encountered. Finally, by using the optima and alternatives chromosome's structures we can produce the phenotype of optimum design.

V. Conclusion

In this paper we proposed a novel algorithmic approach to optimize business processes modeled with petri net. As business process has a key role in enterprises, determining optimum models is irrefutable. Since variety of issues are involved to determine an optimum model such as cost, time, quality of products and etc, genetic algorithm has been utilized efficiently in this paper. Besides, proper operators with their mathematical restrictions to manipulate chromosomes and generate new offspring have been suggested.

Based on the promising theorical results we obtained through this method, in the future, we can apply this method on real practical applications and the results thus obtained can be used to compare with those obtained through other genetic algorithm methods such as SPEA2 and NSGA2. Also, automatic tools can be developed for providing optimum models within a framework that analyze and evaluate business processes.

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