Applied Soft Computing 12 (2012) 2638–2653

Contents lists available at SciVerse ScienceDirect

Applied Soft Computing

journal homepage: www.elsevier.com/locate/asoc

An evolutionary multi-objective framework for business process optimisation

Kostas Vergidis, Dhish Saxena*, Ashutosh Tiwari

School of Applied Sciences, Cranfield University, MK43 0AL, UK

ARTICLE INFO

Article history:
Received 19 February 2010
Received in revised form 10 February 2012
Accepted 11 April 2012
Available online 24 April 2012

Keywords:
Multi-objective optimisation
Business process optimisation

ABSTRACT

This paper aims to investigate the application of evolutionary multi-objective optimisation to the new domain of business process optimisation. Business process optimisation is considered as the problem of constructing feasible business process designs with optimum attribute values such as duration and cost. The feasibility of a process design is based on: (i) the process requirements such as the required input and the expected output resources and (ii) the connectivity of the participating tasks in the process design through their input and output resources. Due to the multi-objective and discrete nature of the problem and the resulting fragmented search space, discovering feasible business process designs is one of the main challenges. The proposed approach involves the application of a series of evolutionary multi-objective optimisation algorithms (EMOAs) in an attempt to generate a series of diverse optimised business process designs for given process requirements. The proposed optimisation framework introduces a quantitative representation of business processes involving two matrices one for capturing the process design and one for calculating and evaluating the process attributes. It also introduces an algorithm that checks the feasibility of each candidate solution (i.e. process design). The results for two real-life scenarios demonstrate how the proposed framework produces a number of optimised design alternatives. NSGA-II proves unfit for the specific problem whilst PESA-II shows the best results due to its sophisticated region-based selection technique.

1. Introduction

A business process is perceived as a collective set of tasks that when properly connected and sequenced perform a business operation. The aim of a business process is to perform a business operation, i.e. any service-related operation that produces value to the organisation. In response to increasingly volatile and competitive environments, organisations are examining how their core business processes may be re-designed to improve business performance and market responsiveness. The design and management of business processes is a key factor for companies to effectively compete in today's volatile business environment. By focusing on the optimisation and continuous improvement of business processes, organisations can establish a solid competitive advantage by reducing cost, improving quality and efficiency, and enabling adaptation to changing requirements. It has been argued in [23] that for systematic and holistic business process planning based on business process automation, there must be techniques that support *modelling*, *analysis* and *optimisation* of business processes.

The focus of this paper is on business process optimisation and analysis and not on modelling [1,12]. Business process optimisation is a new area that provides a formal methodology for improving business processes based on specific objectives. To achieve formal improvement however, business processes also require a formal representation. Despite the abundance of business process modelling techniques in literature, only a few are capable of capturing a business process in a quantitative way so that it can be optimised.

The aim of this paper is to investigate the application of evolutionary multi-objective optimisation to the new domain of business process optimisation. The rationale for adopting a multi-objective optimisation approach towards business processes lies in the following:

1. Business process optimisation is inherently a multi-objective optimisation problem due to the variety of factors that a business process can be evaluated with. Dealing with multiple objectives can make this research more appealing and applicable to real-life business process optimisation problems.
2. Evaluation business processes based on a series of relevant factors ensures that this research is versatile in dealing with different objectives for different business goals at a time. The capability of simultaneously addressing a series of customised quantifiable objectives ensures the generality of the research and

* Corresponding author. Tel.: +44 1234 755579.
E-mail addresses: dhish.official@gmail.com, dhishsaxena@gmail.com (D. Saxena).

1568-4946/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.asoc.2012.04.009

its potential applicability in a wider context of business process improvement initiatives.
3. On the contrary, a single-objective optimisation framework focuses on a particular objective (e.g. cost reduction) and thus loosing its generality and its advantages over context-specific business process improvement approaches that target a specific aspect of a business process (e.g. Six Sigma).

This paper presents the first research attempt aimed at addressing the challenges of business process optimisation using evolutionary multi-objective optimisation algorithms. It introduces a business process representation approach and an evolutionary multi-objective optimisation algorithm that constructs optimised business process designs based on specific process requirements. The utilisation of evolutionary techniques provides the advantage of working with a population of designs, thus providing the capability of generating a set of diverse optimised business process designs in the presence of multiple objectives.

2. Related work

It is commonly accepted that a holistic approach towards business processes should capture a business process (business process modelling), provide the necessary means for bottleneck identification and performance analysis and – finally – generate alternative improved business processes based on specified objectives. But often the last part (business process optimisation) is overlooked – if not completely neglected [7]. It is argued in [21] that business process modelling is essential for the analysis, evaluation and improvement of business processes as it is used to structure the process, such that the existing and alternative task sequences can be analysed systematically and comprehensively.

Business process optimisation as a formal approach for improving business processes has not received the necessary attention in literature. On the contrary, soft approaches for restructuring and redesigning business processes are more frequent. An example is Business Process Re-engineering that had an influential effect on business process related literature. However, it is claimed in [17] that most of Business Process Re-engineering methodologies lack the formal underpinning to ensure the logical consistency of the generation of improved business process models. This leads to a lack of systematic approaches that can guide a process redesigner through a series of (repeatable) steps for the achievement of process redesign [14]. While there are several methodologies for structuring Business Process Re-design projects, the task of developing optimal designs of business processes is generally left to the designer's intuition. Business process optimisation lies on the other end of the spectrum and can provide a formal approach towards improving a business process based on predefined criteria. However, it is underlined in [9] that the concept of 'optimality' of process designs is not trivial and the quality of processes is defined by many, often conflicting criteria. The authors in [24] suggest that business process optimisation should aim at reducing lead-time and cost, improving quality of product, and enhancing the satisfaction of customer and personnel so that the competitive advantage of an organisation can be retained. Along similar lines, the author in [14] suggests that the goals of business process optimisation are often the reduction of cost and flow time.

Interestingly, scheduling problems share commonalities with business process optimisation problems. In that, both disciplines fundamentally target an optimal allocation of resources to tasks [18]. It could be interesting to study if a range of already successful optimisation approaches from scheduling can become available to business processes. However, the authors in [5] claim that optimisation capabilities are generally targeted at a specific application area and cannot be easily transferred to another discipline. Furthermore, business processes involve other elements not covered by scheduling problems, such as decisions and business rules that are hard to be expressed mathematically. Hence relevant approaches can be applied to simplified versions of business processes. There are optimisation approaches on mathematically formulated business processes, such as in [9]. These approaches, although consistent, are overly complicated and still deal with simplistic sequential business processes. Taking into account that scheduling is solely based on mathematical models, it is questionable whether business process optimisation should follow the same path or investigate alternative ways that express a business process using a variety of components.

Evolutionary techniques use the principles of evolution to guide the optimisation process and they have been successfully applied to several combinatorial problems. According to the authors in [13] the most attractive feature of evolutionary algorithms is the flexibility of handling various kinds of objective functions with few requirements on mathematical properties. Evolutionary optimisation could benefit business processes by discovering process designs that are perhaps overlooked by a human designer. Also, these techniques can evaluate a significant number of alternative designs based on the same configuration and determine the fittest based on specific objectives. Given the difficulties in process optimisation due to the non-linear, non-convex and often discontinuous nature of the mathematical models involved, the authors in [22] have developed an evolutionary multi-objective optimisation based framework for this problem.

Regarding business processes, the evolutionary approaches reported are limited. An attempt has been made in [9] to transform and optimise a business process model using Genetic Algorithms (GAs) but non satisfactory results have been reported. The model is based on a series of mathematical formulations and is highly constrained thus making it hard for the algorithm to even produce feasible solutions. In [16,20], this mathematical model has been extended and EMOAs such as the Non-Dominated Sorting Genetic Algorithm 2 (NSGA-II [4]) and the Strength Pareto Evolutionary Algorithm 2 (SPEA2 [25]) have been applied, reporting satisfactory results that provide encouraging opportunities for further investigation. This paper presents the extension of the optimisation framework presented by the authors in [20] by generating optimised business processes with diverse designs that are constructed based on predefined process requirements as opposed to sequential business processes that do not involve process patterns. The above cited publications by the authors do not report the Business Process Optimisation framework proposed in this paper. The representation and compositions of business process designs have also not been published before. The real life scenarios are also new contributions of this paper.

3. Representation and composition of business process designs

This section introduces the proposed representation of a business process designs and also an algorithm that is able to compose business processes based on specific requirements.

3.1. A proposed representation

The aim of a business process is to perform a *business operation*, i.e. any service-based operation that is producing value to the organisation. The elements that are involved in the business process and consequently represented in the business process design are – the participating *tasks*, the *resources* of a