Towards a comprehensive business process optimization framework

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***Abstract*—** Business processes are a collection of related, structured activities performed to achieve a defined business outcome. Adopting a business process perspective is an essential advantage for organizations to orchestrate and achieve continuous improvements on time and within specified resource constraints. The increased popularity of this domain, however, has resulted in a variety of interdisciplinary approaches with limited tangible, quantifiable –and thus measurable- benefits. Operational Research (OR) has critically evolved during the last decades, providing businesses and organizations with problem-solving techniques and methods aiming to enhanced performance and improved efficiency. The proposed project focuses on the development, evaluation and verification of a business process optimisation framework as the central objective of the PhD Thesis. The performed optimisation is intended to use Evolutionary Computing (EC) techniques, as they have been used effectively in a variety of similar problems. The author seeks advice and feedback on the optimal theoretical foundation of the framework, the utilization methods adopted (i.e. in the area of continuous and discrete computational optimization) and the method selection for performance analysis and validation. Furthermore, guidance from experts on the field will decisively influence the PhD Thesis, through directing its orientation to current research trends and future opportunities.

Keywords— business process; combinatorial optimization; business process intelligence; web services; evolutionary algorithms

I. INTRODUCTION - MOTIVATION OF RESEARCH

Business process optimisation is the *automated* improvement of business processes using pre–specified measures of performance (objectives). The importance of business process optimisation lies in the ability to (re)design a business process based on quantitative evaluation criteria. This concept stresses the need for alternative business process designs to be quantitatively evaluated and compared. It also offers the advantage of generating various designs based on the same process requirements. One of the latest trends in business process composition and optimisation, that motivated the author's research, is the employment of web services (i.e. a discretely defined set of contiguous and autonomous business or technical functionality implemented over a network) as the structural elements of a business process design. The intended process optimisation can be performed through Evolutionary Computing (EC) techniques, e.g. Evolutionary Multi-Objective Optimization Algorithms (EMOAs), as they have been successfully applied to several combinatorial problems and demonstrate a series of benefits. One significant advantage lies in the gain of flexibility and adaptability to the task in hand, in combination with robust performance and global search characteristics. Lastly, a section of the PhD research will investigate the potential benefits of the incorporation of pre-processing stages in the execution process of evolutionary optimization algorithms through analyzing experimental results.

II. RESEARCH AIM AND OBJECTIVES/GOALS/QUESTIONS

Despite the potential of a multi-objective optimisation approach for business processes and the recognition of its benefits by the service industry, the limited use of such approaches by organisations, is observed. To address this situation, additional research activities are required that push research by addressing its limitations. There is a need to extend representation and enhance existing state-of-the-art frameworks [1], to fully address the needs of real-life business process optimisation. The research activities for future elaboration of business process optimisation frameworks are:

- To test existing frameworks for more than two objectives.
- To examine the appliance of existing optimisation frameworks on web services, which are in accordance with the Service-Oriented Architecture (SOA) concept that is already popular within the Service industry.
- The influence of the various process patterns can be measured in the calculation of the attributes, and be considered in design optimisation.
- Existing frameworks could embody pre-processing stages that could potentially result in positive effect, through producing more non-dominated solutions in reduced time frames.
- The elaboration of existing frameworks could incorporate process execution feedback (historical data) to refine/optimise a business process design.
- The research in business process optimisation can also move towards the direction of execution flow optimisation and automatic process modification. Execution flow optimisation is the notion of deciding the optimum path for a business process during its enactment (execution). Automatic process modification is the real-time composition of a business process design according to specific needs. The optimum process design can be created, based on the selection and combination of different alternative web services scattered over a network.

Based on the above, the notion of business process optimisation has a potential growth with direct benefit to the business process community and there are still several research activities to be addressed.

III. BACKGROUND/RELATED RESEARCH/LITERATURE REVIEW

IT-controlled business processes are essential parts of modern organizations that motivates why business processes are required to efficiently adapt to these changes in a quick and flexible way. This requirement suggests a more dynamic handling of business processes and their models, moving from design-time business process models to run-time business process models. Many mathematical approaches aiming to business process description and modeling have been developed in the last decades. The most popular include Integration Definition (IDEF), Petri nets, Event Process Chains (EPC), Role Activity Diagrams, Computer Integrated Manufacturing – Open System Architecture (CIM-OSA), Resource-Event-Agent (REA), Business Process Modeling Language (BPMI) and Object-Oriented Modeling. These standards were the basis for developing various tools for business process modeling (ARIS, FirstStep, PrimeObject, etc.). Zakarian [2] integrated the Fuzzy-rule-based Reasoning Approach with IDEF in order to extend the quantitative analysis of the process model. Grigori et al. [3] proposed the Business Process Intelligence, a tool which uses data mining methods for the analysis of business processes.

A methodology for business process improvement is only as good as the tools and techniques that support it [4]. However, relevant literature restricts itself to descriptions of the 'situation before' and the 'situation after', giving very little information on the redesign process itself [5]. While there are several methodologies for structuring business process redesign projects, the task of developing optimal designs of business processes is left to the designer's intuition [6]. Zhou and Chen [7] remark that there is still no systematic optimisation methodology for business processes and suggest that business process optimisation should aim at reducing lead–time and cost. Recently, there are few attempts reported in literature to combine performance evaluation and process optimisation. Regarding the latter, there are some successful attempts reported, but they are highly complicated and yet address only simple sequential business processes. Operational research has evolved algorithmic approaches and task consolidation methods to optimize a business process. In diagrammatic models such as Petri Nets, other techniques (e.g. graph reduction) are applied for optimisation purposes. Despite the fact that these techniques have a positive outcome for the process, many authors ([8],[9]) highlight the reluctance of analysts to use them as they are discouraged by the method complexity, the work needed for preparation of the mathematical model and the difficulty in comprehending and interpreting the results. Extensive research resulted in the development of multiple algorithms for optimization of business problems in the area of logistics [10], due to the fact that most business models are insufficient for multi-criteria analysis. McKay and Radnor [11] introduced a model for the description of business processes which, however, did not include any formal optimization methods. Most scientific work on business process optimization tended to focus on selecting the suitable process model, or on one-dimensional optimization [6] which was insufficient. A distinct problem orientation, though, requires the differentiation of optimization types:

• Single-criterion optimization: if the ideal state depends on a single evaluation criterion;

• Multi-criteria optimization (vector optimization, poly-optimization): if reaching the ideal state depends on multiple evaluation criteria.

A multi-criteria evaluation of an optimal state often results in discrepancies between them. This signifies that the solution looked for does not reach the extreme values of all criteria considered separately. Instead, it provides some kind of compromise between them. Therefore, the poly-optimization problem consists primarily in defining that compromise. In multiple cases, the heuristic knowledge about the process improvement, leads to the introduction of another, substitute criterion in search of the composite solution. This perception,

along with the multiple optimisation methods, modelling techniques and industrial focus has led researchers to holistic frameworks [1], and evolutionary approaches [[12], [13]].

IV. THESIS AND PROBLEM STATEMENT

The problem statement for the research of the PhD Thesis derives from the objectives, as introduced previously. The overall research aims to progress in the direction of intelligent method and evolutionary technique implementation for tackling issues related to business process optimisation.

The development of a holistic optimisation framework poses a number of variant challenges. It requires a modelling or representation technique that can capture the main features of a business process and express them in a way amenable to optimisation methods. It assumes an algorithmic approach to compose new business process designs and a quantitative measure of evaluating them. Another key area is the design of business processes with a range of alternative web services that can lead to the generation of a range of equivalent business process designs. Following, the thesis intends to introduce EC optimisation techniques –that have been efficiently applied in other optimisation problems– and apply them in the context of business processes. During the optimisation procedure the author intends to investigate the value added by preprocessing stages that reduce execution constraints such as calculation time, and improve performance.

V. RESEARCH APPROACH AND METHODS/RELEVANT RATIONALE

The research approach is divided in distinct sections, each one following specific methodology and rationale.

- *Literature Survey:* An extensive literature survey is carried out to present and discuss the current state of research related to business processes. Once the main subjects are selected the literature research involves the investigation of books, peer reviewed journals and on-line articles in order to obtain in-depth knowledge. This assists in attaining a clear understanding of the existing work and the level of any related business process optimisation approaches along with their strengths and weaknesses. The methodology adopted throughout conducting the survey, involves the consideration of review typologies ([14], [15]) and the appliance of systematic literature review practices ([16], [17]).

- *Service industry survey:* The context of this work is the service industry and a relevant survey could help in grounding the research within the industrial context. Companies that belong to the service industry can be surveyed to investigate their business process related activities with main focus any improvement/optimisation initiatives. The survey will be carried out through industry visits and on-line questionnaires for collecting information from related experts. As for the adopted research methodology, the questionnaire is intended to be partly survey-based and partly fully-structured [18], and will be divided into modules as proposed by Oppenheim [19], with each module concentrating on one concept or variable.

- *Development of business process representation technique:* This research should develop a representation technique to correct flaws in existing business process modelling approaches for multi-objective optimisation. The incorporation of web services as input elements will also be examined. Based on the findings and the optimisation focus of this research, the aim and objectives of the proposed representation are defined.

- *Development of the proposed optimisation framework:* The optimisation framework will employ existing state-of-the-art evolutionary multi-objective evolutionary algorithms (EMOAs) to achieve the optimal generation of business process designs based on specific process requirements. The author aims to enhance the framework's performance with the introduction of preprocessing stages executed in a timely manner.

- *Experimental business process scenarios & performance analysis:* In order to assess the optimisation framework in a systematic way, it is essential to devise a strategy for generating experimental business process scenarios.

- *Validation using real-life business process scenarios:* A set of real-life business process scenarios reported in literature will be tested within the proposed framework.

VI. RESULTS TO DATE AND THEIR VALIDITY

The author has co-authored the paper 'Evolutionary Multi-objective Optimization of Business Process Designs with Pre-processing' that has been accepted for presentation at the IEEE CEC 2017 and for publication in the conference proceedings published by IEEE. Due to the complexity of the overall problem, the author examined a possible extension of the BPO framework [20] with an additional stage: the pre-processing of the library of available tasks according to the solution requirements in an attempt to lower the problem complexity and enhance the performance of the EMOAs. The main objective of this stage is to remove the redundant tasks from the library of tasks, reduce the available resources and scale down the overall input problem. Through analyzing the benefit of the pre-processing stage, the author investigates the possibility of incorporating this stage to a final framework.

Moreover, the author is awaiting approval for participation in a project plan for the development of a software tool under the name 'Web Business Process Optimiser (WebBPO)'. The project was designed and will be implemented, upon approval, by a research team comprised by members of the business

process intelligence unit, department of applied informatics, University of Macedonia, Thessaloniki, Greece. The main output of the project is the extension of a framework that models appropriately business processes as sets of independent tasks and utilises evolutionary optimisation techniques to compose and generate optimised business process designs based on multiple evaluation criteria. There are two innovative elements in the WebBPO. The first is the focus on business processes that are exclusively composed of web services (web business processes). This orientation is in accordance to SOA that the majority of the service industry is currently following [8]. Creating an optimiser towards this direction, facilitates the transition to using web services having tangible benefits such as cost reduction and increased quality of execution. The second innovative element is related with the use of evolutionary optimisation algorithms in business process optimisation.

VII. GENERALIZATION AND VALIDITY

There is a variety of research strategies that can be used to collect the data necessary to answer the research question. The method of research chosen depends on the nature of the enquiry. According to Robson [18], research strategies are divided to:

- fixed design strategies, that require tight pre-specification before data collection; also known as quantitative strategies and
- flexible design strategies, that evolve during data collection; also known as qualitative strategies.

Business process optimisation falls under the category of quantitative research (fixed design strategy). To assess the capabilities of the proposed framework and the extent that these contribute to business process research, the performance of the framework and the generated business process designs need to be quantitatively measured and evaluated. Fixed design strategies are theory-driven and therefore they require sound theoretical justification. A traditional approach to quantitative research is the experimental strategy adopted through experimental business process scenarios and performance analysis. This extended dependence on performance analysis of collected data, limits the generalization of the approach.

According to Wieringa and Daneva [21], the research generalization can also be categorized to lab-to-lab and lab-to-field generalization. Each of these can be performed in two ways:

- In case-based generalization, one studies individual cases, and generalizes about components and mechanisms found in a case, by similarity.
- In sample-based generalization, one studies samples of cases, and generalize about statistical properties of these samples.

The object of the PhD study is an optimization framework that resembles an artifact in a context of use, as is in engineering sciences. During the process, the artifact is scaled up to practice and generalizations are increasingly targeted at field conditions. Lab-to-field generalization is a form of technology validation with research methods such as simulation, technical action research, and statistical difference-making experiments in the lab or in the field [22]. Thus, the PhD study falls under lab-to-field generalization and will be performed mostly in a case-based practice, as the framework implementation on specific scenarios will lead to generalizations about the mechanism, by similarity.

VIII. STATUS OF WORK AND NEXT STEPS

The PhD research is at early stage. The hitherto conducted literature review discusses the emergence of the term ‘business process’ and the many different approaches varying in both level of insight and perception. This section introduces and discusses a selection of the most representative definitions in an attempt to highlight the most comprehensive and solid approaches, as many authors orient business processes towards their preferred direction without taking into consideration the innate broad perspective and applicability of business processes. As an outcome, the authors propose a comprehensive definition that takes into account the most usual conceptual terms of the selected state-of-the-art definitions. Following, the authors present the structural elements of a business process and their interconnections based on the relevant literature findings. In contrast to the different business process definitions and approaches depending on the authors’ area of interest, the basic elements of a business process structure are perceived and described in similar terms. The section concludes with a proposed alternative perception of the structural elements of a business process and the way they are interconnected, based on a fragmentation of pre, post conditions from the actual process.

Later on, the author highlights the necessity of managing business processes for every organization. This challenge has raised the interest of many cross-sectional communities such as academia and organizational experts leading to many approaches in the last decades. Successful companies organize and implement their business processes effectively to complete them on time and within the specified resource constraints. Business Process Management (BPM) has developed as a combination of disciplines that consider a process-oriented approach as the one necessary and suitable for significant improvements of compliance and performance of a system [23]. This process-based approach improves customer focus and avoids the limitations of managing by vertical functions, while measures and opportunities for improvement are more convenient to identify [24]. Many empirical researchers have underlined this positive outcome of BPM, through identifying critical success factors [[25], [8]] and theoretically grounding their findings [26].

The literature review encompasses an analysis and comparison of BPM definitions from the most influential researchers on the field. The comprehension of the different terminologies and features of BPM requires the appreciation of what is referred to as BPM lifecycle [27]. As a result, the author introduces BPM lifecycle approaches provided in literature along with their methods and techniques, to realize and detect the optimal ones. The next step of the composed research involves the evaluation of the different techniques available for business process modeling, analysis and optimisation, as introduced in BPM lifecycle. Further on, the author intends to test the appliance of optimisation techniques on business processes composed of web services, and also incorporate the pre-processing stage at the final optimisation framework.

IX. CURRENT AND EXPECTED CONTRIBUTIONS

The main contributions to knowledge that emerge from the developed literature review are:

1. A comprehensive definition for business processes that considers the most influential approaches on the field;
2. A systematic evaluation of appropriate elements aiming to a contemporary business process design;
3. The 'building blocks' approach that describes the business process elements interrelation;
4. A thorough analysis of BPM definitions with an alternative comparison based on focus areas;
5. An enhanced BPM lifecycle with a quantitative orientation in both methods proposed and techniques selected. The outcome is a novel perception of BPM lifecycle with multi-layer construct that highlights the interrelation of steps during execution.

The accepted conference paper, under the title 'Evolutionary Multi-objective Optimization of Business Process Designs with Pre-processing', introduced:

1. A framework implementing an effective quantitative representation for business processes;
2. An evolutionary algorithm that composes feasible process designs;
3. A series of optimization algorithms that generates diverse optimized designs; and
4. The incorporation of a pre-processing stage for business process optimization problems.

The results have demonstrated that the framework with the aid of the pre-processing stage has increased its capability of generating diverse designs and selecting those with optimal objective values for business processes in less time.

The aim of the overall research is the redevelopment of an existing state-of-the-art framework for business process optimisation capable of:

1. Representing business processes in a quantitative way;
2. Composing business process designs with the use of algorithms with specific requirements;
3. Identifying the optimal processes utilizing the evolutionary multi-objective optimisation algorithms (EMOAs);
4. Incorporating pre-processing stages during execution; and
5. Testing the application of the developed framework on business processes solely composed of web services.

Following the framework composition, the author will further examine its capability in assembling, representing and optimising business process designs with real-life scenarios. Through proposing a classification of business process automation the research will utilize the concept of web services as process tasks compiled in libraries. The author intends to test the framework's ability on producing alternative optimised business process designs out of web services. This contribution would ascertain the validity of the final framework, and at the same time be in accordance with the latest trends of business processes implementation.

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