AN EVOLUTIONARY BASED ALGORITHM FOR RESOURCES SYSTEM SELECTION PROBLEM IN AGILE/VIRTUAL ENTERPRISES

PAULO ÁVILA* GORAN D. PUTNIK† ANA M. MADUREIRA[¥]

* Institute of Engineering - Polytechnic Institute of Porto, Portugal
psa@isep.ipp.pt

†University of Minho, , Dept. of Production and Systems
Braga, Portugal
putnikgd@dps.uminho.pt

[¥] GECAD – Knowledge Engineering and Decision Support Research Group
Institute of Engineering - Polytechnic Institute of Porto, Portugal
amd@isep.ipp.pt

Abstract – The problem of resources systems selection takes an important role in Agile/Virtual Enterprises (A/V E) integration. However, the resources systems selection problem is difficult to solve in A/VE because: it can be of exponential complexity resolution; it can be a multi criteria problem; and because there are different types of A/V Es with different requisites that have originated the development of a specific resources selection model for each one of them. In this work we have made some progress in order to identify the principal gaps to be solved. This paper will show one of those gaps in the algorithms area to be applied for its resolution. In attention to that gaps we address the necessity to develop new algorithms and with more information disposal, for its selection by the Broker. In this paper we propose a genetic algorithm to deal with a specific case of resources system selection problem when the space solution dimension is high.

Keywords: Agile/Virtual Enterprises, Resources System Selection Problem, Genetic Algorithms.

I. INTRODUCTION

The resources system selection, including the selection of only one resource (most simple case), that integrates an Agile/Virtual Enterprise (A/V E), is a necessary and important process for its design and reconfiguration phases during the life cycle of the A/V E. Several matters are related with this theme and must be defined before the resources system selection takes place, namely and principally the resources system selection model(1) that will be applied, the most appropriate selection method(2), the responsible(3) (entity) for the process and of course, the requisites(4) imposed or pretended by the Principal of the A/V E.

Related with the first point and based on the limitations existed in the analysed models [17], and because our A/V E project BM_Virtual Enterprise project, like any other A/V E project, needs a selection model to perform the agile configuration and reconfiguration of the system, we have proposed a new model. This new model, whose part is presented in [18], is marked by new functionalities and structure that the selection model should perform in order to minimize the complexities/difficulties for the new A/V Es creation.

Referring to the second, we show in [20] all the possibilities for the resources selection methods (independent selection method, fractionated method with and without a pre-selection of transport resources and the integral / dependent selection method with and without a pre-selection of transport resources) and its implications in the complexity of the resources system selection process.

As far as the responsible for the selection process is concerned we demonstrate in [19] the need for the Broker in the selection process is all the greater, the higher the number of tasks, the number of pre-selected resources and the more complex the selection method.

Concerning the fourth, those requisites can be decomposed into two main sets, resources pre-selection requisites and the resources system selection requisites. Both of them depend of the principal criterion or choice. In [15] are presented the most important requisites that can be considered for the two classes within the compass of the A/V Es.

Although the previous analysis demonstrates too much work done, the resources system selection process still has some gaps in order to be implemented with good performance (efficacy and efficiency). The most difficult problems founded and presented in [16] are:

- Each A/V E project specifies different requisites (which has been causing the creation of a specific selection of rigid models and algorithms);
- Can be of polynomial complexity, of degree 2, during the resources pre-selection phase, but with high coefficients;
- Can be of exponential complexity during the resources system selection phase;
- Can be a multi-criterion optimization problem.

Evolutionary Computation has become an important problem solving methodology among many researchers working in the area of computational intelligence. The population based collective learning process; self adaptation and robustness are some of the key features of evolutionary algorithms when compared to other global optimization techniques. Evolutionary computation has been widely accepted for solving several important practical applications in engineering, business, commerce, and scientific domain etc. As we all know, the problems of the future will be more complicated in terms of complexity and data volume.

In this work we will extend our approach to improve the resources system selection phase in order to deal with the possibility of exponential complexity. We will formalise a case of the problem and will show the possibility of application of genetic algorithms for its resolution.

The paper is structured as follows: section 2 provides an analysis of the resources system selection problem. Section 3 relates some literature revision and classification of resources system and classification of resources system selection algorithms for A/V E. In section 4 the resources system selection problem is described and modelled. Section 5 proposes a genetic algorithm to deal with a specific case of resources system selection problem when the space solution dimension is high. Finally, some conclusions are drawn and some ideas for future work are presented.

II. Analysis of the Resources System Selection Problem or Selection Method

Independently of the solutions space dimension, two limit approaches can be used to define the method to apply in the selection of the resources system selection of A/V E. An approach which analyses the performance of the resources system as a whole, this method we will call *Dependent or Integral Selection Method* (DSM). The other approach which analyse task by task or set of associated tasks, the performance of the resources, we will call *Fractioned Selection Method* (FSM).

Def. - Dependent or Integral Selection Method - Selection method which defines the system of resources to integrate the A/V E project bearing in mind its performance in the total execution of all tasks (including the transport ones) belonging to the tasks plan of the production life cycle of the product.

Def. - Fractioned Selection Method - Selection method which defines the system of resources to integrate the A/V E project bearing in mind its performance in the execution of association of tasks (including the transport ones) belonging to the tasks plan of the production life cycle of the product.

In both methods and problem specification, it may occur or not a pre-selection of transport resources. To distinguish between these two, which will bring other consequences in terms of effort of the selection process, we will differentiate them. We will consider the following four selection methods, placed in increasing order of effort/complexity:

- Fractioned Selection Method without Pre-selection of Transport Resources (FSMWO);
- Fractioned Selection Method with Pre-selection of Transport Resources (FSMW);
- Dependent Selection Method without Pre-selection of Transport Resources (DSMWO);
- Dependent Selection Method with Pre-selection of Transport Resources (DSMW).

While in the pre-selection phase it is a problem of effort proportional to the resources that are pre-selected per each processing or transport task, in the resources system selection phase the effort grows exponentially with the number of tasks and with the number of pre-selected resources as we will see for the last two, DSMWO and DSMW.

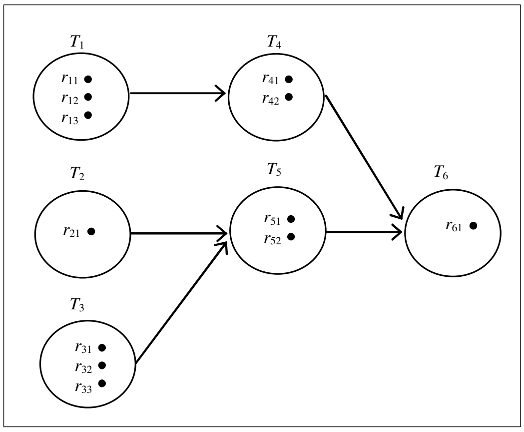

Figure 1- An example of the pre-selected resources for the processing task plan

The Resources System Selection (RSS) problem that integrates an A/V E, can be formulated for Dependent Selection Method without Pre-selection of Transport Resources as follow: known tasks plan with restrictions/requisites asked by the A/V E manager, and knowing the pre-selected resources, with its necessary data, for each task, the goal is to optimize a selection function F(x) that translates the better performance (or guarantees a good performance when it is not possible to certificate the optimal solution) of the resources system selected.

If we consider that each task is executed by only one resource, i.e., that there is no work split, and not considering the selection of transport resources, but considering estimated costs and times of transportation through the distances between resources (dependent selection method without a pre-selection of transportation resources), graphically we can show the selection problem in figure 1 and figure 2.

What we have is one processing task plan, figure 1, to be allocated to the pre selected resources per task, that are represented by dots and designed by r_{ij} inside each task T_i in figure 1, and then select the better resource system considering the possible combinations of these resources taking in account the necessity of transport between two consecutive processing tasks.

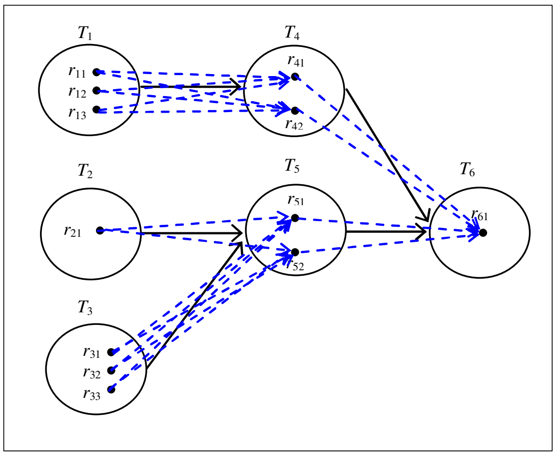

Figure 2- An example of the total transportation tasks to be considered in the RSS

For each pair of pre-selected resources for two consecutive processing tasks there is probably different transportation features (distance and consequently time and costs), translated by dashed arrows in figure 2.

By the fact that pre-selection can be made over universal set of resources, we can expect in a real A/V E situation few resources to perform a task. Then the problem of resources system selection for A/V E configuration belongs to a class of NP-complete problems (Rajamani et al. 1990, Logendran et al. 1994, Sofianopoulou 1999, refereed by Ko [9]).

Considering that there are pre-selected X processing resources per task and the Processing Tasks Plan (PTP) is constitute by n tasks, then, according to the " Choices multiplication's Principle"[15], the total number of processing resources systems will be given by X^n (an illustration of its rapid growing is shown in figure 3). Then we can say that:

$$\textit{Maximal Effort of } RSS_{DSMWO} \propto X^n$$

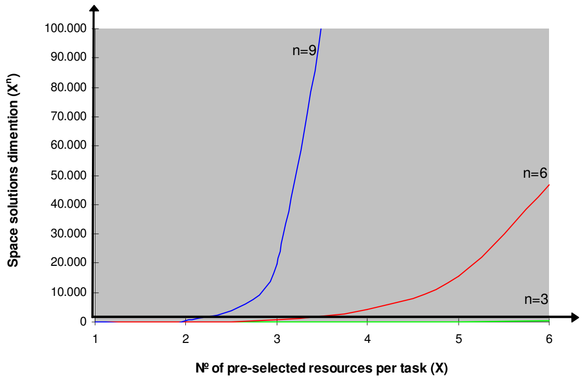

Figure 3- Variation of the resources system number for the DSMWO according to the pre-selected resources number (X) and the processing tasks number (n).

For the case of the DSMW (with the pre-selection of the transport resources), each processing resource system originates needs of transport, which can be measured for each real situation depending however on several factors, e.g., on the number of interlinks of the PTP. However, if we consider that the number of transport tasks required for each processing resources system will be about the number of processing tasks, n, (majored value having in mind the factors that affect the number of transports) and considering that are pre-selected the same number of transport resources per transport task and the same as the number of pre-selected processing resources, X, then we get the dimension of the resources system given by (see its growing in figure 4):

$$\textit{Maximal Effort of } RSS_{DSMW} \propto X^{2n}$$

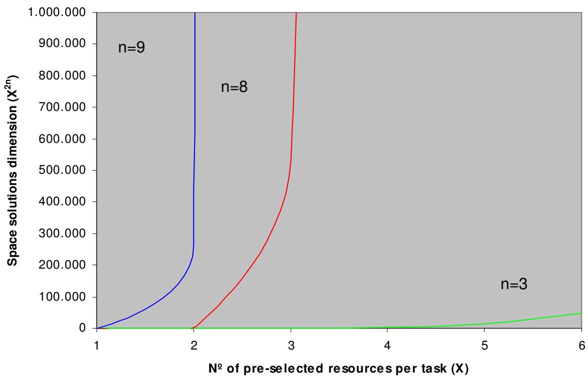

Figure 4- Variation of the resources system number for the DSMW according to the pre-selected resources number (X) and the processing tasks number (n).

This last method or problem specification, DSMW, identified by us in [20], we estimate to be the most precise and complete one. However, in this work we will not attempt in the rest of the work for this case. We will refer only the DSMWO problem approach, but now we know that the problem could be much more complex if DSMW is considered.

Therefore, it is possible to find optimal solutions mathematically, using integer programming, for the simple problem. But for the larger problem in the real world (this is that we expect for A/V E resources configuration), it is difficult to find optimal solutions mathematically [9]. By this reason, we address in our resources system selection model (part is represented in figure 5) the importance and necessity of the selection of the most efficient algorithm, mainly when the dimension of space solution is high. Additionally, the selection of the most efficient algorithm is induced too by the problem specification.

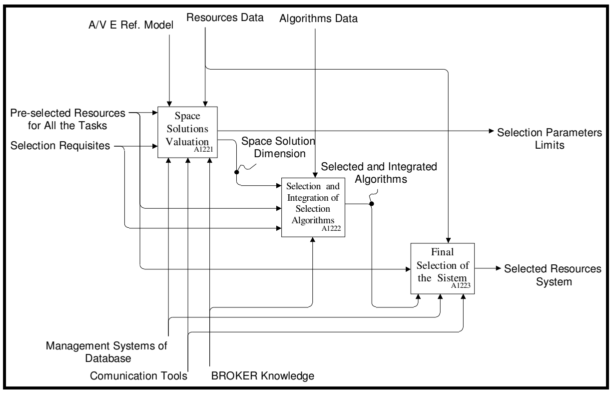

Figure 5- IDEF0 representation of the process A122 – Resources System Selection [18].

As far as algorithms are concern which can be used in the problem resolution we can stand out two kinds of algorithm: Exact solution algorithm and inexact solution (or approximation algorithm [26]). In relation to the first group we can refer its own complexity, that's to say its time complexity, whereas in relation to the second set a measure of its efficiency is not enough, it is required to evaluate its efficacy too, i.e., the quality of the obtained solution. For this reason referring the complexity of these algorithms is not suitable, we should instead refer its performance.

III. LITERATURE REVIEW

According to the revised bibliography made to the selection models and to the selection algorithms applied in the ambit of the A/V Es, in none of the case it is made reference at the differentiation of selection methods or problem specification and its implication in the selection effort and even less to what we estimate to be the most precise method to approach this problem (DSMW).

From revised bibliography there are not many selection algorithms applied to the A/V E, considering the problem referred in section 2 for the DSMWO, comparing with the bibliography that refers to the problem of selection related with the pre selection (phase).

Approaching concretely the combinatorial problem of analyses of resources system selection for DSMWO, we found Subbub [24] that modeled the problem of integrated design, manufacturing and supplier planning for modular products where suppliers and manufacturing resources are distributed. A decision problem in this class consists of three assignments of parts: the assignment of parts to a design that satisfies predetermined functional specifications; the assignment of suppliers who will supply the parts in a design; and the assignment of designs to available manufacturing resources. He considers that each of these assignments affects overall product cost and product realization time, and cannot be considered independently of one another. To solve the problem, he developed an algorithm using evolutionary algorithms techniques. Wu [13] formulated the resources system selection for A/V E using integer programming, but due to the computational complexity, he transformed it in a theoretical graph formulation in order to apply a shorter path algorithm between two points of graph. Ko [9] constructs four heuristic algorithms based on tabu search to show how to minimize the sum of the operation and transportation costs for selecting partners in a distributed manufacturing environment.

For the algorithms that can be applied for the problem of resources system selection for A/V E we did not make an extensive literature review, but we show some applied for planning in a supply chain/extended enterprise, and for dynamic layout problem. Azevedo [1] addressed the problem of planning an incoming customer order, to be produced in a distributed (multi-site) and multi-stage production system. They used an approach based on simulated annealing as well as specially designed constructive heuristics. To solve a similar problem Lee [27] proposed a hybrid simulation-analytic approach. Another algorithm founded, in Dhaenens-Filipo [5], is developed a procedure of spatial decomposition in geographic regions and applied a branch and bound algorithm to solve the scheduling problem of multi-facility production systems geographically dispersed, for the production of different products in a time period. For the same problem the software Global Supply Chain [7] uses an algorithm based on linear and integer programming.

Another algorithms that we suppose to be helpful for our problem, are the algorithms applied for dynamic layout problem (one case can be seen in Baykasoglu [2]).

To promote the selection process of the selection algorithm we need to classify the algorithms according to some criterions designated validation criterions for selection algorithms [12]. These criterions, presented in [16], will be variable decision for the broker to select the better algorithm for each case, among the algorithms that he can use. According to Plasencia [12], validation criterions for algorithms can be classified in three categories:

- **Validation criterions for algorithms** – criterions that are used to validate the algorithms performance. For example: number of iterations, resolution time of computer processing unity (CPU). These criterions are, in fact, measures of algorithm's time complexity.

- **Validation criterions for entries** – are the necessary inputs for the algorithms computation, namely the A/V E requisites and the resources data. For example (A/V E requisites): task plan initial and conclusion task dates. For example (resources data): cost per task, production time.

- **Validation criterions for solutions** – criterions that are used to validate the solutions obtained with the algorithm. For example: total production cost, total production time.

In agreement with the validation criterions for selection algorithms defined, the result of the resources system selection algorithms classification can observe three main points [23].

- There are several types of algorithms applied for resources selection utilizing different entries data according to criterions for solutions.
- None of the algorithms contemplate all the criterions presented. Additionally, for some validation criterions do not exist any algorithm.
- The information available to classify the algorithms according to validation criterions for algorithms, namely time complexity and CPU resolution time is not enough to make a decision about algorithm performance. We should bear in mind that for most of the revised algorithms there is no information whatsoever, namely for those of inexact solution.

In relation to the last item, so that the Broker may overcome the lack of information required to evaluate algorithms performance, we will propose in the next section a formulation of a genetic algorithm to be applied to a particular case of the problem, i.e., for DSMWO.

IV. Resources System Selection Problem Description

The Resources System Selection problem for DSMWO, consists on select a resources system which minimizes the total production times and costs (processing and transport) for production of a single product, independently of the quantities, with a known processing tasks plan, where several resources candidates to process them and the transport parameters are estimated.

A resource j is the entity that makes possible the task realization.

A task i is a complete part of the product/service production cycle, with the identification of its requisites by the A/V E Principal, which is released in the market to be performed, and which execution and control stay in charge of a single resource.

We consider the following assumptions and notation:

s	represents the number of transportation tasks
n	represents the number of processing tasks
m_i	number pre-selected resources for the processing of task T_i
r_j	is a single resource
R_i	$=\{r_1, r_2, r_3, \ldots r_m\}$ represents the set of pre-selected resources that are able of performing task T_i
C_{ij}	is the processing cost of task T_i for resource j
T_{ij}	is the processing time of task T_i for resource j
CT_{kL}	is the transportation cost between resource k and resource L allocated to two adjacent tasks.
TT_{kL}	is the transportation time between resource k and resource L allocated to two adjacent tasks.

Figure 6- Notation.

A task processing plan is the sequence of processing tasks (simple or complex) with temporal interdependency, which define product/service production cycle.

A routing is defined by a sequence of tasks. The Task Processing Plan (TPP) for product i is given by $TPP=\{T_{i1}, T_{i2}, T_{i3}, \ldots, T_{in}\}$. The constituent tasks for the TPP may be performed at several resources.

The goal for Resources System Selection Problem consists on select a resources system which minimizes the total production times and costs (processing and transport)

The problem of Minimization Total Processing Costs (TPC) is given by:

$$\text{TPC} = \min \left(\sum_{i=1}^{n} \mathrm{C_{ij}} + \sum_{m=1}^{s} CT(r_{ik}, r_{\mathrm{i+1L}}) \right) \qquad (1)$$

Where,

$(\mathrm{r_{ik}}, \mathrm{r_{i+1L}})$ is the relation between two resources allocated to a two adjacent tasks.

The problem of Minimization Total Processing Times (TPT) is given by:

$$\text{TPT} = \min \left(\sum_{i=1}^{n} T_{ij} + \sum_{m=1}^{s} TT(r_{ik}, r_{i+1L}) \right) \qquad (2)$$

Where,

(r_{ik}, r_{i+1L}) is the relation between two resources allocated to a two adjacent tasks.

V. Genetic Algorithm for Resources System Selection Problem

Frequently classical optimization methods are not efficient enough for the resolution of these class problems. In most cases they are good for solving only some specific and small size ones. The interest of new approaches, namely Meta-Heuristics such as Tabu Search, Simulated Annealing, Genetic Algorithms and Neural Networks, is that they lead, in general, to satisfactory solutions in an effective and efficient way, i.e. short computing time and small implementation effort.

Genetic Algorithms (GA) were developed by Holland in the 70's and are an attempt to mimic the biological evolution process for discovering good solutions to difficult problems. They are based on a direct analogy to Darwinian natural selection and mutations in biological reproduction [10]. A Genetic Algorithm maintains a population of solutions throughout the search. It initializes the population with a pool of potential solutions to the problem and seeks to produce better solutions by combining the better of the existing ones through the use of genetic operators i.e., selection, crossover and mutation.

Considering that natural evolution is a process of continuous adaptation, it seemed us appropriate to consider Genetic Algorithms for tackling this problem.

GA's have been successfully applied to several classes of optimization problems. Their application to the problem of Resources System Selection Algorithms for A/V E is quite recent. The combinatorial nature of the RSS problem motivated us to use GA as a search technique.

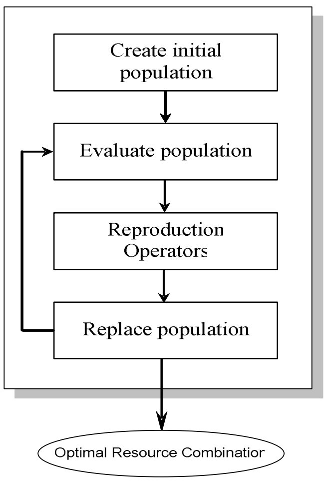

Figure 7- Genetic Algorithm based for Resource Selection System Problem

In developing a genetic algorithm, we must have in mind that its performance depends largely on the careful design and set-up of the algorithm components, mechanisms and parameters. This includes genetic encoding of solutions, initial population of solutions, evaluation of the fitness of solutions, genetic operators for the generation of new solutions and parameters such as population size, probabilities of crossover and mutation, replacement scheme and number of generations. Some considerations on this topic were evaluated on [4].

Details of the algorithm (Figure 7) parameterization are briefly described as follows:

Solution Encoding

In this work, solutions are encoded by the natural representation and similar to the used in [23][3]. In this representation each gene represents a resource index, i.e. the reference index of the selected resource from Ri to perform task Ti. The gene position in a chromosome represents the task position in a sequence, defining, therefore, the task processing order or priority. The number of genes in the chromosome represents the number of tasks in a solution.

Genetic Operators

Individuals, i.e. solutions, are randomly selected from the population and combined to produce descendants in the next generation.

Depending on the problems to solve and their encoding, several crossover operators may be used namely one point, two points, uniform and order crossover [10].

Here, we use the single point crossover operator with probability Pc=0.8. The single point crossover operator will be applied to M pairs of chromosomes randomly chosen, with M=N/2, where N is the size of the population.

The mutation operator is applied with probability Pm=0.001, to prevent the lost of diversity. Thus, a single point in a chromosome is randomly selected, the current select resource, for the task, is replaced for another in the set of alternatives resources.

Replacement Scheme

When creating a new population by crossover and mutation we must avoid loosing the best chromosomes or individuals. To achieve this, the replacement of the less fit individuals of the current population by offspring is based on elitism [10][11]. Thus, the best individuals, i.e. solutions, will survive into the next generation.

Fitness Evaluation

The individuals' fitness evaluation will be based on the minimization of Total Processing Costs and Times.

VI. Conclusions

In this work we show that there are not many algorithms applied for A/V E resources system selection, classified with different validation criterions, i.e., the algorithms presented are not equally applicable to all A/V E models and instances and there are some algorithms gaps showed in its classification. In relation to that gaps we address the necessity to develop new algorithms and with more information disposal, for its selection by the Broker.

A principal contribution of this paper is to propose a Genetic Algorithm based for Resources System Selection Problem, to deal with a specific case of resources system selection problem when the space solution dimension is high. Its implementation is on an ongoing process, and further simulation and computational study will be presented on future work.

Another contribution was to show that the problem specification can be more complex if we consider the DSMW, and we should take care this case in future research too.

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