AN AUTOMATED BUSINESS PROCESS OPTIMISATION FRAMEWORK FOR THE DEVELOPMENT OF RE-CONFIGURABLE BUSINESS PROCESSES: A WEB SERVICES APPROACH

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ABSTRACT

The practice of optimising business processes has, until recently, been undertaken mainly as a manual task. This paper provides insights into an automated business process optimisation framework by using web services for the development of re-configurable business processes. The research presented here extends the framework of Vergidis (2008) by introducing web services as a mechanism for facilitating business process interactions, identifying enhancements to support business processes and undertaking three case studies to evaluate the proposed enhancements. The featured case studies demonstrate that an increase in the amount of available web services gives rise to improvements in the business processes generated. This research highlights an increase in the efficiency of the algorithm and the quality of the business process designs that result from the enhancements. Future research directions are proposed for the further improvement of the framework.

KEYWORDS

Web service, Business process, Optimisation

1. INTRODUCTION

Business processes map complex organisational interactions, often describing tasks that are undertaken manually. However, business process automation can be achieved by translating manual procedures or using semi-automated tools. Davenport (1990) defines a business process as a set of related tasks which are executed to achieve desired outcomes. The aim of a business process is to perform a business operation, i.e. any service-based operation that is producing value for the organisation (Tiwari et al., 2010). According to Vergidis et al. (2008), business process definitions are usually very simplistic or specific to the industry from which they emerge.

It may be asked why there is a need to optimise a business process? Hammer (1990) indicates that companies tend to use information technology to speed up old business processes without changing them. This can lead to inefficient processes that do not recognise or incorporate more recent automated process steps. Optimisation, in relation to business processes, is about improving performance and achieving maximum results within time, cost and efficiency parameters. Vergidis et al. (2007) suggested that improving performance helps to establish competitive advantage for organisations. These authors also noted that optimisation has a direct implication on costs and process duration. Business processes are represented in this paper as being composed of tasks, the discrete steps or sub-components of a process, and resources, the inputs and outputs of a task. Within this paper each task will be represented by a web service performing a specific function. Resources within a process link up all of the tasks, they are the inputs and outputs of each web service in a process (in graph theory resources, as described in this paper, can be thought of as edges). The use of web services in this research stems from the rise of the Service Oriented Architecture (SOA), on which web services are based. The functionality of each web service is described by the interface it exposes. The interface of a web service defines the inputs it may receive and the outputs it returns. Nagappan et al. (2003) state that web services are modular business applications that expose business logic as a service over the Internet by subscribing, invoking and finding other services. The concept of interchange-ability of web services is an important process improvement benefit utilised by the business process optimisation framework to allow for tasks to be swapped in and out.

Each task within a process can be given attributes such as cost and efficiency. In this way the task of a process may be changed in order change the overall attribute totals, such as reduce the overall cost of a process if each task has a cost attribute attached to it. In the case studies within this paper the attributes cost and efficiency are used as optimisation parameters (reduced cost and increased efficiency are the target outcomes).

The business process optimisation framework presented in this paper is a soft computing approach utilising Evolutionary Multi objective Optimisation Algorithms (EMOAs). Evolutionary techniques allow for the production and exploration of a population of diverse process designs based on a specific set of process requirements (Tiwari et al., 2010). Wang et al. (2004) note that process optimisation is a difficult task due to the inherent discontinuous nature of the underlying mathematical models. In terms of related work Hofacker and Vetschera (2001) have attempted to transform and optimise a business process model using GAs though they concede that the results they obtained were not satisfactory. Tiwari et al. (2006) and Vergidis et al. (2006) extended the mathematical model of Hofacker and Vetschera (2001) and utilised multi–objective optimisation algorithms, such as the Non-Dominated Sorting Genetic Algorithm 2 (NSGA2). The results obtained from these investigations were satisfactory and led to the development of the business process optimisation framework (bpo^F). The aim of the research presented in this paper is to show that an increase in the amount of available web services gives rise to improvements in the business processes generated. In the case studies the use of a modified and extended web service library is evaluated to this end.

2. BUSINESS PROCESS OPTIMISATION FRAMEWORK (BPO^F)

Vergidis (2008) proposed an evolutionary multi-objective optimisation framework for business process designs. The main steps and the structure of the business process optimisation framework (bpo^F) are shown in Figure 1. This research utilises NSGA2 and the Large Scale Search Algorithm (LSSA). NSGA2 is responsible for plotting the optimised results. It is the most popular engine for use in the optimisation of fragmented data. The main parameters for use with bpo^F are shown in Table 1.

From Table 1 it can be seen that the population is set to 250. This means that 250 versions of a business process are produced for each generation that the evolutionary algorithm is run for (25,000 generations are iterated, shown in Table 1). Table 1 also demonstrates that two objectives are being optimised; that is cost, represented in the case studies as Service Delivery Price (SDP), and efficiency, represented as Service Fulfilment Target (SFT).

The Business Process Optimisation Framework (bpo^F), presented here, is described in detail in Vergidis (2008).

Table 1- General parameters

Population	Generations	Crossover Probability	Mutation Probability	Objectives
250	25,000	0.8	0.2	2

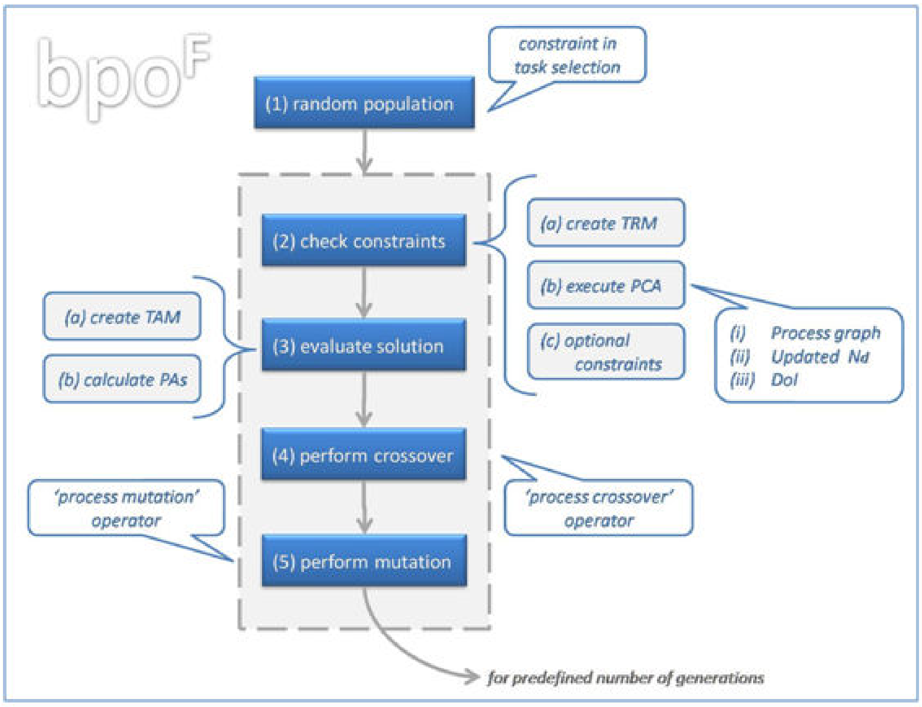

Figure 1 - The main steps of the business process optimisation framework (bpo^F) (Vergidis, 2008)

The bpo^F consists of five steps:

1. *Generate random population:* The first step of the optimisation process is the generation of a random population. This step occurs only once in the optimisation process as then the population is evolved for a defined number of generations. However, for each of the sets there is a constraint in the random allocation of tasks. The constraint is that a task must appear only once in the same set. This constraint avoids having duplicate tasks in one set and in a potential business process design.

2. *Check constraints:* For each solution of the population, the problem constraints are checked. Note that bpo^F checks the constraints prior to solution evaluation due to a specific reason: *the constraints modify the solution.* One particular constraint measures the Degree of Infeasibility (DoI) of the solution. It is here that the Process Composition Algorithm (PCA) is run. The PCA is an algorithm for composing new business process designs. The PCA ensures that there is a one-to-one relationship between the inputs and outputs of tasks within the solution to ensure consistency in the optimisation. If a solution cannot be built into a graph (because edges between graph tasks are missing for example) the solution is deemed infeasible and a penalty is added. Additional optional constraints can force solutions to contain or exclude a certain set of tasks.

3. *Evaluate solution:* The solution evaluation involves two stages based on the proposed representation: (i) The Task Attribute Matrix (TAM) is created and (ii) the various Process Attributes (PAs) are calculated. The TAM is created based on an updated version of the solution involving the tasks in the design and their attribute values. Based on this matrix, the solution is evaluated in terms of the process attribute values.

4. *Perform crossover: Crossover is* a genetic operator that exchanges information between two solutions. Crossover occurs directly in the N_d set of each solution. Initially, the solutions are selected for crossover based on a given crossover probability. The solutions that are chosen for crossover are split into pairs. For each pair a unique crossover-point is defined based on a random number (between 1 and n_d-1). Note that step 2 checks whether the solution is feasible.

5. *Perform mutation:* This genetic operator randomly alters information in a chosen solution. The operator is applied on the N_d set of tasks of a particular solution. When mutation occurs a task is replaced with an *arbitrary* task from the task library (the task library is a set of tasks which may be inserted into a given process if the input and output resources of a task, selected from the library, correspond with the input and output resources of a set of adjoining tasks in that process).

In this approach the Large Scale Search Algorithm (LSSA) maps all possible solutions that constitute the overall search space. NSGA2 complements LSSA by providing the capability to visualize the results in the form of a scatter graph with Pareto front. In order to view individual results and process graphs the JGraph (2011) software is used. JGraph (2011) translates each individual into a flowchart showing tasks linked by resources (and includes AND and OR construct indicators).

3. BUSINESS PROCESS OPTIMISATION USING WEB SERVICES

As mentioned earlier in this paper each task in the process is represented by a web service. Each web service has two attributes: cost (Service Delivery Price or SDP) and efficiency (Service Fulfilment Target or SFT). These values are fictional though they do represent a rating mechanism for web services. Each business process can be composed of many web services generated in a random order. Every web service has its specific function which depends on its inputs and outputs. This ensures that the algorithm is able to pick up a better web service, depending on the requirements. For each scenario appropriate web services are chosen and are converted into a script readable format for the algorithms. After execution, NSGA2 generates 250 graphical business processes and a log file with cost and efficiency values. These values are plotted with a scatter diagram to compare the results.

Three scenarios are featured in this paper. The first scenario describes an automated sales forecasting process (scenario provided by Grigori et al. (2004)). The scenario is described by the initial business process design shown in Figure 2. The initial process design shows the main process steps (each represented by a web service) and the inter connections between the steps. The scenario starts with two inputs: (a) company name and (b) market update request.

One output is produced in this scenario: (a) results report (which is the completed sales forecast). An information retrieval stage, whereby financial information about a business is retrieved along with an update from the financial markets, is the first step in this scenario. In subsequent stages a sales forecast is created and a graph service provides a number of visualisations of the forecast data for inclusion in the report.

Scenario 2, shown in Figure 3, describes the placing of an order in an on-line store (scenario provided by Havey (2005)). The initial process design starts with three inputs (a) Customer ID & password, (b) Order details and (c) Website tracking request (required to track the customer's progress through the website). The customer credentials are necessary to access the on-line store and form the first step of this process. A secure online payment is then made for the goods, shown in step 2 (Vergidis, 2008). Paying for the order invokes the payment validation in step 3 and the monitoring of the order progress, step 4. The web analytics track the customer's progress in the website and are the final step. Three outputs are evident from this process(a) payment confirmation, confirms that the payment processing is successful, (b) order tracking status returns the order status in terms of delivery to the customer and (c) website statistics record the customer's behaviour in the website and influence the store's marketing strategy in terms of customer's individual needs (Vergidis, 2008).

Scenario 3, shown in Figure 4, describes an initial design for a fraud investigation process (scenario provided by Havey (2005)). The process requires 1 input, the security credentials of the customer. The first step of the process utilises the security credentials to allow the customer access to the data. Steps 2 and 3 are executed in parallel; one check is carried out on the customer's identity and one on their credit history. After the checks in steps 2 and 3 are completed, the outcomes are compiled into a report which forms the single output of the scenario.

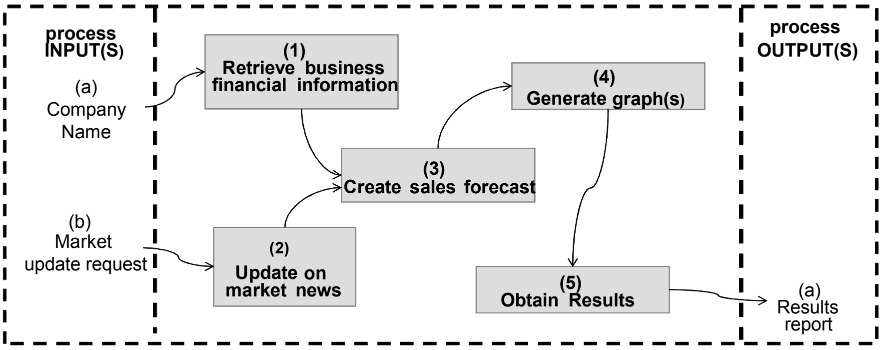

Figure 2 - Initial business process design of the sales forecasting scenario (scenario 1)

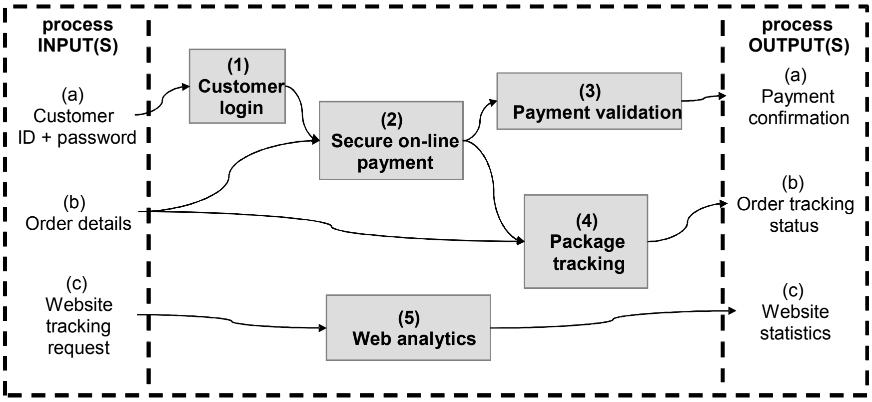

Figure 3 - Initial business process design of the on-line order placement scenario (scenario 2)

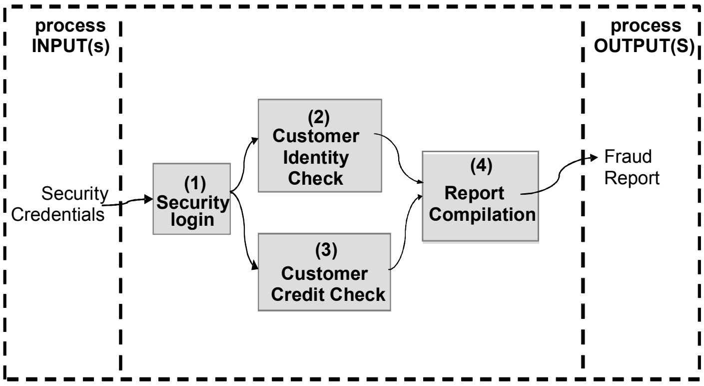

Figure 4 - Initial business process design of the fraud investigation scenario (scenario 3)

Table 2 shows an example task library for use with bpo^F. In Table 2 it can be seen that each task is represented by a web service, with each web service requiring a number of inputs and outputs. The cost (Service Delivery Price or SDP) and efficiency (Service Fulfilment Target or SFT) attribute values for each web service are also shown. In order to expand and refine the web service library beyond the work of Vergidis (2008) it has been necessary to employ a categorisation of web services.

The most common approach to web service categorisation is to classify web services by their functionality. The intention is to help bpo^F to find appropriate web services more quickly. This categorisation strategy is comprised of three different initiatives. Large Internet companies such as Google, Yahoo, eBay and Amazon expose a number of different web services through their APIs. They also attempt to provide a directory with basic categories that can be assessed in terms of the functional characteristics of web services. Another approach is to study the library in terms of the inputs and outputs for each web service and make a comparison on that basis. Lastly, there is an opportunity to assess web services by business models. Almost every web service is built on a revenue raising basis. Javalgi et al. (2005) stated four main internet activities which add value to information based products: search, transaction, evaluation, and problem solving. The three initiatives described above have influenced the route selected for the categorisation used in this work. After creating an enlarged web services library in the previous section, analysis was completed to detect the most frequent transformational activities and unite them by functional groups. The categorisation is displayed in Table 3.

Table 2 - Example partial task library (used in Scenario 2)

No.	Task Name	Input(s)	Output(s)	SDP	SFT
0	Achworks Soap (Rico Pamplona)	1, 2	3	208	113
1	Drupal Authentication	0	1	200	103
2	Entrust Login	0	1	206	103
3	ecommStats Web Analytics	6	7	218	112
4	Internet Payment Systems	1, 2	3	226	105

Table 3 - Web service categorisation for use with bpo^{F}

Functionality	Description	No of web services
Information Analysis	Responsible for searching, evaluating, comparing, forecasting, listing, and monitoring information.	21
Event Driven Services	Responsible for providing notifications and alerts based on triggers	10
Security Checks	Perform verification checks to detect frauds, assess risks, and validate information.	8
Location Based Services	Provide geography related services.	8
User Profile	Involve operations with user accounts.	8
Statistic Services	Track real time and historical records to generate reports.	7
Payment Processing	Facilitate purchasing process from filling shopping basket to confirming payment.	6
Records Management	Update, delete, remove, add, amend, edit.	6
Data Manipulation	In charge of exchanging information between different parties, converting and calculating new combinations, and providing translating or transliterating services.	6
Authentication Services	In charge of identifying requester's credentials and authorising requester to access or to do certain actions.	5
Integration Services	Providing services for embedding information by integrating third party services and their results into own web services and business processes.	5
Transaction	Services that support transactional processing.	4
Online Order Placement	Placing and managing online orders.	2
Communication	Provide messaging, networking, hosting or queuing services.	1
Problem Solving	Involve services that bring two parties to do the job each other.	1

4. OPTIMISATION RESULTS

The aim of business process optimisation is the automated improvement of business processes using pre-specified measures of performance. The importance of business process optimisation lies in its ability to re-design a business process based on quantitative evaluation criteria. This concept stresses the need to generate alternative business process designs based on the given process requirements, and quantitatively evaluate and compare these designs. In this research two parameters are being optimised; the cost (Service Delivery Price or SDP) and efficiency (Service Fulfilment Target or SFT) values for each web service help in the evaluation and selection of 'optimal' process designs. This section of the paper presents the results gained from the optimisation of the three process scenarios set out in section 3, using bpo^{F} as the optimisation engine. In order to determine the effect of extending the web service library the results of Vergidis (2008) gained for the same three scenarios are presented along with the authors' results. The results are displayed in the form of scatter graphs.

4.1 SCENARIO 1: DEMONSTRATING BPO^{F}

This scenario modelled a sales forecasting process. The results are shown in Figure 5. In Figure 5 the overall search space is represented by the darker dots with the optimised results shown in a lighter grey. Each cloud represents a set of process results of a given size (in the cloud containing point B1 for, example, each process has 4 tasks). Three test cases are highlighted in Figure 5. And the differences between the cases are shown in Table 4.

Table 4 - Test case differences for scenario 1

Category	Case	Tasks	Differences	SDP	SFT
Statistics, Information Analysis, Event Driven Services	B1	4	No chart service	853	446
	B2	5	Chart service added	1056	553
	B3	6	More services added with charting capabilities	1257	658

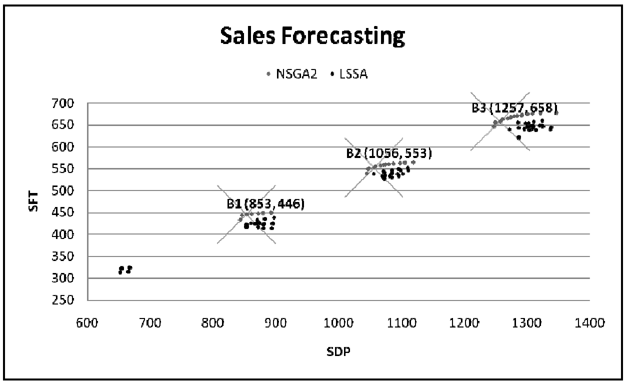

Figure 5 - Scenario 1 results

4.2 SCENARIO 1: A COMPARISON BETWEEN PUBLISHED AND AUTHORS' RESULTS

As mentioned before in order to effectively assess the use of an enlarged task library it has been necessary to compare the authors' results with the published results of Vergidis (2008). Such a comparison should highlight differences in the way NSGA2 generates output in terms of efficiency and cost. The NSGA2 algorithm in bpo^F has, in both cases, been used to obtain the results displayed in this section. Using the same scenarios as Vergidis (2008) though with an enlarged task library the following results were obtained as shown in Table 5 and in the form of the process graphs Figure 6 (Vergidis (2008) result) and Figure 7 (Authors' result). With this scenario the differences between the authors' results and those obtained by Vergidis (2008) are minor. Though, by looking at Figure 8 it can be seen that curve of values from the author's results (shown with black dots) is slightly better than achieved in Vergidis (2008) (with grey dots).

Table 5 - Test case differences for scenario 1

Criteria	Vergidis (2008)	Authors' Results
Tasks	6	6
Cost	1264	1261
Efficiency	663	663
ANDs	2	2
ORs	2	2
Unique Services	Xignite Get Balance Sheet	Mergent Company Fund.
Web Services	20	41

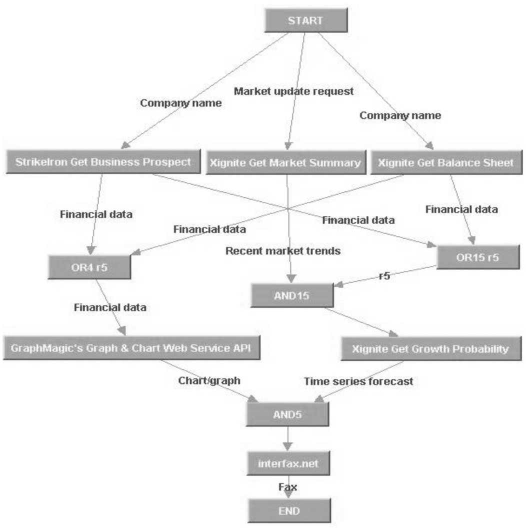

Figure 6 - Scenario 1 (Vergidis, 2008)

Both results have an equal number of tasks and clauses. The use of the NSGA by Vergidis (2008) produced more expensive results than that achieved by the Authors'.

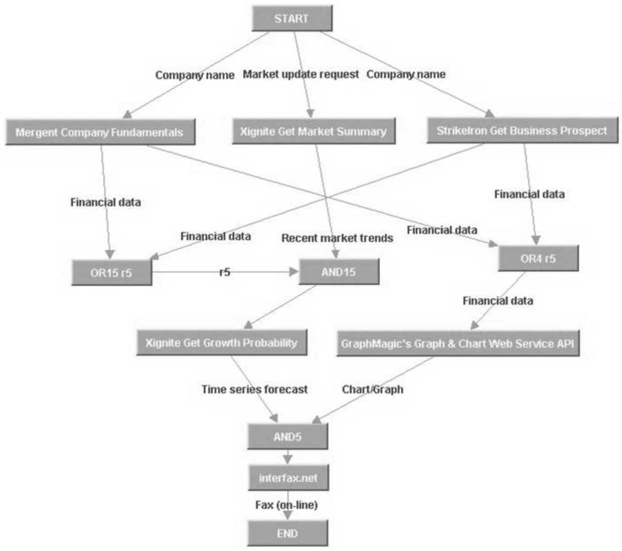

Figure 7- Scenario 1, Authors' Results

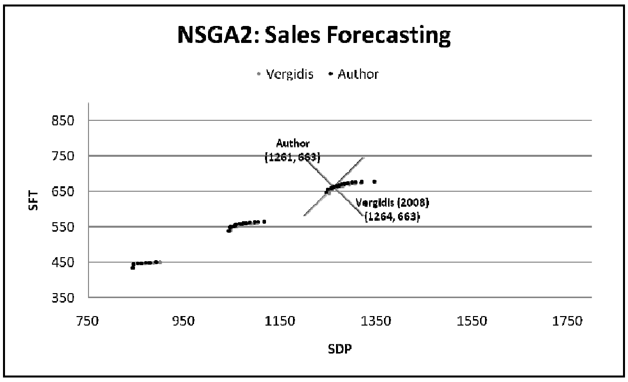

Figure 8 - Scenario 1: Scatter graph comparison of authors' and Vergidis (2008) results

4.3 SCENARIO 2: A COMPARISON BETWEEN PUBLISHED AND AUTHORS' RESULTS

From looking at Table 6 and the process graphs shown in Figure 9b (Authors' results) and Figure 9a (Results of Vergidis (2008)) it may be noted that the authors' results had a higher efficiency than those of Vergidis (2008). In addition both results have an equal number of tasks and clauses. The results of Vergidis (2008) are more expensive and less efficient than the authors' results (the scatter graph of the results is shown in Figure 10).

Table 6 - Result comparison table for scenario 2

Criteria	Vergidis (2008)	Authors' Results
Tasks	6	6
Cost	1240	1237
Efficiency	658	667
ANDs	2	2
ORs	1	1
Unique Services	SXIP Login	Yahoo Maps
Web Services	29	48

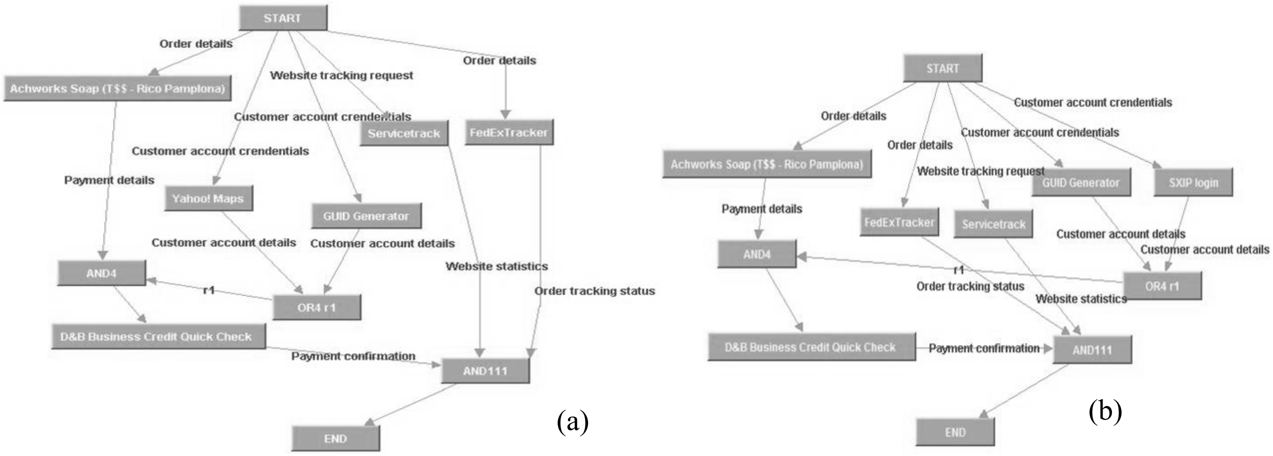

Figure 9 - Scenario 2: Vergidis (2008) results (a) and Authors' results (b)

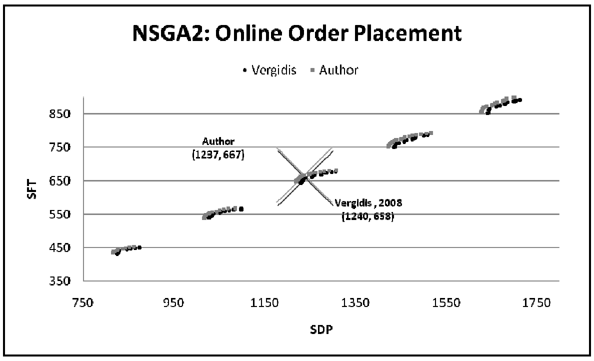

Figure 10 - Scenario 1: Scatter graph comparison of authors' and Vergidis (2008) results

4.4 SCENARIO 3: A COMPARISON BETWEEN PUBLISHED AND AUTHORS' RESULTS

The curve of values obtained by the authors' results is longer and less sharp than Vergidis (2008). This curve may be seen in Figure 11. The results are detailed in Table 7 and are characterised by the following observations. Both results have an equal number of tasks but a different number of clauses. The results of Vergidis (2008) NSGA2 are situated nearby the central part of the cloud (shown in Figure 11). The authors' results sketched two extra clouds.

The authors result (shown in Figure 12 and detailed in Table 7) has a lower cost than that achieved by Vergidis (2008).

Table 7-Result comparison table for scenario 3

Criteria	Vergidis (2008)	Authors' Results
Tasks	10	10
Cost	2062	2047
Efficiency	1086	1079
ANDs	0	0
ORs	10	2
Unique Services	Drupal Authentication	WebservicesX.NET Validate Email
Web Services	31	72

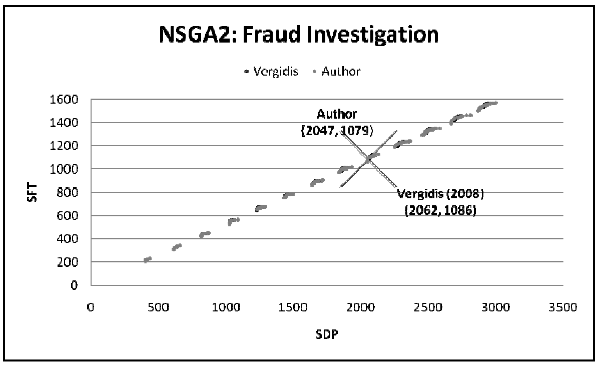

Figure 11 - Scenario 3: Scatter graph comparison of authors' and Vergidis (2008) results

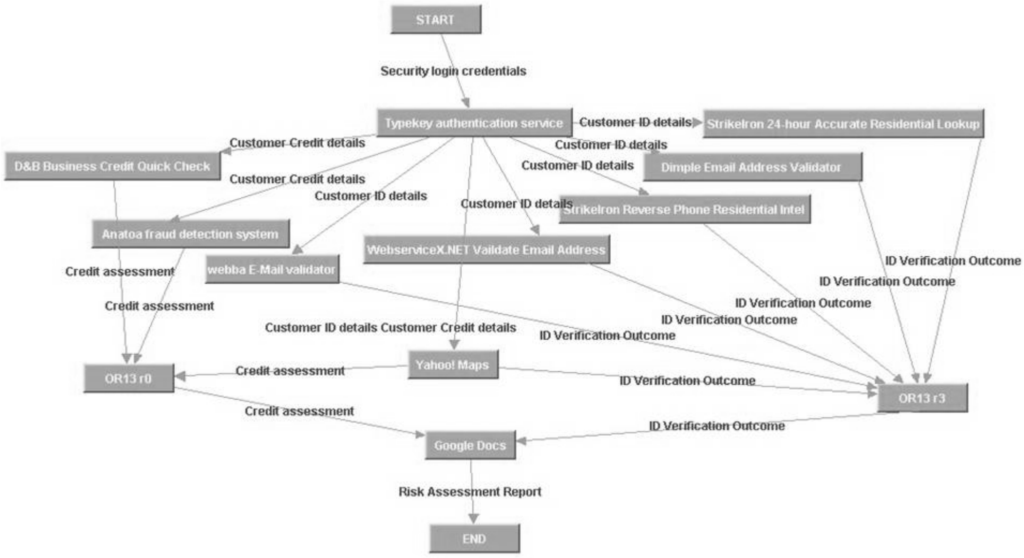

Figure 12 - Scenario 3 Authors' result

The results described in this section demonstrate the benefit of using an extended web service library with bpo^F. It is also the case that additional new process combinations are created when a greater range of web services are provided to the framework (as evidenced in the scatter diagrams). The three scenarios in this paper illustrate the range of processes that may be optimised by this approach.

5. CONCLUSIONS

This paper has explored the optimisation of business processes by providing insights into the use of web services for the development of re-configurable business processes. In particular the effect of using of an expanded web service library has been investigated. From the case study scenarios featured in this work it is clear that an expanded library based on a categorisation of common web services can lead to the identification of better processes. In terms of the experiments in this paper, processes that have a higher efficiency and lower cost may be identified though the use of the expanded web service library. A categorisation of web services has been provided for the classification of web services used in the research presented in this paper. This has aided the selection of web services for use within a process by bpo^F. Observations in this research note that additional result clouds containing new and novel process designs also result from the use of an expanded web service library. Further work is required to standardise the way web services are defined and made available to users. There is also no standard way of determining the true price of using a web service along with the comparative level of efficiency it provides; this would increase the amount of web services available to the practice of business process optimisation. The bpo^F would also benefit from the development of an additional library composed of process templates and sub sequences. Such a template library would aid the efficient construction of valid sub processes and enable bpo^F to explore a wider variety of solutions. The ability to re-use existing processes, technology and business requirements has great potential in the future.

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