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A team building approach for competency development

O. Hlaoittinun, E. Bonjour, M. Dulmet
Laboratoire d’Automatique de Besançon, Université de Franche-Comté, Besançon, France

Abstract – An approach for multidisciplinary team building is proposed through three steps. We suppose that tasks and team members are characterized by a set of attributes (technical competencies). First, the calculation of distance measure between task and team member (profile matching) are proposed. Second, an array-based clustering algorithm is used as an effective means for providing an alternative solution in task and team-member clustering. The proposed approach generates a systematic formation of task and team member families by sequencing the rows and the columns of a task/ team member incidence matrix. Finally, an integer programming model is formulated to solve the task assignment problem. The proposed method is demonstrated by applying it to an example in a team building problem.

Keywords – Array-based clustering algorithm, distance measure, integer mathematical programming, task assignment, team building

I. INTRODUCTION

The concept of multidisciplinary team building is one of the key aspects of problem solving in many product development projects. Specialists from various disciplines (e.g. micro robotics, electronics, thermodynamics, manufacturing, mechanics, image processing, optics) are gathered to develop a new product. Team building is a crucial issue in project management. Design teams are multidisciplinary groups composed of members representing many engineering disciplines. Three main elements have to be defined: task, team member and attribute. Design tasks correspond to a group of tasks to be performed in a design project. Team members from different departments possess different competencies, characterized by a set of attributes required in performing the tasks. Attributes can be viewed as soft competency or technical competency. Fig. 1 gives the global overview of our team building approach.

Furthermore, for the task assignment, we suppose that the competencies of an individual increase during task realization and can decrease with time. Therefore, task assignment implies the increase in the competency development of an individual. So, the problem of preserving an intra-domain expert is considered here in order to maintain a team member in his or her expert domain. The literature about team building does not provide the solution reinforcing the intra-domain expert competencies, or dealing with the competency dynamics.

II. REVIEW OF RELATED LITERATURE

Numerous works about team building deal with psychological and sociological competencies (personality types, leadership, communication skills, decision-making ability etc.) [1], [2], [3]. Technical competency is the most common attribute found in team building literature in order to characterize tasks and team members [1], [4], [5], [6], [7]. De Korvin et al. [8], emphasized that the important factor in selecting human resources to a team are the technical competencies. These competencies will be required to implement the various activities for each phase of the project. Moreover, competencies can be considered from two points of view. First, a competency is required to carry out a task and second, a competency is possessed by one (or several) team member(s).

Boucher et al. [18] indicated that competencies can be seen from three distinct views: static, functional and evolutionary. This paper focuses on the functional point of view. This concerns the mechanisms of competency mobilization in a work context where the goal is to make an efficient use of available competencies.

There are various solutions to be found in the research literature. Chen and Lin [2], [9] proposed an integrated methodological framework in team member assignment. The objective of their work was to develop a framework for project task coordination and team organization from the concurrent engineering perspective in order to assign the right tasks to the right team members. In other words, it is important to know the competencies and performance levels of a team member possesses before being able to allocate tasks to him or her. Zarakan and Kusiak [4] emphasized the importance of multifunctional teams in product development. The proposed method is based on QFD and AHP method. De Korvin et al. [8] developed a personnel selection model for a multiple phase project. The “fuzzy compatibility” method has been used to select the potential team members.
members for each project phase. Braha [10] presented a mathematical formulation for the problem. Two main issues are addressed by the model: 1) how to specify task dependencies, and 2) how to optimally partition the tasks between a number of teams. Gronau et al. [11] developed an algorithm to propose a team composition for a specific task by analyzing the knowledge and skills of the employees. This method is based on the Knowledge Modelling and Description Language (KMDL).

The clustering method presented in this paper is based on one of the array-based clustering algorithms: ROC (Rank Order Clustering). A common characteristic of this algorithm is that all the methods consecutively reorder the rows and columns according to an index until the diagonal blocks are formed. The array-based clustering approach is one of the group technology algorithms. Originally, this approach was applied in manufacturing cell formation in order to group similar part families on dedicated clusters of machines. Examples of array-based clustering algorithms are as follows: ROC (Rank Order Clustering) [12], ROC2 [13], DCA (Direct Cluster Algorithm) [14], BEA (Bond-Energy Algorithm) [15], [16]. Chu and Tsai [17] outlined a procedure for evaluating alternatives in clustering algorithms under different measuring criteria.

This paper is composed of two parts. First, we will explain our approach in team building. Second, we will illustrate our approach through a simple example.

III. TEAM BUILDING APPROACH

Our approach comprises three main steps (Fig. 2). First, we explain how to generate a task/team member incidence matrix. Second, we present an algorithm in order to group task/team members into families using an array-based clustering algorithm. Third, we show how to solve the task assignment problem by means of an integer linear programming model. The model is based on the attributes of engineering characteristics (task/ team member incidence matrix).

1) Generate a task/ team member incidence matrix: The approach given here is based on incidence matrices. An incidence matrix is a matrix that shows the relationships between two classes of objects. If the first class is X and the second is Y, the matrix has one row for each element of X and one column for each element of Y. Below are the five sub-steps to this method:

- Identify relevant attributes to characterize both task and team member. (In this paper, we consider attributes as technical competencies or disciplines).
- For each task, evaluate the demanded performance for each attribute (for instance, we obtain the task-discipline matrix (Table I))
- For each team member, evaluate the performance level for each technical competency. (for instance, we obtain the team member-discipline matrix (Table II))
- Define a compatibility indicator between task and team member (matching process).
- Generate a task/ team member incidence matrix. (see the result in Table III, we obtain the task / team member matrix)

The compatibility indicator (similarity measure) is one of the methods often used in team selection. This method finds the shortest distance between two skill sets so as to find the appropriate candidate. Numerous distance measures have been mentioned in research literature - for example, the Hamming distance used in the personnel selection [19]. What is missing in these existing measure methods is that they haven’t taken into account the difference between the positive and negative gap values. The positive gap value can be viewed as an overcompetency level, and the negative gap value as an undercompetency level. Therefore, we propose a compatibility indicator as a distance measure that will be helpful to find the best correlation value between two sets of disciplines (task and team member).

Let T, D and P denote ordinary non empty sets. Let $R_i$ be a relation from T to D and let $R_k$ be a relation from D to P. Then ($R_i ° R_k$) is a relation from T to P. Let us denote $T=\{t_1,..., t_p\}$, $D=\{d_1,..., d_q\}$, $P=\{p_1,..., p_r\}$,

$$
R_i(t_i, d_i) = R_i^{mk}, \quad R_k(d_k, p_m) = R_k^{lm}.
$$

(\text{Composition value} \, (R_i ° R_k)(t_i, p_m)) \quad \text{Compatibility indicator between the task } k \text{ and the team member } m

$R_i^{kl}$ \quad \text{Level of discipline } l \text{ required by the task } k,

$R_m^{kl}$ \quad \text{Level of discipline } l \text{ acquired by the team member } m.

Overcompetency ($R_i^{kl} < R_m^{kl}$) indicates that the acquired discipline level of a team member is higher than the task requirement, whereas undercompetency ($R_i^{kl} > R_m^{kl}$) indicates that it is lower. For our approach, we consider only the undercompetency case and propose the following function to calculate a compatibility indicator.

$$
(R_i ° R_k)(t_i, p_m) = 1 - \frac{\sum_{l=1}^{q} \max(0, R_i^{kl} - R_m^{kl})}{\sum_{l=1}^{q} R_i^{kl}} \quad (1)
$$

Composition value $(R_i ° R_k)$ can be interpreted as the strength indicator of such a relational chain. It can be demonstrated that this value is included between 0 and 1. 

2) Identify task/ team member families by clustering method: The ROC clustering method will

![Fig. 2. Multidisciplinary team building approach](image-url)
transform the task/team member incidence matrix into
task/team member families. Algorithm principle:

Step 1: For each row of the task/team member
matrix, calculate the decimal weight.

Step 2: Sort rows of the matrix in decreasing
order of the corresponding decimal
weights.

Step 3: Repeat the preceding two steps, for each
column.

Step 4: Repeat the preceding three steps until the
position of each element in each row and
column does not change.

A weight for each row \( k \) and column \( m \) is calculated as
follows, where \( r \) is the number of team members and \( p \) is
the number of tasks.

Weight for row \( k \):

\[
\sum_{m=1}^{r} R_{km} 2^{-r-m} \quad (2)
\]

Weight for column \( m \):

\[
\sum_{k=1}^{p} R_{km} 2^{p-k} \quad (3)
\]

This array-based clustering method is simple to apply to
task/team member matrices. However, it requires visual
inspection of the output to determine the composition of
the diagonal block formation. We adopt here the Group
Density Index proposed by [5]. This index will be used to
identify the potential groups after using the ROC
algorithm. The variables ' \( p \) and ' \( r \) refer respectively to
the number of rows and the number of columns in
potential groups. The following function will be used to
calculate the GDI index:

\[
GDI = \frac{\sum_{k=1}^{p} \sum_{m=1}^{r} R_{km}}{p^r} \quad (4)
\]

3) Assign tasks to team members: The task
assignment contains a group of tasks (The mission
requirement) to be accomplished. The mission
requirement is defined here as a set of tasks \( \{t_1, \ldots, t_p\} \).
The integer programming model is formulated to solve the
task assignment problem.

IV. ILLUSTRATIVE EXAMPLE

1) Problem Formalization: A design project with
seven tasks requiring ten disciplines is used as an
illustrative example. The design department has eleven
members; and each member knows a set of different
disciplines and related performance levels. We may
consider a set of tasks, a set of team members, and a set of
disciplines. The value \( R_{tj} \) is defined as the demanded
performance level of the discipline required by the task.
The value \( R_{pm} \) is defined as the performance level of the
discipline possessed by the team member.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>TASK-DISCIPLINE INCIDENCE MATRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>D2</td>
</tr>
<tr>
<td>T1</td>
<td>0.8</td>
</tr>
<tr>
<td>T2</td>
<td>0</td>
</tr>
<tr>
<td>T3</td>
<td>0</td>
</tr>
<tr>
<td>T4</td>
<td>0</td>
</tr>
<tr>
<td>T5</td>
<td>0</td>
</tr>
<tr>
<td>T6</td>
<td>0.2</td>
</tr>
<tr>
<td>T7</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE II</th>
<th>TEAM MEMBER-DISCIPLINE INCIDENCE MATRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>P2</td>
</tr>
<tr>
<td>D1</td>
<td>0.7</td>
</tr>
<tr>
<td>D2</td>
<td>0</td>
</tr>
<tr>
<td>D3</td>
<td>0</td>
</tr>
<tr>
<td>D4</td>
<td>0.5</td>
</tr>
<tr>
<td>D5</td>
<td>0</td>
</tr>
<tr>
<td>D6</td>
<td>0.7</td>
</tr>
<tr>
<td>D7</td>
<td>0</td>
</tr>
<tr>
<td>D8</td>
<td>0.6</td>
</tr>
<tr>
<td>D9</td>
<td>0</td>
</tr>
<tr>
<td>D10</td>
<td>0</td>
</tr>
</tbody>
</table>

2) Results from the clustering algorithm: Integrating
the relation \( R_{tj} \) and \( R_{pm} \), we will obtain the task/team
member incidence matrix \( R_{km} \) presented in Table III. This
matrix contains the value of compatibility indicator \( R_{km} \).
The compatibility indicator can be interpreted as the
performance level of a team member (\( p \)) to achieve a task
(\( t \)). These values are calculated from (1).

From a task/team member incidence matrix, team
members and tasks will be grouped in diagonal blocks by
the ROC algorithm. The algorithm furnishes three blocks
separately: the first block associates five team members
and three tasks; the second associates three team members
and two tasks, and the third associates three team
members and two tasks.

3) Task assignment: Considering the assignment of
the team members as a binary variable, the team can be
selected by minimizing the project cost. The objective is
to find one suitable candidate for each task which
minimizes the total salary cost of the project.

To consider the minimization of salary cost, a simple
objective function is defined. The cost function depends
on the individual salary multiplied by the compatibility
indicator. For our hypothesis, we suppose that the lower
the compatibility indicator, the longer the duration of the
execution of a task— as long as the compatibility indicator
is not lower than the lower bound (\( a \)).
TABLE III

<table>
<thead>
<tr>
<th>TASK/TEAM MEMBER INCIDENCE MATRIX</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
</tr>
</thead>
<tbody>
<tr>
<td>P3</td>
<td>T4 = 0.84, 0.75, 0.72, 0.72</td>
<td>T5 = 0 0, 0 0</td>
<td>T6 = 0 0, 0 0</td>
</tr>
<tr>
<td>P10</td>
<td>T7 = 0 0, 0 0, 0 0</td>
<td>T8 = 0 0, 0 0, 0 0</td>
<td>T9 = 0 0, 0 0, 0 0</td>
</tr>
<tr>
<td>P8</td>
<td>T10 = 0 0, 0 0, 0 0</td>
<td>T11 = 0 0, 0 0, 0 0</td>
<td>T12 = 0 0, 0 0, 0 0</td>
</tr>
<tr>
<td>P4</td>
<td>T13 = 0 0, 0 0, 0 0</td>
<td>T14 = 0 0, 0 0, 0 0</td>
<td>T15 = 0 0, 0 0, 0 0</td>
</tr>
<tr>
<td>P5</td>
<td>T16 = 0 0, 0 0, 0 0</td>
<td>T17 = 0 0, 0 0, 0 0</td>
<td>T18 = 0 0, 0 0, 0 0</td>
</tr>
<tr>
<td>P7</td>
<td>T19 = 0 0, 0 0, 0 0</td>
<td>T20 = 0 0, 0 0, 0 0</td>
<td>T21 = 0 0, 0 0, 0 0</td>
</tr>
<tr>
<td>P6</td>
<td>T22 = 0 0, 0 0, 0 0</td>
<td>T23 = 0 0, 0 0, 0 0</td>
<td>T24 = 0 0, 0 0, 0 0</td>
</tr>
<tr>
<td>P2</td>
<td>T25 = 0 0, 0 0, 0 0</td>
<td>T26 = 0 0, 0 0, 0 0</td>
<td>T27 = 0 0, 0 0, 0 0</td>
</tr>
<tr>
<td>P9</td>
<td>T28 = 0 0, 0 0, 0 0</td>
<td>T29 = 0 0, 0 0, 0 0</td>
<td>T30 = 0 0, 0 0, 0 0</td>
</tr>
<tr>
<td>S_p</td>
<td>1500 1400 1450 1300 1200 1300 1270 1410 1380 1360 1300</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For each diagonal block in Table III, to formulate the model, the following notation is introduced:

- $k$ = index for multidisciplinary tasks
- $m$ = index for team members
- $p$ = number of multidisciplinary tasks
- $r$ = number of team members
- $S_m$ = salary of team members
- $R_{km}$ = compatibility indicator of each couple of task and team members
- $C_{km}$ = adjusting factor of each couple of task and team members

Constraint (7) demonstrates that a team member could not be allocated more than one task. Constraint (8) demonstrates that the selected team member needs to have a compatibility indicator of at least 0.6. The value of 0.6 represents the lower bound (a) of the compatibility indicator.

IV. CONCLUSION

This paper has presented a team building approach and it is illustrated through an example. This promising approach differs from the use of existing team building approaches, because it has adopted a clustering algorithm to enable tasks and team members to be grouped into families (departments). The advantage of using the clustering method in the selection process is that it allows the team members to perform tasks in order to maintain their expert domains.

Our study in team member selection can be divided into two sections. At the beginning, we presented the method for competency structuring. The solution encourages the representation of attributes in order to characterize tasks (or team members) and it encourages demonstrating the potential diagonal block of tasks and team members. In the second part, we have studied the task assignment problem in design projects. An integer programming model is formulated to solve the multidisciplinary task assignment problem.

The objective of competency structuring is to give a global image of competency to the project managers and to help them to deal with a multi-functional team building problem. In team building literature, team members belong to a functional department. But in the innovative product design, new jobs (that is, new tasks) may appear; some team members may leave or be recruited by the company. So departments may evolve. No existing
method has been proposed to link task- and team-member evolution.

In this paper, some limitations should be noted, as they might lead to interesting perspectives in future research.

1) We have not considered the workload (man-hours) of team members and multi-project task assignment. If a team member is assigned to multiple teams, the member’s availability will need to be taken into account. We consider here the single-project team building. Each team member works full time for a single project.

2) In the context of competency dynamics and development, the performance level of team members will gradually increase during the project execution and continuously decrease if they are not assigned to the task corresponding to this competency for some time. The question that we might ask is: how can we apply this approach to support the global competency development of a company?

REFERENCES


