Optimal Team Formation for Software Development Exercise
— Evaluating a Method for Team Formation Based on the Type of Project Manager —

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Abstract: - In the software development exercise for the third graders of the Shibaura Institute of Technology Department of Information Science and Engineering, students are assigned to each team with the capability to carry out a role, for optimization of team formation in 2006. However in the questionnaire results after the end of the exercise, it turned out that the low motivation of some students caused the shortage of communication of the members in the team. Then, the authors built up the hypothesis that "each student's motivation is decided by whether the type of PM (Project Manager) and the PM type each member desire is in agreement. As a result, the team formation of the students without the practice experience confirmed that high team formation of the cooperativeness between team members was realizable by considering a PM type.

Key-Words: - Optimizing Project Team Formation, Exercises in Units of Groups, Exercise for Software Development, Genetic Algorithm, Factor Analysis, Covariance Structure Analysis, Path Diagram, PBL, Role Assignment

1 Introduction
In the software development exercise for the third graders of the Shibaura Institute of Technology Department of Information Science and Engineering, students are assigned to each team with the capability to carry out a role, for optimization of team formation. In the team formation of 2006, performed by Shirakawa, et al.[1] each student who expected to play an active part for the success of exercise subject played an active part also in the actual exercise lesson in each team. As a result "all the teams achieved the exercise subject without any halfway dropouts". However in the questionnaire results after the end of the exercise, it turned out that the low motivation of some students caused the shortage of communication of the members in the team. Therefore in order to solve this problem hypothesized that "it is decided whether the motivation of each student agree with the type of PM (management type or partnership type) and the type of PM desired by each member". In order to inspect the hypothesis for the target students (1st, 2nd grade) of Shibaura Institute of Technology, analyzed "character suitable for PM", and applied the analysis results to the character of each student attending the lecture. By the results, it was judged that the students having aptitude of PM are of two types "management type" and "partnership type". Afterwards, it was found that a member is classified into two groups according to the type of PM, which (students other than PM) desires.
In the team for a software development exercise, each member has three roles, Analyst in charge, Coding in charge, and in charge of QA(Quality Assurance) to bear other than PM. In order to determine a role assignment of each member a substitute characteristic and an expression of relations with each role to express a role performance by a covariance structure analysis is requested. Based on an expression of relations, decide assigned members according to the PM type and perform role assignment and the team formation of each member. As a result, it is confirmed that the exercise subject is successful without halfway dropouts in any team and an ability difference between teams realized small team formation. Furthermore, in the team formation of the students without the exercise experience, it is confirmed that the high team
formation of the sense of cooperation of team members respect to each other can be realized by considering a PM type.

2 Related research
For research of group organization of software development exercise there is a need to consider a student’s individual skill. That is why there is a study of using the skill information of the individual student for group formation. Hazeyama[2], Hazeyama, et al.[3], and Hashiura, et al.[4] about the attributes information of the skill, collected system analytical abilities, concerns of the system development, future courses, abilities for leadership, communicative competence by a questionnaire. And considered them to be attributes information about the skill that a student had. And performed an experiment organizing a group based on the strategy how abilities difference between groups becomes smallest while referring to these attributes information. This study pays attention to the skill information of the individual student, but does not consider role assignment based on skill information. Besides, it uses evaluation values provided by the questionnaire that used an interval scale for personal attributes information (subjective value). Therefore the formation results may be controlled by the self-evaluation (subjectivity) of the student. In this study, a sense of cooperation for each other in respect of members of the team and the motivation of the individual students can be raised in the team formation of students without experience of the software development practice by considering a PM type.

3 Measures of 2008 fiscal year
The purpose of the exercise is to experience all making processes of software development from demand extraction to program development, and to learn knowledge and the technologies that are necessary for development. In addition, in this exercise all information of functions and the students such as communication support /result management support / project management support which were developed for work efficiency improvement of the students with automatic log information collection function of software development exercise lesson support environment "EtUDE" (Environment for Ultimate software Development Exercise) [5] is used. The project practice to learn here shares each role, and it is a form to cooperate, and to solve a problem. That is why the scale of a given problem is big, and the degree of freedom of the work of the attending individuals is big. Therefore in the project exercise, if the ability gap between teams is not made small there is unevenness of the result matters between teams. In addition, it is very likely not to achieve the problem within a period, if there is at least not one person in the team per role with the ability for role sharing. Optimization of the team formation that clarifies human factors is important for software development exercise to make project exercise of the software development an effective thing. The definition that Shirakawa, et al. [1] added a postscript to the factor of the depths to use to assign roles for conditions (limitation) of the team formation that Hashiura, et al.[4] established is Fig. 1.

<table>
<thead>
<tr>
<th>C1:</th>
<th>The type of PM and the type of PM that each team member desires are coincided.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2:</td>
<td>One or more students with the aptitude who can carry out roles are assigned to each team for every role, respectively. However, the 2 roles, the factor of the depths, which determine the capability to carry out various roles are made into “the special skill (henceforth described as Skill) of software development”, and “the analysis ability for software development (henceforth described as Capability)” have performance capability. Skill: Capability of special skill, such as programming in software development, which become high by study or experience Capability: Capability required for software development analysis / reasoning logically</td>
</tr>
<tr>
<td>C3:</td>
<td>The capability gap between teams is made as small as possible.</td>
</tr>
<tr>
<td>C4:</td>
<td>The number of people difference between teams is assumed to be less than 1 people.</td>
</tr>
<tr>
<td>C5:</td>
<td>Even the students who do not fit to accomplish any roles are assigned to any one team by all means. (Educational consideration).</td>
</tr>
</tbody>
</table>

Fig. 1 Team formation conditions definition

Shirakawa, et al.[1] used SEM (Structural Equation Models) to contain CSA (Covariance Structural Analysis) of one technique of the multivariate analysis. The relation of the criterion variables and the explanatory variable of the model are clarified and the criterion variables are expressed in the expression of relations of the explanation variables. After that by using GA in this expression of relations, performed the most suitable team formation automatically by applying system "EtUDE/GO" (Environment for Ultimate software Development Exercise/Group Organizer)[6][7]. By this application, created the most suitable plan of the team formation. And performed
4 Analysis method

4.1 PM type determination and selection of PM

PM as for project team "concentrate on means to achieve targets" and demand the answer to "can targets be achieved?" On the other hand, the leader "defines results to be expected" and finds the answer to "what we want to achieve?" PM by this exercise can be referred to as close to the role of the leader instead of the business capability currently searched for in the actual world. Enforcement of the prior questionnaire for PM candidate selection was done for 207 students of 1st and 2nd grade of this school who understand the leader's concepts. In addition, used the expression by 1st and 2nd grade of this school who understand the targeted persons did not have a concept of PM. PM type suitable for (1:PM) was understood as in Table 1. In addition, the data used for this analysis is 39 data, which had "Yes" reply for the question "Are you active?" of the questionnaire.

Each student's PM type determination was by adding the numerical values of (linear rating measure 1-4) from X1 to X9 of the questionnaire results and classified types by average marks (neglecting the decimal parts) of all the persons of study. As a result by classification of the students with bigger than average marks "management type", and the students with lower than average marks "partnership type", there were 32 persons and 13 persons in each. Selection of PM, based on coefficients of Table 1 and on the reply of each question (from X1 up to X10) of the questionnaire, total of two coefficients "1:PM suitable" and "0:PM non-suitable" was demanded. As a result of the calculation the students with the larger numerical value of "1: PM suitable" were selected. By the calculation result of all the students, a total of 12 persons, 7 persons of management PM and 5 persons of partnership PM were selected. Therefore as a result of considering students other than candidates with PM expectations (18 management types, 15 partnership types) and a team with condition

<table>
<thead>
<tr>
<th>No</th>
<th>aptitude for a PM</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>energetic character</td>
<td>4.152</td>
<td>3.773</td>
</tr>
<tr>
<td>X2</td>
<td>creative approach</td>
<td>6.851</td>
<td>3.414</td>
</tr>
<tr>
<td>X3</td>
<td>take the initiative and set a good example for others</td>
<td>0.591</td>
<td>0.609</td>
</tr>
<tr>
<td>X4</td>
<td>form an operational control framework</td>
<td>2.716</td>
<td>3.071</td>
</tr>
<tr>
<td>X5</td>
<td>assert one's firm belief</td>
<td>2.867</td>
<td>3.070</td>
</tr>
<tr>
<td>X6</td>
<td>give a concise explanation to someone's question</td>
<td>3.989</td>
<td>1.054</td>
</tr>
<tr>
<td>X7</td>
<td>to demand detailed explanation from a person</td>
<td>6.742</td>
<td>6.369</td>
</tr>
<tr>
<td>X8</td>
<td>engage in an active debate</td>
<td>-4.068</td>
<td>-1.615</td>
</tr>
<tr>
<td>X9</td>
<td>approach someone with an authoritarian stance</td>
<td>4.590</td>
<td>2.986</td>
</tr>
<tr>
<td>X10</td>
<td>one's own style</td>
<td>4.370</td>
<td>1.759</td>
</tr>
<tr>
<td>Intercept</td>
<td>-40.872</td>
<td>-28.264</td>
<td></td>
</tr>
</tbody>
</table>

* Right people for PM: $Y_0 < Y_1$

$Y_0 = \sum a_n * X_n + \beta_0$, $Y_1 = \sum a_n * X_n + \beta_1$ (n=1 ~ 10)
of four numbers, there are 6 persons of management type and 5 persons of partnership type. In addition, this time 11 students to play the role of PM were selected.

4.2 Capability rating other than PM
Performance capability other than PM conducts analysis by SEM based on skill of persons of study, and the data of aptitude.
SEM is the analysis method into which verification factor analysis was developed further as how to find out a true factor. The procedure of analysis by SEM is as follows.
① The structure of a question is modeled using a Path Diagram (illustration).
② By referring to a Path Diagram, the relation of three, a latent variable, an observed variable, and an error variable is expressed by a regression equation.
③ By checking the applying condition of SEM hypothetical model by examination of $\chi^2$ (chi-square), SEM hypothetical model is improved.

4.3 The process which evaluates the effect of team formation optimization
It requests for the relation between an alternative characteristic and a true factor, and expresses a latent variable with the expression of relations of an observed variable. Next it substitute a alternative characteristic for EtUDE/GO (Fig. 2) in an expression of relations and use the expression to demand the value of the latent variable from the observation data of the alternate characteristic and generate the most suitable plan of the team formation automatically.

Then it is confirmed if the most suitable plan of team formation generated then satisfies condition (C1) - (C5) which Shirakawa, et al.[1] defined. In addition by confirmation of condition (C3) it is checked that the multiple comparison, which does not use an analysis of variance and F statistics, there is no difference in the capability between teams. The other conditions are confirmed manually. After checking all, team formation based on this optimum proposal is performed, and exercise is done by assigning students to each team.
After the software development exercise end, it is analyzed that the influence that optimization of the team formation gave to exercise class, and by optimization of the team formation, these students play active parts as expected and confirm whether, as a result, all teams were able to achieve the exercise problem. In the exercise class, discriminate analysis is used to prove that the team formation optimization was effective. In software development practice, the professors including TA (Teaching Assistant) of the exercise class judge whether each student really played an active part by seeing the log information of the students, which EtUDE acquires automatically.

5 Collection and evaluation of data
5.1 Narrowing down of the alternative characteristics used for analysis
Acquisition of alternative characteristics considers seven variables the skill (JAVA1, JAVA2, JAVA3, PGM1), which can be quantified and knowledge of (PM, a test, an analysis design) which Shirakawa, et al.[1] used by newly added 2 knowledge data to five data (value of an alternative characteristic), the definition of each variable is as follows.
JAVA1: The definition problem of the operator currently used by JAVA
JAVA2: The knowledge problem of a JAVA language
JAVA3: The fundamental grammar problem of JAVA
PGM1: The problem which measures programming capability
Test: The problem about the test coverage
PM: The problem of scheduling using the PDM method
Analysis: The problem which creates a class figure and a design: sequence figure based on a robustness figure

5.2 The Web system for data collection
This section describes the configuration of the questionnaire system carried out this time, and the outlines of the technologies introduced. This system was implemented by Web application mounted described in the Java language. It is possible to acquire the questionnaire without depending on the platform.
of the client by using the Web application. Clients can access using the web browser (Internet Explorer or Safari) preinstalled in OS. For this reason there is no necessity of installing special software. Moreover, when the questionnaire is filled out, simultaneously the total is completed, so this can reduce the labors for making total. Further it was based on Java Servlet 2.4 specifications and JSP 2.0 specifications. By this if it is the Web application server corresponding to Java Platform and Enterprise Edition based standards, it is possible for this system to operate without the hardware requirement used this time. When using the system, it is necessary to input the data of the questionnaire into the system that questionnaire creators want to acquire. But if questionnaire contents are written directly in application each time when acquiring the questionnaire, the source code must be rewritten and must be recompiled. So, in order to ease a questionnaire maker's burden adopted the XML file as an interface file. By this it became possible to take multiple questionnaires in one application system. Further the result of a questionnaire is saved by CSV format and can be downloaded.

5.3 Decision of the model based on a hypothesis

Devised the hypothetical model of the human factors, which has an influence on the team formation for a software development exercise. Since PM is already finished with selection, the analysis of the hypothesis model Fig.3 excluding the factor Capability of the depths and the role of PM. Roles other than PM are as follows.

\[
\begin{align*}
\text{Analyst} &= 0.76 \times \text{Analysis design} + 1.00 \times \text{JAVA1} \\
\text{Coding} &= 0.32 \times \text{JAVA2} + 1.00 \times \text{JAVA3} \\
\text{QA} &= 0.47 \times \text{PGM1} + 0.52 \times \text{PM} + 1.00 \times \text{Test}
\end{align*}
\]

(1)

Then classified it according to PM type each student demand except PM and the role assignment and team formation based on the classification were performed. Since there were 45 persons in the exercise study, composed 11 teams in all with 4-5 members in each team.

Table 2 Outlines of an exercise, 2008 fiscal year

<table>
<thead>
<tr>
<th>Exercise Task</th>
<th>Development of the bookselling system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Objective Students</td>
<td>44 students</td>
</tr>
<tr>
<td>Number of Teams</td>
<td>11 teams(3 to 5 students)</td>
</tr>
</tbody>
</table>

Table 3 Analysis of variance (Single factor) Results

<table>
<thead>
<tr>
<th>Team No.1~6</th>
<th>Source of Variance</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
<th>F cnt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>0.148</td>
<td>5</td>
<td>0.030</td>
<td>0.003</td>
<td>1.000</td>
<td>2.773</td>
<td></td>
</tr>
<tr>
<td>Within Groups</td>
<td>194.848</td>
<td>18</td>
<td>10.825</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>194.996</td>
<td>23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Team No.7~11</th>
<th>Source of Variance</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
<th>F cnt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>1.099</td>
<td>4</td>
<td>0.275</td>
<td>0.036</td>
<td>0.998</td>
<td>3.056</td>
<td></td>
</tr>
<tr>
<td>Within Groups</td>
<td>138.419</td>
<td>15</td>
<td>9.228</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>139.518</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

According to the type of PM, made 6 management type teams, and 5 partnership type teams. So that the par capability value of a team may become equal according to PM type by system EtUDE/GO
using a GA, generated the team formation proposal so that distribution of average value is the minimum. The result of this team formation is an exercise summary as in Table 2.

Team formation based on SEM confirms that it satisfy limitations of the team formation for an analysis of variance. The evaluation results that can be "said to have a gap or neither" are the results and satisfy the restrictions of team formation (Table 3).

7 Validity evaluation of the team formation optimization after the end of the exercise

The instructors containing TA evaluated the contribution to the subject achievement in all exercise lessons participants' teams after the end of the exercise based on the presentation of middle and the last announcement, and the log information which the last product and EtUDE of the exercise acquired. Validity evaluation of the team formation classified by PM type is performed by "evaluation of the product according to team", and "the questionnaire result after an exercise." In this team formation, carried out equalization of capability according to the type of the team. Therefore it was judged that there is the difference of capability between the team type 1 and the team type 2, when seen from the team type point, but evaluation was judged with no gap.

Therefore it was proved that evaluation became equal by considering the type of the team rather than the method to make capability equality simply.

8 Conclusion

According to the type of PM decided position members and performed role allotment and the team formation of the members. As a result, was able to realize team formation with small capability difference between teams, and confirmed was able to achieve exercise problems without one halfway dropout in all teams. Furthermore, by this inspection, the team formation of the students without the exercise experience was able to realize the high team formation of the sense of cooperation of team members respect to each other by considering a PM type. PM allots the work to the team of the management type by result units, and a tendency to be able to leave to each person is in particular strong. But the unevenness was big, and PM confirmed that the team of the partnership type made results for every WBS by cooperating with all the members.

In evaluation comparison of the degree of fullness of the cooperativeness and the exercise in this time and the team of 2006, "it was very substantial" became 31.1% in 2008 from 12.3% in 2006, and "all the members cooperated" became 60.0% in 2008 from 47.4% in 2006.

References:


