Adaptations of a resources system selection problem of Distributed/Agile/Virtual Enterprises for using genetic algorithms

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Abstract

The selection of resource systems is still a difficult matter to solve in distributed / Agile / Virtual enterprises (D/A/V Es) integration. Attempts to solve the resources selection problem, has originated several models and consequently different algorithms have been applied to obtain solutions. The exact algorithms have good performance (in terms of computational time) for low dimension problems. However, become ineffective as the complexity increases. Genetic algorithms are considered robust and versatile. These have been applied to complex problems in several application areas and gained popularity in innumerable research works. To improve the computational time in solving the resources selection problem, we pretend to apply a genetic algorithm. Due to the characteristics of the model, the application of this algorithm forced adjustments in the initial model. In this work, we present the adaptations performed in the study model in order to use genetic algorithms.

Keywords

Distributed/Agile/Virtual Enterprises; Resources System Selection Problem; Exact Algorithms; Genetic Algorithms.

1. Introduction

The concept of Distribute/Agile/Virtual Enterprise (D/A/V E) has been a subject of research and development. A D/A/V E can be distributed (several resources/partners distributed geographically), should be dynamic and has a virtual structure able to respond to a business opportunity, where the resources/partners involved (partially or in full), do not lose their identity or culture throughout the production process or D/A/V E life cycle. The development of such dynamic enterprises has led to increase the research interest in the resources selection process, as can be seen in (Pires, A., et al.).

The resources selection process is important either in the design phase or in the operating phase. The first one is critical to design the resources system of the D/A/V E and the second one to assure the maintenance of the system, i.e., reconfigures the system in order to improve its performance. The resources selection models must be able to adapt to each specific projects of D/A/V E. In our model (Ávila, P., et al.) we consider two main phases, the pre-selection of resources (phase 1) and the resources system selection (RSS, phase 2). The RSS phase has been treated of different ways (problems) and considering a few algorithms to solve each problem, as can be seen in the most important works in the area (Wu et al., 1999 and 2005; Subbub et al., 1999; Ko et al., 2001; Sha and Che, 2005; Zeng et al., 2006; Chen et al., 2007; and Jarimo and Salo,

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2007). In spite of that, none of them are aligned with the necessity of develop a broker tool and do not supply the desired information to its construction. In order to assist the development of a web prototype tool (broker tool), intelligent and flexible, that integrates all the selection model activities and tools, and with the capacity to adequate to each D/A/V E project or instance (this is the major goal of our final project), we intend in this paper to propose an adaptation of an initial problem formulation in order to apply with effectiveness a Genetic Algorithm (GA).

In Chapter 2, we give a detailed description of the problem with the basic assumptions and present a mathematical formulation. In Chapter 3 are showed the performance limitations of exact solution algorithm to solve the problem, whose results potentiate the Genetic Algorithms approach explained in Chapter 4. Finally, conclusions are drawn and future work delineated.

2. Problem Description and Mathematical Formulation

The Resources System Selection (RSS) problem that integrates a D/A/V E, can be formulated from different forms or instances. Here in this paper we will address the following case: knowing a plan of processing tasks with restrictions/requisites asked by the D/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 to perform the entire plan of processing tasks.

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 this kind of resources selection problem can be showed as it is in figure 1 and figure 2.

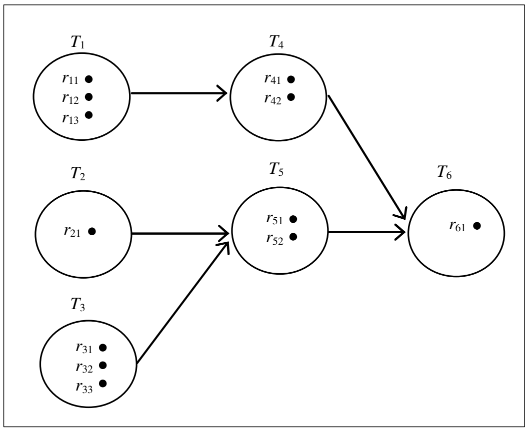

Figure 1. An example of the pre-selected resources for the plan of processing tasks (Ávila, P., 2004).

What we have is one plan of processing tasks, figure 1, to be allocated to the pre-selected resources per task, that are represented by dots and designated by r_{ij} inside each task T_i. Then, select the better resource system (RS) considering the possible combinations of these resources taking into account the necessity of transport between two consecutive processing tasks. For each pair of pre-selected resources, for two consecutive processing tasks, there are probably different transportation features (distance and consequently time and costs), translated by dashed arrows in figure 2.

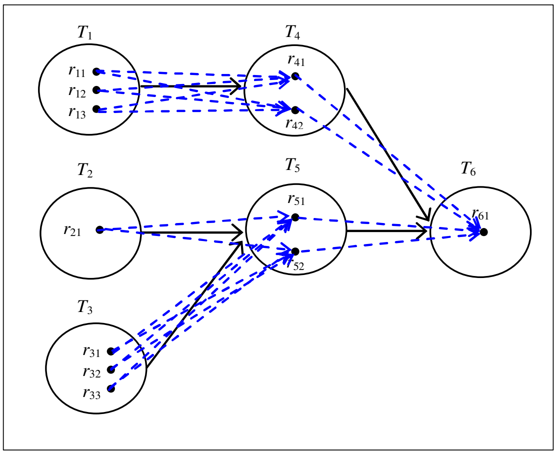

Figure 2. An example of the total transportation tasks to be considered in the RSS (Ávila, P., 2004).

Assuming that in our example had found the solution, i.e. the RS_i selected, its constitution could be for example RS_i = < r_{11}, r_{21}, r_{32}, r_{42}, r_{51}, r_{61} >, as can be seen in figure 3. And the value of the objective function considering the minimization of cost, will consider all costs associated with the processing tasks and the costs of transportation between all adjacent processing resources.

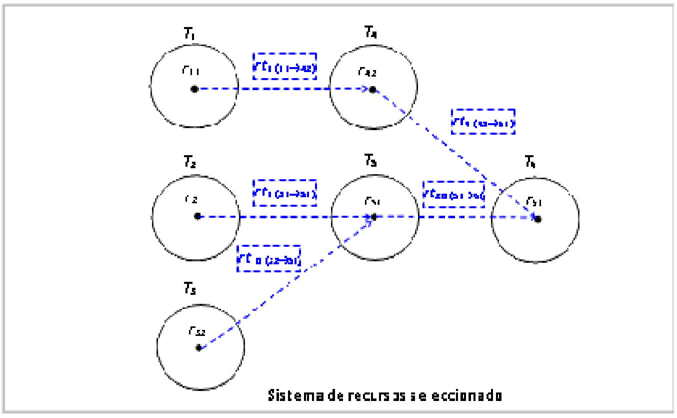

Figure 3. An example of the resources system selected (Ávila, P., 2004).

The problem was described, by the authors in Ávila et al. (2010), as an integer programming optimization problem with the following mathematical formulation:

Min fc = $$\sum_{i=1}^{n}\sum_{j=1}^{k} C_{ij} * r_{ij} + \sum_{i=1}^{n}\sum_{l=1}^{n}\sum_{j=1}^{k}\sum_{m=1}^{k} TC_{ij,lm} * T_{ij,lm} \quad (1)$$

Subject to:

$$\sum_{j=1}^{k} r_{ij} = 1, \quad i = 1,2,\dots,n \quad (2)$$

$$r_{ij} = 0,1 \quad \text{(binary variable)}$$
$$T_{ij,lm} = 0,1 \quad \text{(binary variable)} \quad (3)$$

$$R_{ij} + R_{lm} - 2T_{ij,lm} \geq 0, \quad \forall T_{ij,lm} \quad (4)$$
$$-R_{ij} - R_{lm} + T_{ij,lm} \geq -1, \quad \forall T_{ij,lm}$$

Where:

T_i is a processing task

PPT $= \{T_1, T_2, \ldots, T_n\}$ is the plan of processing tasks for the product

n represents the total number of processing tasks

r_{ij} is a pre-selected processing resource j to perform the processing task T_i

R_i $= \{r_{i1}, r_{i2}, \ldots, r_{ik}\}$ represents the set of pre-selected resources that are able to perform task T_i

k_i is the number of pre-selected processing resources to perform the task T_i. If this number is equal for all the processing tasks, then $k_i = k$

C_{ij} is the processing cost of task T_i for the resource j

$T_{ij,lm}$ is the affectation of the transportation between the resource r_{ij}

and resource r_{lm} allocated at two adjacent tasks of the PPT

$TC_{ij,lm}$ is the transportation cost between the resource R_{ij} and resource R_{lm} allocated at two adjacent tasks of the PPT

The objective function of cost (1) considers the two types of costs, processing and transportation. The first constraint (2) imposes that each processing task is performed only by one resource. The next group of constraints (3) force the variables to be binary. The last two constraints obligate that when each pair of adjacent resources are selected then its transportation is select too. Simultaneously these restrictions permit that a single resource can be selected without be the other adjacent resource. The formulation for minimization of the time is similar to the previous one. For that reason, we excuse to expose it.

This optimization problem (1) was solved by the authors in Ávila et al. (2010) too, using bintprog solver of Matlab (exact solution algorithm). The solver is a combination of the simplex algorithm with the branch and bound algorithm. The Figure 4 shows the results obtained.

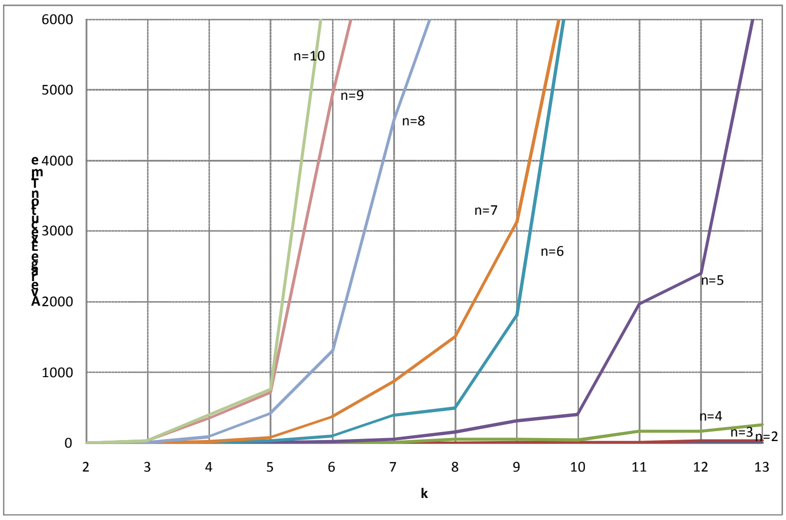

Figure 4. Simulation results with exact solution algorithm (Ávila et al., 2010).

As seen in Figure 4, the runtime increases exponentially with the increase of the number of tasks (n) and pre-selected resources (k). The bintprog solver is only efficient for problems with a small number of tasks and resources, however, is not able to find a solution in a reasonable runtime for problems of a large dimension. In order to find an algorithm that improves the runtime, even not giving an exact solution, we used a genetic algorithm.

3. Application of a genetic algorithm

We run the problem (1) by the ga solver of the MATLAB. This solver solves integer optimization problems. However, it does not include equality constraints and for that, were considered two approaches in order to overtake this problem.

3.1. Elimination of the equality constraints using inequalities

Thus, equality constraints (2) of the problem (1) were transformed into two inequality constraints:

$$\sum_{j=1}^{k} r_{ij} > 1, \quad i = 1,2,\dots,n$$
$$-\sum_{j=1}^{k} r_{ij} < -1, \quad i = 1,2,\dots,n \tag{5}$$

We performed several tests, wherein the parameters of problem were adjusted and we verified that for small problems (n=3 and k=3), the algorithm was not able to find a feasible solution. In our opinion and although we have transformed equality constraints into inequality constraints, the penalty function implemented in the solver assigns randomly a penalization in the violation of these constraints. Leading to a non-convergence of the algorithm.

To overcome equality constraints' problem, we use the matrix of the null space. This technique is used in optimization problems and in addition to eliminating equality constraints also reduces the number of variables of the problem. In the next section we show how the matrix of the null space is used in optimization problems and we will present the changes made to the objective function (1).

3.2. Elimination of the equality constraints using the null space matrix

A technique to eliminate the equality constraints, in a optimization problem is the use of the nullspace matrix (Boyd, S., 2004). This technique is advantageous because in addition to make the optimization problem simpler, reduces the number of variables of the problem.

Consider the following optimization problem:

$$\min f(x)$$
$$s.t. \quad Ax = b \tag{6}$$

where, $A \in R^{n+p}$ and the rank of A is p.

The solution set {x|Ax=b} can be presented as the set $\{Fz + \hat{x} | z \in R^{n-p}\}$, wherein $\hat{x}$ is a particular solution and $F \in R^{n \times (n-p)}$ is the null space matrix of A . The rank of F is n-p and AF=0.
So, the problem (6) can be transformed into an unconstrained problem as:

$$\min f(Fz + \hat{x})$$

where $z \in R^{n-p}$ is the variable of the problem and the solution z^* is obtained by $x^* = Fz^* + \hat{x}$.

This technique was applied to the problem (1) and we obtained the following optimization problem:

$$\min fc = \sum_{i=1}^{n}\sum_{j=1}^{k} c_{ij} \times \left(F\hat{r_{ij}} + r_{ij}^*\right) + \sum_{i=1}^{n}\sum_{l=1}^{n}\sum_{j=1}^{k}\sum_{m=1}^{k} TC_{ij,lm} \times T_{ij,lm} \tag{7}$$

$s.t.$

$$\hat{r_{ij}} = 0,1 \ (binary\ variable)$$
$$T_{ij,lm} = 0,1 \ (binary\ variable)$$
$$\sum_{i=1}^{n}\sum_{k=i+1}^{n} T_{ij,lm} + T_{kt,vs} < 1 \tag{8}$$
$$F\left(\hat{r}_{ij} + \hat{r}_{lm}\right) - 2T_{ij,lm} \geq 0, \forall T_{ij,lm}$$
$$-F\left(\hat{r}_{ij} + \hat{r}_{lm}\right) + T_{ij,lm} \geq -1, \forall T_{ij,lm} \tag{9}$$

Where F is the null space matrix, $\hat{r}_{ij}$ are the variables of the problem and r^{*}_{ij} is a particular solution. To use the matrix null space was necessary to adapt the inequality constraints and introduce new constraints, as shown in (8) and (9). These changes ensure that only one transportation $T_{ij,lm}$ is selected between two resources. This model was solved by ga solver of the MATLAB, but the first results were not promising.

3. Conclusions

In this paper was reviewed the resolution of a problem of resources system selection problem through an exact solution algorithm. In order to improve the run times, we adapted the mathematical formulation of the problem to be able to use genetic algorithm of MATLAB for integer programming problems. This solver found it hard to converge to acceptable solutions in this kind of problems. In order to overcome them the technique of matrix of the null space was used to eliminate equality constraints. Using the matrix of the null space it was necessary to adapt and embed inequality constraints to the initial mathematical formulation of the problem. After running the algorithm the results of the tests were not promising.

As future work we plan to change the solution encoding of the, i.e., the representation of a solution by the chromosome.

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